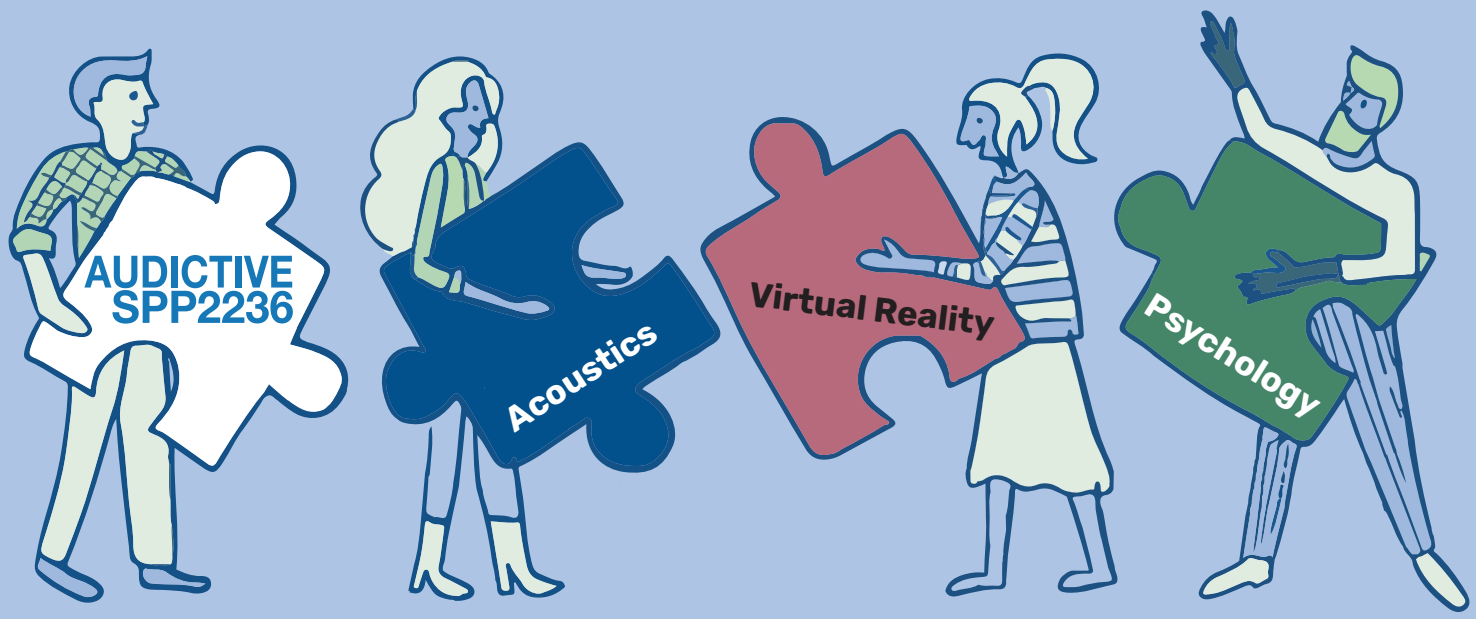
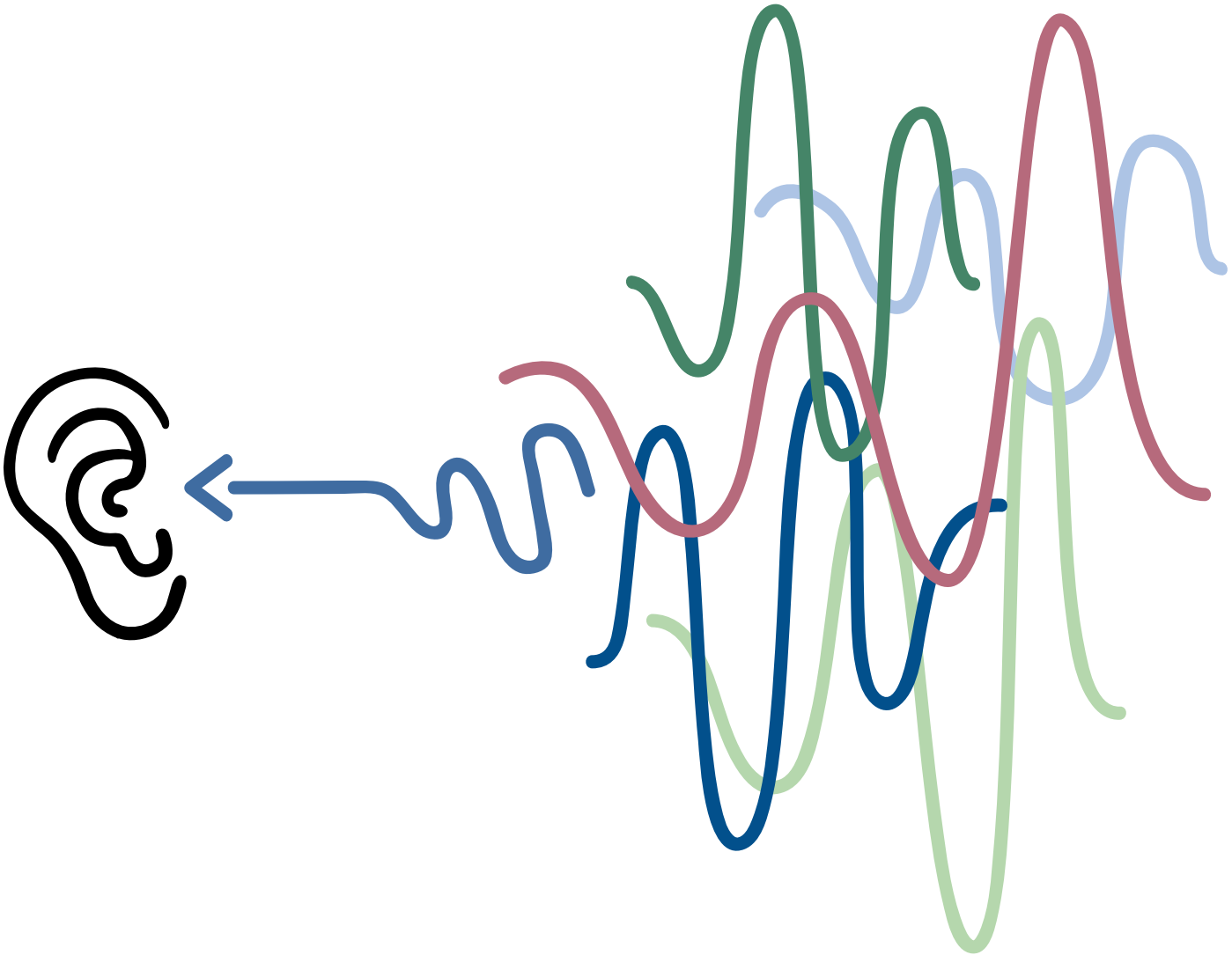
AUDICTIVE Conference 2023

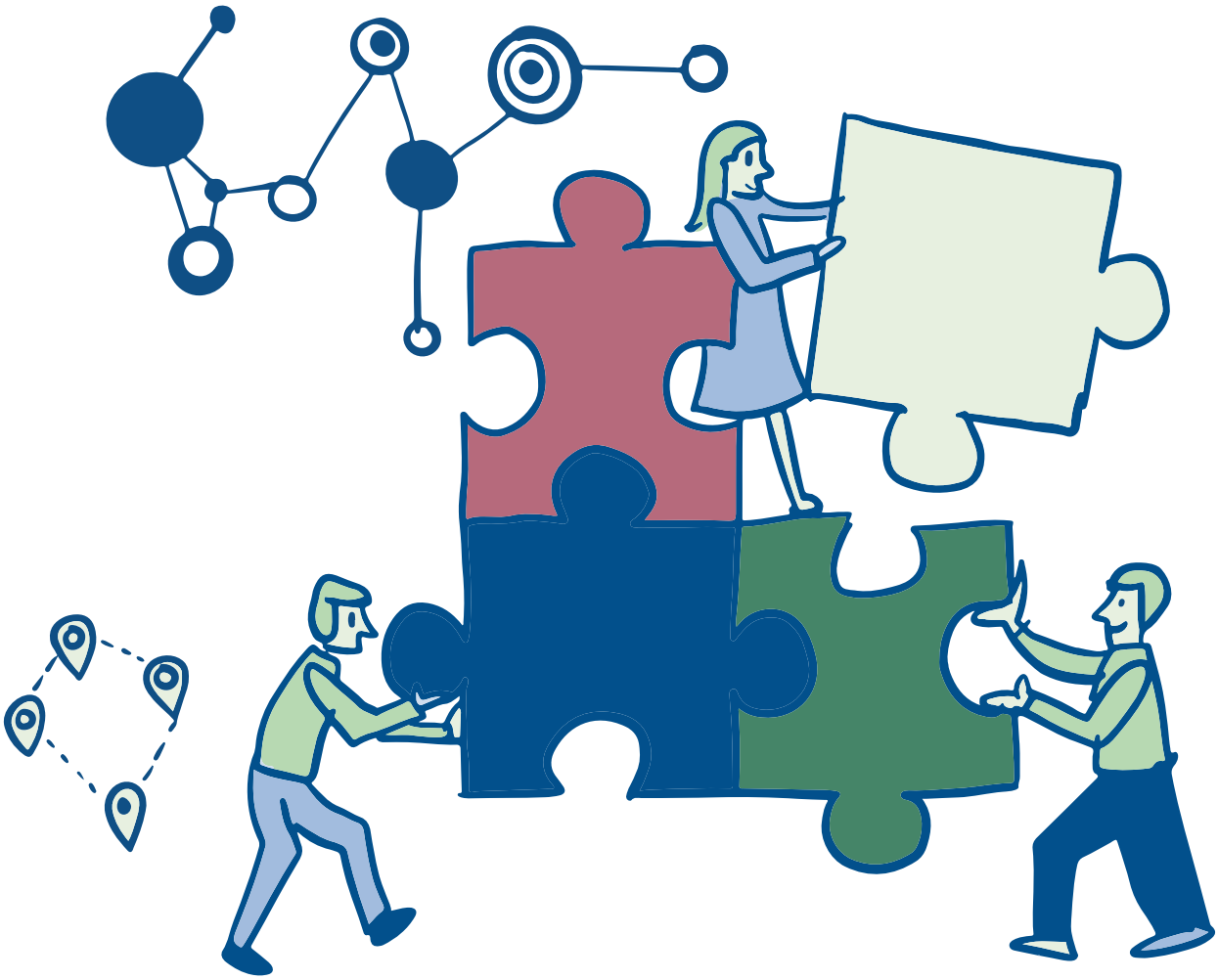
Aachen, Germany
19.06.2023 - 22.06.2023

Booklet





Content



Welcome to AUDICTIVE Conference 2023

Dear colleagues and guests,

On behalf of the Institute for Hearing Technology and Acoustics at RWTH Aachen University, it is our pleasure to welcome you to the Conference. We are thrilled to host this exciting event that brings together experts from diverse fields to explore the intersection of acoustics, virtual reality, and psychology.

The interdisciplinary nature of this conference is one of its most exciting features. We have speakers from diverse backgrounds, including acoustics, psychology, and virtual reality, who will be sharing their latest research findings and insights. We are confident that the presentations and discussions will foster new ideas and collaborations that will drive progress in these fields.

We hope that you enjoy your stay in Aachen and take the opportunity to explore the city's vibrant culture and rich history. Its roots go back to the Roman Empire, as it was once a prominent spa town known for its hot springs. During the social evening you will have the opportunity to discover Aachen's history in the Centre Charlemagne, a Museum dedicated to the most important events, peolpe and stories of the city.

Thank you for joining us for this exciting event, and we look forward to fruitful discussions and stimulating interactions.

Best regards,

Janina Fels & Jamilla Balint

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Points of Interest:

1. Super C, conference location
2. Conference Dinner Karls Cafe
3. IHTA Institute
4. Aachen West train station
5. Aachen main train station
6. Motel One at the theater
7. Theater
8. Elisenbrunnen
9. Aachen Cathedral
10. Aachen city hall
11. Restaurants & Bars (blue area)

●●● Walking route

About Aachen

Aachen is the most western city in Germany, near Belgium and the Netherlands. As the city of Charlemagne, it is also a historical city, and offers a blend of rich heritage and modern charm. Famous for its UNESCO-listed Aachen Cathedral, medieval Rathaus, and Charlemagne's legacy, the city features picturesque Old Town streets, vibrant squares, and local culinary delights like Printen gingerbread cookies. Aachen is a great city with a lot to offer. To discover Aachen, we recommend walking through the old city, discovering the historical monuments and enjoying the beautiful façades of its buildings.

The Market square:

The smell of coffee, fresh fish or warm rolls lingers in the air, next to the Karlsbrunnen fountain. Experience city life in Aachen against the impressive backdrop of Aachen city hall! From the market square, you can reach all the attractions of the city by foot, or simply spend some time over a cup of coffee or a glass of wine in one of the many cafés and restaurants and enjoy watching life in the city pass by.

Aachen Rathaus (city hall):

The Aachen Rathaus is actually Charlemagne's palace! From the outside, the historic façade is already an indication of the building's glorious history: 50 rulers, 31 of whom were crowned in Aachen, surround the central figures of Charlemagne, Jesus and Pope Leo III. In the elaborately decorated rooms, the story of the city hall, which was built on the historic site of the great palace hall of Emperor Charlemagne, is brought to life. In the coronation hall, where formerly the rulers took a meal after being crowned, copies of the imperial regalia remind us of this glorious era today.

The Aachen Cathedral and its treasury:

Located in the heart of the old city, Aachen Cathedral is one of the main attractions of Aachen. It is also the first site in Germany to be awarded UNESCO World Heritage status, for its architecture and the events that took place here for over hundreds of years. Ordered by Charlemagne at the end of the 8th century, it was the capital of his empire, his burial place, and the coronation site of a long line of Holy Roman kings.

Wet your hands at Elisenbrunnen:

Nearby the city hall and cathedral the Elisenbrunnen fountain can be found. It is the symbol of Aachen as a spa and bathing city. Here, the hot springs, which were valued not only by Charlemagne, but also the Romans, can be seen bubbling up from below. The classicistic building with its two fountains is a popular meeting place for young and old, Aacheners and non-Aacheners! The water that flows from two fountains inside is the Kaiserquelle, flowing naturally at 53°C. You'll know you're close when you smell the strong scent of hydrogen sulphide!

Information provided by the aachen tourist service e.V.

Information for authors & guests

Oral Presentations:
The duration for the presentations is 30 min (20 min presentation + 8 min discussion + 2 min change to the next presenter). A computer will be provided with PowerPoint and Adobe Acrobat. Loudspeakers will be provided as well. The conference language is English, so presentations should preferably be given in English, slides should be prepared in English as well. You have to upload your slides prior to the presentation, a laptop will be provided in the MEDIA CORNER.

Poster pitches:
The duration of the poster pitches is 5 min (3 min pitch + 2 min change to next presenter). A computer will be provided with PowerPoint and Adobe Acrobat. Loudspeakers will be provided as well. The conference language is English, so pitches should preferably be given in English, the poster should be prepared in English as well. You have to upload your slides prior to the presentation, a laptop will be provided in the MEDIA CORNER.

After the pitches, the poster session with coffee and snacks will follow immediately. We will provide poster boards with dimensions 196 cm x 96 cm (height x width). Please prepare your poster in DIN A0 portrait format. The conference language is English and thus the posters should be in English.

Conference Dinner:

The conference dinner will take place at Karls Cafe, Katschhof 1, in the Museum Centere Charlemagne from 18:00 - 22:00. You have the opportunity to visit the museum from 20:00 - 22:00. The permanent exhibition displays Aachen's history from its foundation to today, including the thermal baths of the Romans, Charlemagne's Palace, and Napoleon's chic spa town. More information can be found here: https://centre-charlemagne.eu/museum/

Demos at IHTA:

We prepared demos at RWTH Aachen University (Institute for Hearing Technology and Acoustics + RWTH Virtual Reality and Immersive Visualization). The demos will include most likely a tour through the aixCAVE and a tour behind the scenes, an audiometry for experts in our MobiLab and VR demos.

Date: Tuesday, 20.06, 16:30-18:30

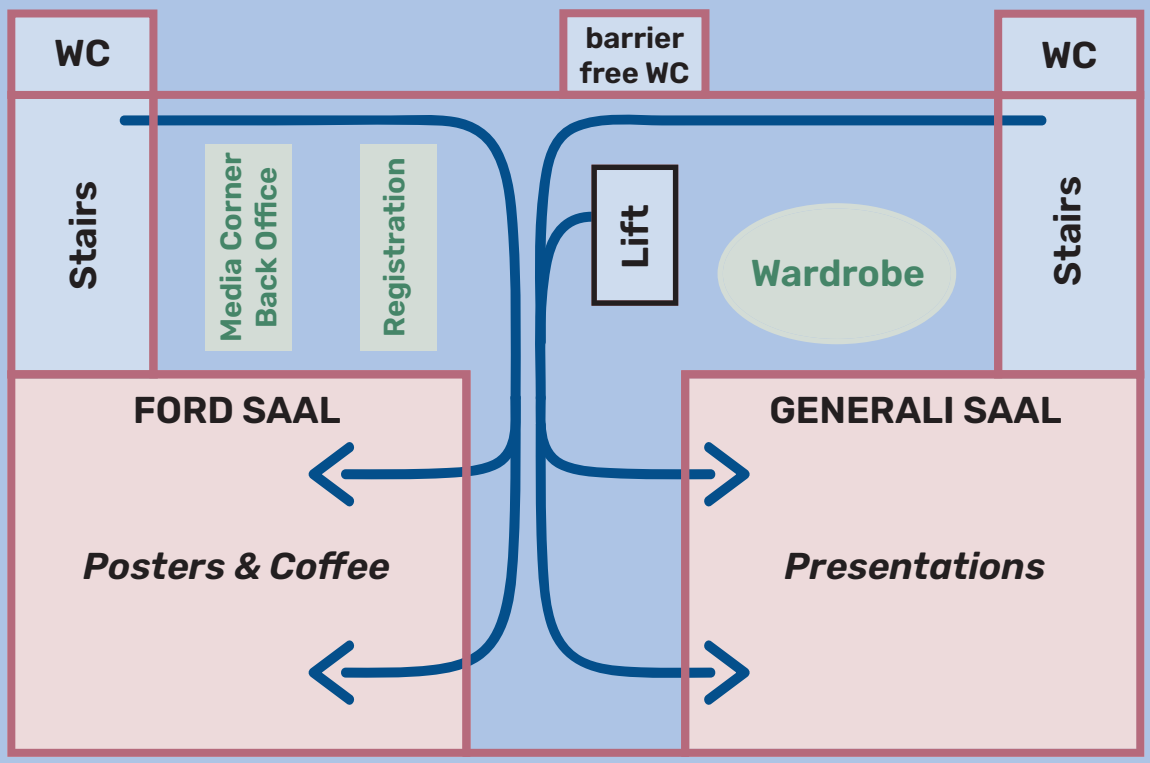
Where: Kopernikusstraße 5 + 6

How to participate:
Please sign up for the demos at the registration desk on Tuesday upon arrival due to limited availability.

How to get there:
Staff will be waiting in front of the conference location SuperC at 16:15 and guide you to Kopernikusstraße 5. It is a short walk of 10 min duration. If you cannot walk, please let us know and we will organize a cab.

Conference Map

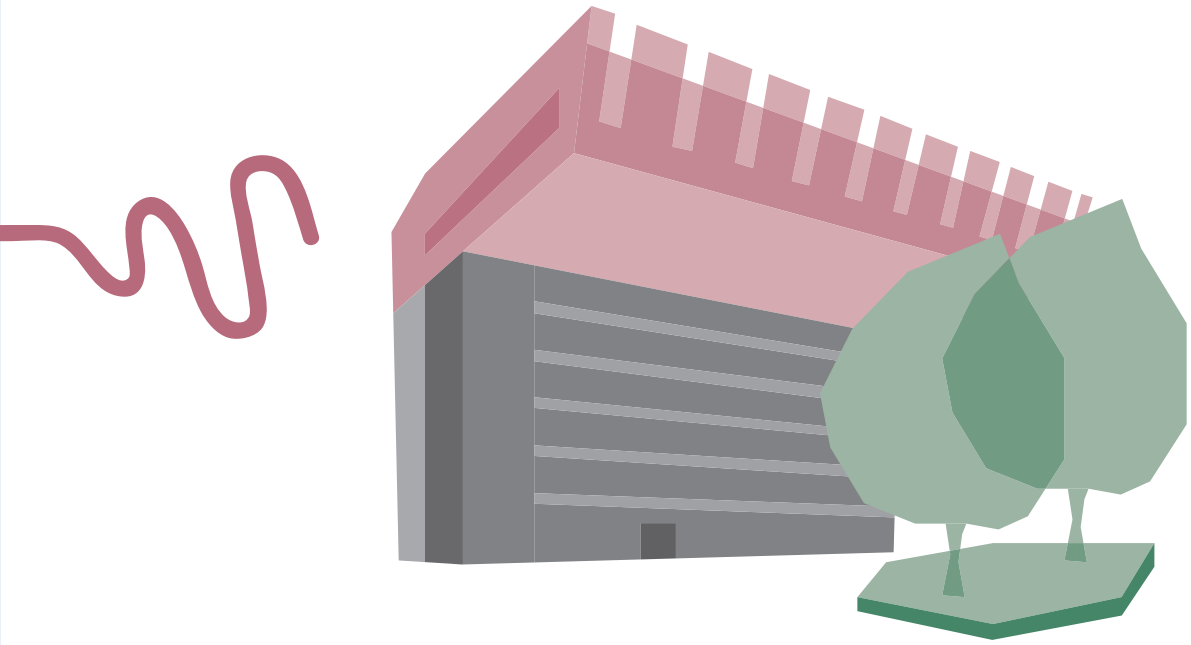
All Presentations and Poster Sessions are held on the 6 th floor of Super C



Monday - 19.06.

Overview:

TIME	AGENDA
18:00 - 20:00	Welcome Drinks at Super C on the 6th floor at Templergraben 57, 52062 Aachen



DAY/01

Tuesday - 20.06

Overview:

TIME	AGENDA
09:00 - 09:30	Welcome: Janina Fels *Music by the string quartet of the Aachen Student Orchestra* *Violin: Felix Zipfel & Mareike Digel • Viola: Theresa Steidle • Cello: Leonie Schmitz*
09:30 - 10:30	Keynote 01: **Barbara Shinn-Cunningham** „How peripheral and central factors together control auditory attention in complex settings“
10:30 - 11:00	Poster Pitches
11:00 - 12:00	Poster Sessions & Coffee
12:00 - 12:30	Lunch break
13:30 - 14:30	Presentations
14:30 - 15:00	Coffee break
15:00 - 16:00	Presentations
16:30 - 18:30	Demos at IHTA Institute Please book a slot at the registration desk
SESSION CHAIR:	Janina Fels

DAY/02

Wednesday - 21.06

Overview:

TIME	AGENDA
09:00 - 10:00	Keynote 02: **Frank Steinicke** „B(l)ending Natural and Artificial Intelligence and Realities“
10:00 - 10:30	Poster Pitches
10:30 - 11:30	Poster Session & Coffee
11:30 - 12:00	Presentations
12:00 - 13:30	Lunch break
13:30 - 14:30	Presentations
14:30 - 15:00	Coffee break
15:00 - 16:30	Presentations
18:00	Conference Dinner in Karls Cafe at Centre Charlemagne (Museum) Katschhof 1 Museum is open during the dinner visit is highly recommended

SESSION CHAIR: Torsten Kuhlen

DAY/03

Thursday - 22.06

Overview:

TIME	AGENDA
09:00 - 10:00	Keynote 03: **Alexandra Bendixen** „Sensory prediction in auditory scene analysis, audio-visual interplay, and VR evaluation“
10:00 - 10:30	Poster Pitches
10:30 - 11:30	Poster Sessions & Coffee
11:30 - 12:00	Presentations
12:00 - 13:30	Lunch break
13:30 - 14:00	Presentations
14:00 - 14:45	Round Table Discussion
Closing	

SESSION CHAIR: Sabine J. Schlittmeier

Abstracts

DAY 1 - Tuesday, 20.06

Keynote

9:30 - 10:30

How peripheral and central factors together control auditory attention in complex settings

Barbara Shinn-Cunningham [a]

[a] *Carnegie Mellon University, USA*

Abstract:

In healthy, normal-hearing listeners, complex negotiations between volitional, top-down attention and involuntary, bottom-up attention allow you to focus on and understand whatever talker matters in a given moment— while also ensuring that you evaluate and respond to new sound sources around you. This talk explores how peripheral and central factors together determine how successful you will be when communicating in everyday environments with both expected and unexpected sounds, focusing especially on the cortical networks that mediate competition for attention.

Biography:

Barbara Shinn-Cunningham became the Director of the Carnegie Mellon Neuroscience Institute in 2018. Before joining Carnegie Mellon, she spent over twenty years on the faculty of Boston University (first in Cognitive and Neural Systems, and later in Biomedical Engineering). Her innovative work in auditory neuroscience has been recognized by the Alfred P. Sloan Foundation, the Whitaker Foundation, and the Vannevar Bush Fellows program. She has held numerous elected and appointed leadership positions in professional organizations such as the Association for Research in Otolaryngology and the Acoustical Society of America, and serves on numerous advisory boards within both academia and industry. Barbara Shinn-Cunningham has just been elected as the President-Elect of the Acoustical Society of America (ASA).

Posters & Pitches 10:30 - 12:00

10:30

On the capacity of geometrical methods to restitute the material properties impact on room acoustic comfort

Cédric Camier [a], Marina Malgrange [a], François Salmon [b], Charles Verron [b], Pierre Chigot [c]
[a] *Saint-Gobain Research Paris, FRA* [b] *Noise Makers, FRA* [c] *Saint-Gobain Ecophon AB, FRA*

Abstract:

In various building contexts, acoustic comfort attributes (such as intelligibility, vocal effort, etc) are related to room acoustic metrics (such as Reverberation time, Clarity, strength, etc) that depends on the room geometry and material properties of solutions. A precise auralization of indoor absorption building solutions is crucial for assessing relevantly their impact on room acoustic comfort through VR environment. On the first part of this work, a geometrical acoustic engine combining source-image model and raytracing is used to conduct parametrical studies on basic geometry and material configurations. Results are compared in terms of impulse responses as well as room acoustics metrics. On the second part, real rooms are numerically replicated. Various method parameters and scattering models are evaluated in comparison against measurements. Finally, psychoacoustic tests assessing the realism of sound environment deduced from simulations are conducted in comparison to the real rooms. They aimed at assessing the capacity of geometrical method-based strategies to restitute adequately the material variation impact on room acoustic comfort attributes. The results will be related to the relevant room acoustic metrics computed from the simulated and recorded cases.

10:35

Investigating simplified head-and-torso models to simulate binaural room impulses for training deep neural networks

Jasper Maes [a], Siyuan Song [a], Stijn Kindt [a], Pieter-Jan Maes [a], Bruno Masiero [b], Nilesh Madhu [a]
[a] *Ghent University, BEL* [b] *University of Campinas, BRA*

Abstract:

Deep learning is establishing itself for single- and multi-microphone signal processing. A key limitation of such approaches is the availability of suitable training data to ensure that the trained models can generalise well. For free-field arrays, state-of-the-art demonstrates that even when DNNs are trained on simulated data (e.g., simple shoebox acoustics), they can generalise well to real-life conditions – provided the training paradigm is appropriately designed to mimic these. This permits the generation of arbitrary amounts of training data. To extend these approaches to binaural hearing instruments, appropriate binaural room impulse responses (BRIRs) should be incorporated in the room-acoustics simulations. However, since BRIRs are specific to the type of listening device and user, such data generation is not straightforward. The traditional process of recording BRIRs and using these for simulations is time-consuming and costly. We investigate the use of simplified head-and-torso models to simulate BRIRs, for training a DNN-based source localisation approach. Contrasting the results of this model to that using measured BRIRs of a behind the ear hearing aid, insights into generating training data for the binaural case can be obtained. Thereby, robust training of DNNs for hearing-prostheses becomes possible, with significantly reduced time and effort for acquiring training data.

10:40

Virtual-reality based examination of audiovisual prosody in cochlear implant recipients

Khaled Abdellatif [a], Isa Samira Winter [a], Moritz Wächtler [a], Pascale Sandmann [b], Hartmut Meister [a]
[a] *University of Cologne, GER* [b] *University of Oldenburg, GER*

Abstract:

Prosody plays a vital role in verbal communication. It is important for the expression of emotions, but also carries information on sentence stress or the distinction between questions and statements. Cochlear Implant (CI) recipients are restricted in the use of acoustic prosody cues, especially in terms of the voice fundamental frequency. However, prosody is also perceived visually, as head and facial movements accompany the vocal expression. To date, few studies have addressed multimodal prosody perception in CI users. Controlled manipulations of acoustic cues are a valuable method to uncover and quantify prosody perception. For visual prosody, however, such a technique is more complicated. We describe a novel approach based on animations via virtual humans. Such a method has the advantage that – in parallel to acoustic manipulations – head and facial movements can be parametrized. It is shown that animations based on a virtual human generally provide similar motion cues as video recordings of a real talker. Parametrization yields fine-grained manipulation of visual prosody, which can be combined with modifications of acoustic features. This allows generating both congruent and incongruent stimuli with different salience. Initial results of using this method with CI recipients are presented and discussed.

10:45

Acoustic and Non-Acoustic Effects on Speech Intelligibility during Reverberant, Spatialised Two-Talker Listening Scenarios

Jona Schebesta [a], Lars Hausfeld [b]
[a] *Maastricht University, NLD* [b] *Maastricht Brain Imaging Center, NLD*

Abstract:

In two-talker situations, listeners need to segregate a stream of interest (target speech) from a second stream (distractor speech). Our auditory system utilizes several spectro-temporal cues that support successful stream segregation and intelligibility of the target speaker. As most of these cues were investigated in dry listening environments, potential behavioral effects from reverberation are less clear. Reverberations induce distortions by disrupting fine, transient cues of the sound signal. On the other hand, reverberations offer distance-related cues and listeners might employ different listening strategies to compensate for the signal degradation. Here, we aimed at 1) replicating previous findings of spatial unmasking in naturalistic environments including reverberation and 2), investigating potential effects of relative distance and adaptation of listening strategies to current stimuli. We find that distance-related cues aid intelligibility when no other binaural cues are present. In addition, our results indicate different attentional strategies that are adopted implicitly when being presented with a spatially fixed target or spatially fixed masker. We find that while not providing the maximum performance in anechoic conditions, the strategy adopted for a spatially fixed masker appears to be more robust against reverberation in contrast to a location-based strategy.

10:50

Influence of context recognition on the representation of acoustic horizon: investigations on auditory distance perception

Pierre Fleurence [a], Mitsuko Aramaki [a], Richard Kronland-Martinet [a]
[a] *Aix-Marseille Université, FRA*

Abstract:

Distance perception in an audio content has long been investigated as sources' distance, how far the source is from the perspective of a listener. Yet, an audio spatial scene is not only perceived as a sum of punctual audio entities but it also takes into account a broader aspect, based for example on shape or textures. Moreover, in the domain of soundscape studies, researchers describe soundscapes as a sonic environment with emphasis on the way it is perceived and understood by an individual. This leads to the existence of an interaction between the recognition of the sonic environment and its perception. Based on this framework, how does the auditory distance perception, defined as acoustic horizon, is influenced by the recognition of the environment? For that, we designed an experiment which showed that it does exist an interaction between the recognition and the perception of the acoustic horizon. In addition, we discussed how this interaction could be linked to multiple factors. We will present our results and the leads for a better perceptual characterization of the acoustic horizon.

10:55

Hoarseness among university professors and how it can influence students' listening impression: an audio-visual immersive VR study

Isabel Sarah Schiller [a], Lukas Aspöck [a], Carolin Breuer [a], Jonathan Ehret [a], Andrea Bönsch [a]
[a] *RWTH Aachen University, GER*

Abstract:

For university students, following a lecture can be challenging when room acoustic conditions are poor or when their professor suffers from a voice disorder. Related to the high vocal demands of teaching, voice disorders are much more common among university professors than among the general population. Their main perceptual symptom is hoarseness. The aim of this study is to investigate the effect of hoarseness on university students' subjective listening effort and listening impression using audio-visual immersive Virtual Reality (VR) including a real-time room simulation of a typical seminar room. Equipped with a head-mounted display, participants are immersed in the virtual seminar room with typical binaural background sounds where they perform a listening task. This task involves comprehending and recalling information from text, read aloud by a female virtual professor positioned in front of the seminar room. Texts are presented in two experimental blocks, one of them presented in a normal (modal) voice, the other one presented in a hoarse voice. After each block, participants fill out a questionnaire to evaluate their perceived listening effort and overall listening impression under the respective voice quality. Results of this study are presented and discussed regarding potential implications for students' motivation and performance in academic learning spaces.

Presentations

Tuesday 13:30 - 14:00

Fostering interdisciplinary research: auditory cognition experiments in virtual reality

Jamilla Balint [a], Janina Fels [a]
[a] *RWTH Aachen University, GER*

Abstract:

Cognitive psychological experiments are predominantly based on simple laboratory settings, thus limiting investigations of complex environments such as classrooms, multi-party communication or navigating in traffic. With new virtual reality (VR) technology it becomes possible to conduct such experiments in more complex settings, thus approaching close-to-real-life scenarios. The question is, if the existing theories based on those simple laboratory settings hold true for cognitive performances in complex and close-to-real-life virtual environments? The priority program SPP2236 - AUDICTIVE (Auditory cognition in interactive virtual environments) addresses this question from an interdisciplinary viewpoint. Linking the three research fields acoustics, cognitive psychology, and virtual reality, allows for investigating acoustically complex scenes in controlled virtual environments to extend the knowledge of hearing-related cognitive performances. Each research project in AUDICTIVE is designed as a combination of acoustics on the one hand and either cognitive psychology and/or virtual reality on the other hand. Hence, by linking the three disciplines, AUDICTIVE targets fundamental research addressing three research priorities, namely auditory cognition, interactive audiovisual virtual environments, and quality evaluation methods. In this paper we describe the objectives of the ten research projects and summarize preliminary findings and challenges. Additionally, we present measures undertaken by the coordination fund in order to foster interdisciplinary work.

Tuesday 14:00 - 14:30

Adaptation to manipulated cues in auditory distance perception

Jakab Pilaszanovich [a], Fabian Brinkmann [b], Johannes M. Arend [b], Stefan Weinzierl [b], Marc Schönwiesner [a]
[a] *University of Leipzig, GER* [b] *TU Berlin, GER*

Abstract:

Our auditory system with its ability to orient itself in natural acoustic environments can today be considered well researched in many respects. This applies to the physical cues that are relevant for the perception of direction and distance of sound sources in anechoic and reverberant environments as well as to the acoustic qualities of natural and synthetic spatial environments itself. With virtual and augmented realities becoming part of our everyday experience, however, the question becomes important to what extent our perceptual system is able to orient itself in a reality that is not subject to physical laws. Virtual environments can deviate from the rules of the physical world, because of the limited performance of the underlying numerical simulations, because of the limited interaction possibilities of a user with the virtual environment, or because the quality of experience of the virtual environment may consist precisely in crossing the physical boundaries of the real world. In this talk, we present initial results for the adaptation to virtual acoustic environments that employ manipulated distance laws. We show results from psychoacoustic distance experiments as well as insights into neurological aspects of distance perception and adaptation to new distance cues.

Tuesday 15:00 - 15:30

Realism in Acoustic Room Simulations

Stefan Fichna [a], Viola G. Matten [b], Virginia L. Flanagin [b], Stephan D. Ewert [a], Steven van de Par [a]
[a] *Hearing4All, GER* [b] *University Hospital Munich, GER*

Abstract:

The development of affordable virtual reality systems has brought a concomitant increase in attention to auditory virtual-environments (AVE). Realistic AVEs bridge the gap between "classical" psychoacoustics with simplified, artificial stimuli and real acoustic environments in hearing research. Recent studies have demonstrated that a well-designed acoustical rendering allows for perceptual realism. Therefore, a perfect physical reproduction of the sound signal may not be necessary. Instead, higher cognitive factors appear to play a determining role in the perceived realism. Which physical aspects of a sound are decisive to generate the impression of realism in AVE is still unclear. Two studies were conducted to compare the perception of sounds in real rooms in contrast to room simulations with varying degrees of realism. The first study combined sparse multiband functional magnetic resonance imaging (MRI) and psychophysical experiments to investigate brain activity signals resulting from real versus simulated rooms. While lying in the MRI, listeners performed an auditory distance perception task with headphone auralizations. The second study evaluates measured binaural room impulse responses (BRIRs) and simulated BRIRs with multiple acoustic levels of detail for three different rooms using headphones and a 3-dimensional loudspeaker array. The experiments included plausibility, speech intelligibility, externalization estimation and an evaluation of multiple spatial audio quality items.

Tuesday 15:30 - 16:00

Development and Validation of Audio-visual VR Technology on the Basis of Experiments on Auditory Localization and Attention in Virtual and Real 3D-Spaces

Daniel Neudek [a], Benjamin Stodt [b], Rainer Martin [a], Stephan Getzmann [b]
[a] *Ruhr-University Bochum, GER* [b] *TU Dortmund, GER*

Abstract:

Cognitive processes such as object localization and spatial attention play an important role in real-world environments, like on modern factory floors, where workers receive input from, and have to respond to collaborative machines. However, experiments in real environments are often difficult to realize. The use of virtual realities (VR) appears to be a promising alternative, but its ecological validity needs to be verified. To provide insights on significant cues and features in developing experimental scenarios in VR, we develop and evaluate a virtual environment, covering visual and auditory characteristics of a real room, simulating a factory floor. EEG-based behavioral experiments on audio-visual localization and attention in the real and the virtual room are conducted (using a VR headset with headphones) and results gathered in both environments are compared. Using an auditory oddball paradigm, our first studies indicate that distance perception is less accurate in VR, especially when loudness cues are missing. However, EEG patterns and event-related potentials are similar in both environments, providing evidence that the virtual environment is suitable to study neurocognitive processes of distance perception and spatial attention. Based on these results we will explore more complex audio-visual scenes with different auralization techniques in upcoming VR experiments.

DAY 2 - Wednesday, 21.06

Keynote:

Wednesday 9:00 - 10:00

B(l)ending Natural and Artificial Intelligence and Realities

Frank Steinicke [a]

[a] *University Hamburg, DEU*

Abstract:

The fusion of extended reality (XR) and artificial intelligence (AI) will revolutionize human-computer interaction. XR/AI technologies and methods will enable scenarios with seamless transitions, interactions and transformations between real and virtual objects along the reality-virtuality continuum indistinguishable from corresponding real-world interactions. Yet, todays immersive technology is still decades away from the ultimate display. However, imperfections of the human perceptual, cognitive and motor system can be exploited to bend reality in such a way that compelling immersive experiences can be achieved. In this talk, we will review some XR illusions, which bring us closer to the ultimate blended intelligence and reality.

Biography:

Frank Steinicke is professor for Human-Computer Interaction at the Department of Informatics at the Universität Hamburg. His research is driven by understanding the human perceptual, cognitive and motor abilities and limitations in order to reform the interaction as well as the experience in computer-mediated realities. He studied Mathematics with a minor in Computer Science at the University of Münster, from which he received his Ph.D. in 2006, and the Venia Legendi in 2010, both in Computer Science. He published about 300 peer-reviewed scientific publications and served as program chair for several XR and HCI-related conferences. Furthermore, he is chair of the steering committee of the ACM SUI Symposium, and member of the steering committee of GI SIG VR/AR. Frank Steinicke is a member of the editorial boards of EEE Transactions on Visualization and Computer Graphics (TVCG) as well as Frontiers Section on Virtual Reality and Human Behaviour.

Posters & Pitches 10:00 - 11:30

10:00

Virtual reality environments for soundscape research

Anne Heimes [a], Ming Yang [b], Michael Vorländer [a]
[a] *RWTH Aachen University, DEU* [b] *HEAD acoustics GmbH, DEU*

Abstract:

Soundscape research demands a holistic approach for the analysis of environments, yet any research method, e.g. soundwalk or lab-based listening test, has its advantages and limitations. The virtual reality (VR) and augmented reality (AR) technology provides an alternative method for soundscape research, which may preserve as much context as possible while enabling controlled conditions. The paper describes the scene rendering at different levels of details and of different types, such as recordings, AR and VR. These scenes are used for further soundscape research by comparing a real soundwalk to different levels of virtual soundwalks. The scenes are made publicly available.

10:05

The Role of Realistic Ambient Noise for the Spatial Presence Experience in VR-Learning Environments

Marc Bastian Rieger [a], Björn Risch [a]
[a] *University of Kaiserslautern-Landau, DEUa*

Abstract:

Virtual reality (VR) is increasingly becoming an important tool for STEM educational fields. Thus, a variety of learning processes can be supported by VR: Visualizing invisible phenomena (e.g., submicroscopic processes at the particle level), going to places that would normally be inaccessible (e.g., as part of a virtual field trip), and much more. To date, however, there is a lack of suitable VR learning environments in everyday school settings (Rieger et al. 2023). This is also due to the fact that potential developers do not have instructional design criteria to guide VR conceptualizations. Rieger & Risch (2023) use a study with four different tenth grade classes to show how the practical evaluation and design of a VR learning environment for everyday school life can succeed. From their results, they derive design principles for creating VR learning environments.

10:10

Augmented Listening Preference in a Virtual Cocktail Party Environment

Mark Dourado [a], Jesper Udesen [a], Stefania Serafin [b]
[a] *GN Audio Research, DNK* [b] *Aalborg University, DNK*

Abstract:

Assessing the ability to focus on a single speaker in a noisy environment, known as the cocktail party effect, is typically done in controlled conditions with simple stimuli. The ability to separate streams is not defined by the auditory modality alone, with studies showing that discrimination of sources is significantly aided by viewing the speaker's face. This study aims for a higher degree of ecological validity and explores different auditory presentations and interactions of a dynamic, audio-visual cocktail party scenario. The scenario involves multiple speakers, augmented hearing capabilities and audiovisual congruency, through the use of virtual reality. Results show that floor-dependent, automated augmentation was preferred out of six different modes of listening and that signal-to-noise ratio, spatialisation and interaction had a significant effect on preference.

10:15

Virtual reality implementation of the Attention Network Test-Revised

David Tekampe [a], Anxhela Sulaj [a], Lars Hausfeld [a], Michael Schwartze [a]
[a] *Maastricht University, NLD*

Abstract:

The widespread availability of high-quality virtual reality (VR) headsets allows integration into neuropsychological settings to develop and optimize cognitive assessment methods. This study aimed to introduce an adapted VR version of the Attention Network Test-Revised (ANT-R; Fan et al., 2009), a well-established computerized neuropsychological assessment tool that differentiates between operationally defined alerting, orienting, and executive aspects of attention, and to test its construct validity. Reaction time and accuracy performance of participants (N = 40) was compared between computerized and VR versions (ANT-VR). Testing took place in a confined laboratory space, with the ANT-VR virtual environment resembling an everyday home setting delivered through a standalone headset (MetaQuest 2). Participants additionally completed the Quality of Experience Test (Brunnström et al., 2020). Results indicated good utilization of the headset during the testing. The main analyses revealed some notable differences such as overall longer reaction times and a smaller orienting effect for the ANT-VR. However, a comparable result pattern and correlated network scores confirmed that alerting, orienting, and executive control attention networks were adequately assessed and differentiated by the ANT-VR. The ANT-VR thus instantiates a viable mobile and ecologically more valid alternative without compromising experimental control in terms of accurate and reliable data collection.

10:20

Comparison of pupillometry data from virtual reality headset and Eyelink 1000 eye tracker

Tim Green [a], Lorenzo Picinali [b], Tim Murray-Browne [b], Isaac Engel [b], Craig Henry [b]
[a] *University College London, GBR* [b] *Imperial College London, GBR*

Abstract:

In an initial exploration of virtual reality (VR) for assessing speech recognition and listening effort in realistic environments, pupillometry data collected via a consumer Vive Pro-Eye headset were compared with data obtained via an Eyelink 1000 system, from the same normally-hearing participants presented with similar non-spatialized auditory stimuli. Vive testing used a custom platform based on Unity for video playback and MaxMSP for headphones-based audio rendering and overall control. For Eyelink measurements, head movements were minimized by a chin rest and participants fixated on a cross presented on a grey screen. No such constraints were present for Vive measurements which were conducted both using a 360° cafe video and with a uniformly grey visual field. Participants identified IEEE sentences in babble at two signal-to-noise ratios (SNRs). The lower SNR (-3 dB) produced around 65% word recognition, while performance for the higher SNR (+6 dB) was at ceiling. As expected, pupil dilation was greater for the lower SNR, indicating increased listening effort. Averaged across participants, pupil data were very similar across systems, and for the Vive, across the different visual backgrounds, thereby supporting the idea that VR systems have the potential to provide useful pupillometric listening effort data in realistic environments.

10:25

Visual speech benefit provided by realistic sentences in noise and the effect of hearing loss and aiding

Joerg M. Buchholz [a], Kelly Miles [a], Ronny Ibrahim [a], and Peter Derleth [b]
[a] *Macquarie University, AUS* [b] *Sonova AG, CHE*

Abstract:

Understanding speech in background noise presents a significant challenge to listeners with hearing loss, and current hearing devices provide only limited benefit in very noisy conditions. While seeing a talker's face can improve intelligibility, visual benefit has typically been quantified using rather unrealistic audio-visual speech materials that likely overpredict the benefit experienced in the real-world. Here, we investigated visual benefit using realistic effortful speech from the ECO-SiN corpus. Audio-only, audio-visual and visual-only sentences were presented in three simulated real-world environments at their realistic sound levels in a 3D loudspeaker array with an integrated high-resolution video projector system. Ten young normal-hearing (NH) listeners as well as 16 older listeners with sensorineural hearing loss participated in the experiment with and without their own hearing aids. Results showed a substantial visual benefit for both groups. While the NH listeners rapidly hit ceiling, listeners with hearing loss struggled to understand the audio-only sentences in the louder background noise conditions – even when aided. There was, however, demonstrable visual benefit in the audio-visual condition. Future research will explore if the individual outcomes of the audio-visual ECO-SIN test better reflects real-world hearing abilities, and how far this is maintained when using virtual reality glasses.

Presentations

Wednesday 11:30 - 12:00

Influence of visual cues in interactive audiovisual virtual environments on auditory attention decoding and cortical tracking of speech

Mareike Daeglau [a], Jürgen Otten [a], Bojana Mirkovic [a], Giso Grimm [a], Volker Hohmann [a], Stefan Debener [a]
[a] *University of Oldenburg, DEU*

Abstract:

Interactive virtual environments (VEs) with realistic auditory and visual presentation capabilities provide a unique opportunity to combine the reproducibility of laboratory research with the complexity of every-day life communication. We focus on investigating the influence of audio-visual cues on sustained attention to speech in a social setting by means of motion sensor data, electroencephalography (EEG) and neural speech tracking. The EEG results of our first study (N=20) indicate that congruent lip-movements indeed facilitate neural speech tracking for both realistic and virtual realistic scenes compared to audio-only in noise for young, normal hearing adults. These findings are currently complemented in a second study investigating the influence of head movements on conversational turn taking recognition. Both studies will help to pave the way for an interactive, immersive communication in VE, where participants will be actively involved in unscripted, real-time conversations in contrast to non-interactive, passive listening tasks. We will present our EEG results along with motion sensor results and a lip-synchronization algorithm evaluation. Further, we present our procedures for stimulus design and synchronization of data streams. Our research will be valuable in advancing our understanding of the interplay between visual and auditory information processing and its impact on neural speech tracking.

Wednesday 13:30 - 14:00

Towards Plausible Cognitive Research in Virtual Environments: The Effect of Audiovisual Cues on Short-Term Memory in Two-Talker Conversations

Jonathan Ehret [a], Cosima A. Ermert [a], Chinthusa Mohanathasan [a], Janina Fels [a], Torsten W. Kuhlen [a], Sabine J. Schlittmeier [a]
[a] *RWTH Aachen University, DEU*

Abstract:

When three or more people are involved in a conversation, often one conversational partner listens to what the others are saying and has to remember the conversational content. The setups in cognitive-psychological experiments often differ substantially from everyday listening situations by neglecting speech-related audiovisual cues. However, the presence of such cues, as the spatial position and non-verbal behavior of the conversing talkers may influence the listener's memory and comprehension of conversational content. In our project, we provide first insights into the contribution of acoustic and visual cues on short-term memory, and (social) presence. Analyses have shown that the memory performance is affected by increasingly more plausible audiovisual characteristics. Furthermore, we have conducted a series of experiments regarding the influence of the visual reproduction medium (virtual reality vs. traditional computer screens) and different aspects of audiovisual mismatch on auditory short-term memory. Adding virtual embodiments to the talkers allowed us to conduct experiments on the influence of the fidelity of co-verbal gestures and turn-taking cues. Thus, we are now able to provide a more plausible paradigm for investigating memory for two-talker conversations within an interactive audiovisual virtual reality environment.

Wednesday 14:00 - 14:30

Evaluating Cognitive Performance in Classroom Scenarios using Audiovisual Virtual Reality

Carolin Breuer [a], Larissa Leist [b], Stephan Fremerey [c], Alexander Raake [c], Maria Klatte [b], Janina Fels [a]
[a] *RWTH Aachen University, DEU* [b] *University of Kaiserslautern-Landau, DEU* [c] *TU-Ilmenau, DEU*

Abstract:

In ECoClass-VR we investigate the suitability of audiovisual virtual environments to assess the influence of complex visual and acoustic scenes on cognitive performance in classroom-type scenarios. Until now, most studies have investigated rather simple acoustic and visual representations, which do not reflect the reality of school children. To improve the validity of the research on cognitive performance in classroom-like scenarios, we successively increase the realism of these paradigms with regard to cognitive tasks and audiovisual scenes. For this purpose, we investigated the suitability of three test paradigms on different cognitive performances that are crucial in school: scene analysis, listening comprehension and auditory selective attention. The first paradigm was created for VR-based research on classroom scenes, while the other two paradigms needed to be transferred from their audio-only focus to complex audiovisual scenes. To increase the realism of the experimental procedures and to compare two different visualization approaches, new 360°videos and computer-generated models of classrooms were created. Further, the complexity of acoustic scenes was increased, reflecting typical classroom noise. Subsequently, the influence of these newly introduced audiovisual variables on the cognitive measures was explored. In this paper, we describe the results from various experiments that have been conducted with adults and children.

Wednesday 15:00 - 15:30

APlausE-MR: Investigating Multi-Party Communication in Audiovisual Mixed-Reality Environments

Felix Immohr [a], Gareth Rendle [b], Annika Neidhardt [a], Anton Lammert [b], Karlheinz Brandenburg [a], Bernd Froehlich [b], Alexander Raake [a]
[a] *TU-Ilmenau, DEU* [b] *Bauhaus-University Weimar, DEU*

Abstract:

The APlausE-MR project aims to gain a robust understanding of the factors influencing the audiovisual plausibility of shared experiences and communication in multi-party mixed reality environments. In this context, we have developed a distributed audio-visual VR framework to realize multi-party study scenarios, and an immersive analytics studio to record and replay the virtual context of study trials. We conduct two experiments on plausibility and social presence in two different interactive VR communication scenarios. In the first scenario, we evaluated the effect of spatial audio on a virtual face-to-face task in a multi-modal IVE and compared it to face-to-face communication in the real world. We noticed only a minor influence of binaural over diotic audio which might be due to the task employed. Therefore, the subsequent study was designed to be more suitable to evaluate the influence of spatial audio on plausibility and presence during a collaboration task. Due to the lack of established evaluation methods to examine such experiences in social VR/MR we discuss and revise methods established in spatial audio, visual VR and teleconferencing. Our hypothesis is that the revised evaluation method is suitable to differentiate between the different audio rendering qualities. A detailed analysis will be presented.

Wednesday 15:30 - 16:00

Audio-visual perception of vehicles while navigating in traffic: Design, evaluation, and research application of multimodal virtual environment technologies

Daniel Oberfeld-Twistel [a], Ercan Altinsoy [b], Thirsa Huisman [a], Friedrich Beyer [b], Marlene Wessels [a],
[a] *Johannes Gutenberg University Mainz, DEU* [b] *TU Dresden, DEU*

Abstract:

Our project investigates the role of auditory perception in street-crossing scenarios using audio-visual VR simulations. The group in Mainz implemented an improved version of their simulation system which provides physically plausible acoustic simulations of approaching vehicles in combination with visual VR, and, so far, conducted eight experiments on time-to-collision (TTC) estimation and street-crossing decisions. One series of experiments showed that pedestrians estimate shorter TTCs and make riskier street-crossing decisions for softer compared to louder vehicles, both in an auditory-only and an audiovisual condition, indicating potential risks associated with quieter vehicles. Another series of experiments showed that when the sound of an accelerating conventional vehicle (ICEV) is presented, this largely removes the inadequate consideration of acceleration observed in visual-only TTC estimation. This benefit provided by the car sound is, however, strongly reduced for electric vehicles (EVs) with and without AVAS. Compatible with these results, the probability of unsafe road-crossing decisions increases significantly with the acceleration level for EVs with and without AVAS, but remains low for ICEVs. In the remaining 18 project months, the group will focus on investigating how the different (psycho-)acoustic cues that are potentially informative for TTC estimation are combined, based on simulation techniques developed in the project that can shift these cues against each other. Such an experimental approach is only possible in virtual environments.

The group in Dresden implemented some of the traffic scenarios that were investigated in Mainz with Higher Order Ambisonics (HOA) rendering, using the wave field synthesis system (WFS) in Dresden. The aim was to compare the two audio reproduction approaches in terms of perception and behavior in the simulated traffic scenarios. Therefore, this joint study used the same design as an experiment on the effect of loudness on TTC estimation conducted in Mainz. A Matlab-Toolbox was developed to create the virtual environment in the WFS and to control the experiment. The results are very promising in the sense that both audio reproduction systems deliver comparable TTC estimation results. In both setups, the data show that TTC was estimated significantly longer for louder compared to softer vehicles, and the pattern of estimated TTCs was generally similar between the two setups. The group in Dresden also started to develop a synthesis model for auralization of synthetic vehicle pass-by sounds and achieved good progress so far. In the following months, validation experiments will be conducted and the validated version of the model will be ready. Also, an audio-visual recording tool for plausible VR reproduction is planned.

In the following joint studies, we will further compare the different simulation and rendering approaches in the relevant tasks. In addition to this behavioral evaluation of the quality of the VR systems, perceptual evaluations of the sound quality, comparisons based on psychoacoustic models, and further physical validation measurements are planned.

DAY 3 - Thursday, 22.06

Keynote:

Thursday 9:00 - 10:00

Sensory prediction in auditory scene analysis, audiovisual interplay, and VR evaluation

Alexandra Bendixen [a]
[a] *TU Chemnitz, DEU*

Abstract:

How humans make sense of the complex auditory world around them, can be studied by creating scenes with multiple interpretations, and recording listeners' scene perception over time. Using this approach, we investigate factors that stabilize auditory perception in ambiguous scenes, such as predictability of the acoustic input, and how the use of predictability may change with auditory aging. Many of our paradigms rely on subjective reports of listeners' perception, and we continuously work on methods for verifying those reports based on physiological responses. Our recent combinations of auditory multistability with eyetracking have given us novel insights into the interplay of auditory and visual multistability, with implications for our general understanding of scene analysis across the senses. Most recently we have turned the psychophysiological measurement logic around and now use brain responses relating to sensory prediction to evaluate certain aspects of virtual reality (VR), such as the adequacy of VR latencies.

Biography:

Alexandra Bendixen studied Psychology at the Universities of Leipzig and Grenoble (France) and received her diploma degree in 2005. She obtained her doctorate at the intersection of Psychology and Neuroscience in 2008. After working at the Hungarian Academy of Sciences in Budapest as a postdoctoral researcher, she returned to Leipzig for her habilitation. In 2013, she joined the Cluster of Excellence "Hearing4all" at Oldenburg University as a junior professor on Psychophysiology of Hearing. In 2015, she joined Chemnitz University of Technology as a full professor at the Institute of Physics, where she heads the Cognitive Systems lab. Throughout her academic career, Alexandra Bendixen has been fascinated with the highly interdisciplinary topic of human hearing. Her research methods include psychophysics, EEG-based psychophysiology, and more recently also eye-tracking and virtual reality.

10:00

Influence of stand configurations on ecological validity of audiovisual recording systems

Angela Guastamacchia [a], Giuseppina Emma Puglisi [a], Andrea Bottega [a], Louena Shtrepi [a], Fabrizio Riente [a], Arianna Astolfi [a]

[a] *Politecnico di Torino, ITA*

Abstract:

Lately, auditory research has stressed the importance of maximizing the ecological validity of the laboratory tests used for assessing hearing loss degree, empowering hearing-aids and performing their fitting. Thus, simulations and in-field recordings of spatialized audiovisual scenes returning complex acoustic environments are now being integrated into these tests. However, because of the complicated interplay between visual and aural human perception, capturing through in-field recordings synchronized audiovisual scenarios might be tricky. Indeed, to accomplish ecological high-quality audio-video footage, audio-video coherence is essential, which occurs when visual and acoustical scenes' origins match. Yet, most of the available recording devices embed high-resolution 360° stereoscopic cameras but support spatial audio recording only up to 1st ambisonics order, often requiring the use of two different devices placed on the same stand, one for video footage and one for high-order ambisonics audio acquisitions. This work proposes a method for choosing the best stand configuration, for a case study involving Zylia ZM-1 3rd-order ambisonics microphone and Insta360 Pro or Insta360 ONE X2 cameras, based on the evaluation of (i) the influence of the camera on the captured sound field and of the microphone on the visual field, (ii) the degree of quasi-coincidence between ZM-1 and camera devices.

10:05

Shifting Attention Between Simultaneous Voices: How we Prepare to Listen to a New Speaker

Amy Strivens [a], Iring Koch [a], Aureliu Lavric [b]

[a] *RWTH Aachen University, DEU* [b] *University of Exeter, GBR*

Abstract:

Following a conversation in a "cocktail party" situation requires not only selectivity of attention but also its flexible shifting between speakers. The knowledge that a different person is about to start speaking should allow the listeners to "retune" their auditory attention in advance. Surprisingly, the evidence on the benefits of such preparatory attentional shifts has been contradictory. Here we investigated the optimal conditions for detecting of preparatory shifts of auditory attention using a reaction-time paradigm, which required switching attention between simultaneous voices. We manipulated: the probability of having to shift attention to a different speaker (vs. continuing to attend to the same speaker); how often the distractor and target voice required the same response; whether a change vs. repetition of an irrelevant voice attribute (e.g. location) influenced attentional shifts to the relevant attribute (e.g. sex). The probability of a required attentional shift was the only condition to significantly influence preparation for a shift, with a preparation benefit found only when shifts were relatively rare. Our results suggest that this may be due to a general tendency (bias) to commit more strongly to the currently relevant attentional template when shifts are relatively rare and less strongly when shifts are likely.

10:10

Give me a break! Designing future VR scenarios for acoustically demanding work environments

Jan Grenzebach [a], Thea Radüntz [a], Jonas Obleser [b], Malte Wöstmann [b]
[a] *Federal Institute for Occupational Safety and Health, DEU* [b] *University of Lübeck, DEU*

Abstract:

At the workplace, the soundscape (e.g., noise) influences the well-being of employees. Dependent on the occupation, cognitive functions involved are prone to interferences from the irrelevant sound. Breaks help prevent mental overload. Similarly, demanding soundscapes are often presented to subjects in (virtual reality; VR) experiments, but little is known about subjects' need for breaks. Presenting a reanalysis of an existing dataset from an effortful listening task with irrelevant speech, we aim to understand the influence of acoustic distractions on the self-paced recovery breaks between trials. We find that break duration can be explained by mental demand, quantified by accuracy and acoustics of distracting speech signals. Furthermore, break duration changes with time on task and exhibits serial dependencies (i.e., past break durations predict current break duration). Eventually, we propose the design of an experiment including appropriate breaks, relying on a digital twin ("VR") of an office workplace recreated in a living lab ("real-world"). There, we will investigate the difference in effect between real and artificially produced sounds on mental workload by electroencephalography. Our goal is to validate a VR environment that can be easily adapted to today's fast-changing work characteristics for understanding and preventing potentially harmful working conditions.

10:15

Detection of pattern repetitions in continuous acoustic sequences is robust against inattention and temporal irregularity

Hanna Ringer [a,b,c], Erich Schröger [b], Sabine Grimm [d]
[a] *Max Planck Institute for Human Cognitive and Brain Science, DEU* [b] *University of Leipzig, DEU* [c] *Max Planck Institute for Empirical Aesthetics, DEU* [d] *TU Chemnitz, DEU*

Abstract:

Detection of repeating patterns within continuous sound streams is critical for efficient auditory perception. Previous research demonstrated that our auditory system is remarkably sensitive to periodic repetitions in randomly generated sounds. Automatic repetition detection was reflected in different EEG markers, partly attributed to dissociable functions. The present study sought to test how listeners' attention and the temporal regularity of sounds modulate repetition detection, and how this is reflected in different EEG markers. We presented listeners with random acoustic sequences that did or did not contain repetitions of a certain sound segment. Repetitions were temporally regular or jittered, and attention was directed towards or away from the sounds. Across all attention and regularity conditions, pattern repetitions led to increased sustained response amplitudes, a positivity-negativity complex in the event-related potential relative to pattern onset, and enhanced inter-trial phase coherence of low-frequency oscillations. While there was no clear evidence for a modulation by regularity, attention significantly enhanced the processing of pattern repetitions, reflected consistently in all EEG markers. This suggests that repetition detection relies on a flexible mechanism that is robust across varying listening demands, such as they occur in naturalistic contexts, and can be sharpened by attention to the auditory input.

10:20

Soundscaping the Game World: The Impact of Character and Ambient Sounds on Immersion and Avatar Identification

Luise Haehn [a], Leonie Borowczak [a], Sabine J. Schlittmeier [a], Christian Böffel [a]
[a] *RWTH Aachen University, DEU*

Abstract:

Modern videogames are interactive audio-visual environments that generally feature an elaborate sound design to deepen the game experience, enhance immersion and increase fun. Character sounds, such as the sound of footsteps when a character is walking, are used to convey a sense of interactivity and realism in the digital world and strengthen the bond between a person and their avatar. Ambient sounds on the other hand, create a vibrant and lifelike acoustic environment that draws people in, further immersing the player. While past research has primarily focused on the effects of background music, the current study investigates how character and ambient sounds influence the gaming experience. We further explore how these types of sounds interact with each other in creating an immersive soundscape. The degree of subjective immersion and identification with the avatar during gameplay is measured under different ambient and character sound conditions using self-report measures. The relationship between these different measures of the gaming experience is examined by calculating correlations between them. Based on the results, we hope to gain insight on how immersion in interactive audio-visual environments can be influenced and discuss implications for future research and sound design in videogames.

Presentations

Thursday 11:30 - 12:00

Influence of audio rendering in virtual environments on realism, presence, and socio-cognitive processing

Matthias Blau [a, d], Steven van de Par [b, d], Andreas Mühlberger [c], Felix Stärz [a], Leon O. H. Kroczek [c], Sarah Roßkopf [c]

[a] *Jade University, DEU* [b] *University of Oldenburg, DEU* [c] *University of Regensburg, DEU* [d] *Hearing4All, DEU*

Abstract:

Although it is commonly agreed that auditory stimuli are crucial in studying perception and cognition in iVEs, the quality of the audio rendering is often neglected. In this project, we create and evaluate virtual representations of communication scenes in mid-sized rooms, by using a combination of visual renderings presented via head-mounted displays and head-tracked binaural rendering presented via headphones. In a first series of experiments, we investigate concepts to assess the transfer of the acoustic perception from the original to the rendered scene. This includes various degrees of virtualization (audio only, audio-visual) and experimental paradigms. Results show that highly plausible and realistic virtual representations can be created which are extremely difficult to distinguish from loudspeaker presentations in the same room. Concurrently, we focus on the effect of the audio rendering on socio-cognitive processing, in particular in relation to social anxiety. One important aspect in this context is the perception of distance of persons in, e.g. classroom scenarios. Results show that distance perception and presence are influenced by many factors, including the plausibility of the audio rendering. Further work will focus on rendering virtual scenes in ordinary office rooms and on studying the role of attention in social anxiety.

Thursday 13:30 - 14:00

Quality of Experience in Interactive Virtual Environments: Contributions Towards a Methodological Framework

Thomas Robotham [a], William Menz [b], Ashutosh Singla [b], Alexander Raake [b], Emanu ël A. P. Habets [a]

[a] *Friedrich-Alexander-University Erlangen-Nürnberg, DEU* [b] *TU-Ilmenau, DEU*

Abstract:

The QoEVAVE project, which is part of the DFG priority program Auditory Cognition in Interactive Virtual Environments (AUDICTIVE), aims to establish a methodological framework for evaluating the Quality of Experience (QoE) in interactive virtual environments. The project has pursued both long-term and short-term research goals, resulting in the publication of several articles that contribute to the three AUDICTIVE research priorities: auditory cognition, evaluation methods, and interactive virtual environments. This review article outlines the contributions of the QoEVAVE project in the context of the research priorities. First, an evaluation tool has been developed allowing QoE research to be conducted in an immersive setting. Secondly, new content is created that focuses on audiovisual elements in addition to exposing higher-level cognitive functions in QoE formation. Thirdly, using a combination of the above contributions, we provide several specific insights regarding evaluation methods and cross-modality perception through saliency analysis and quality-judgment-based approaches. Finally, the article highlights future research considerations for both the QoEVAVE project and the AUDICTIVE initiative, based on the knowledge and insights gained through the project.

Thank you

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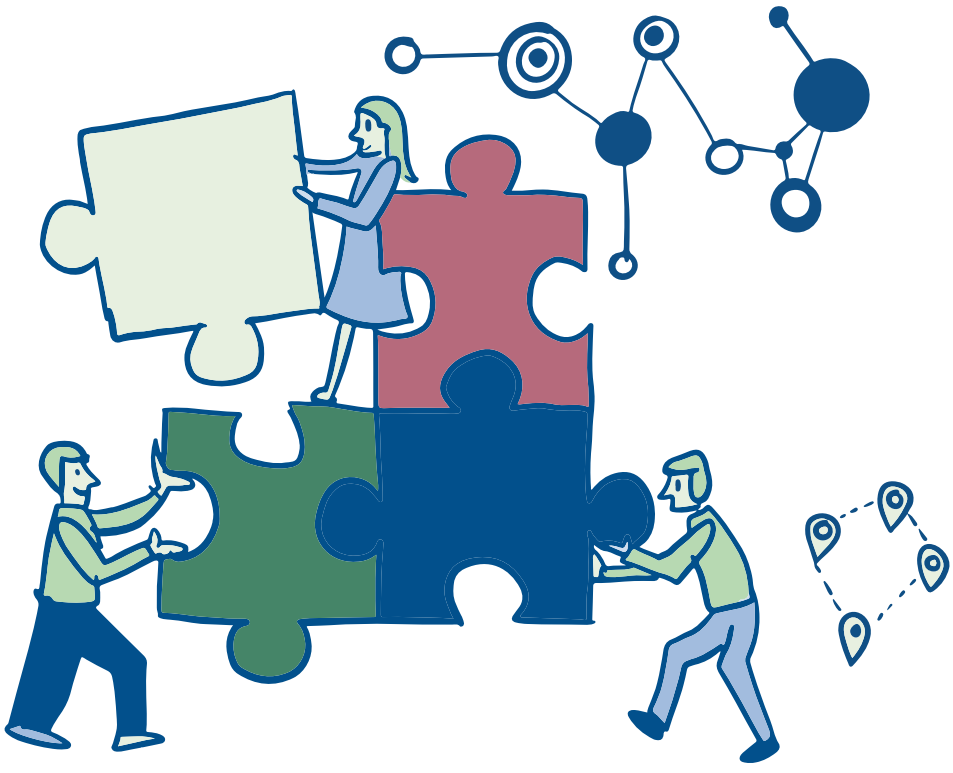

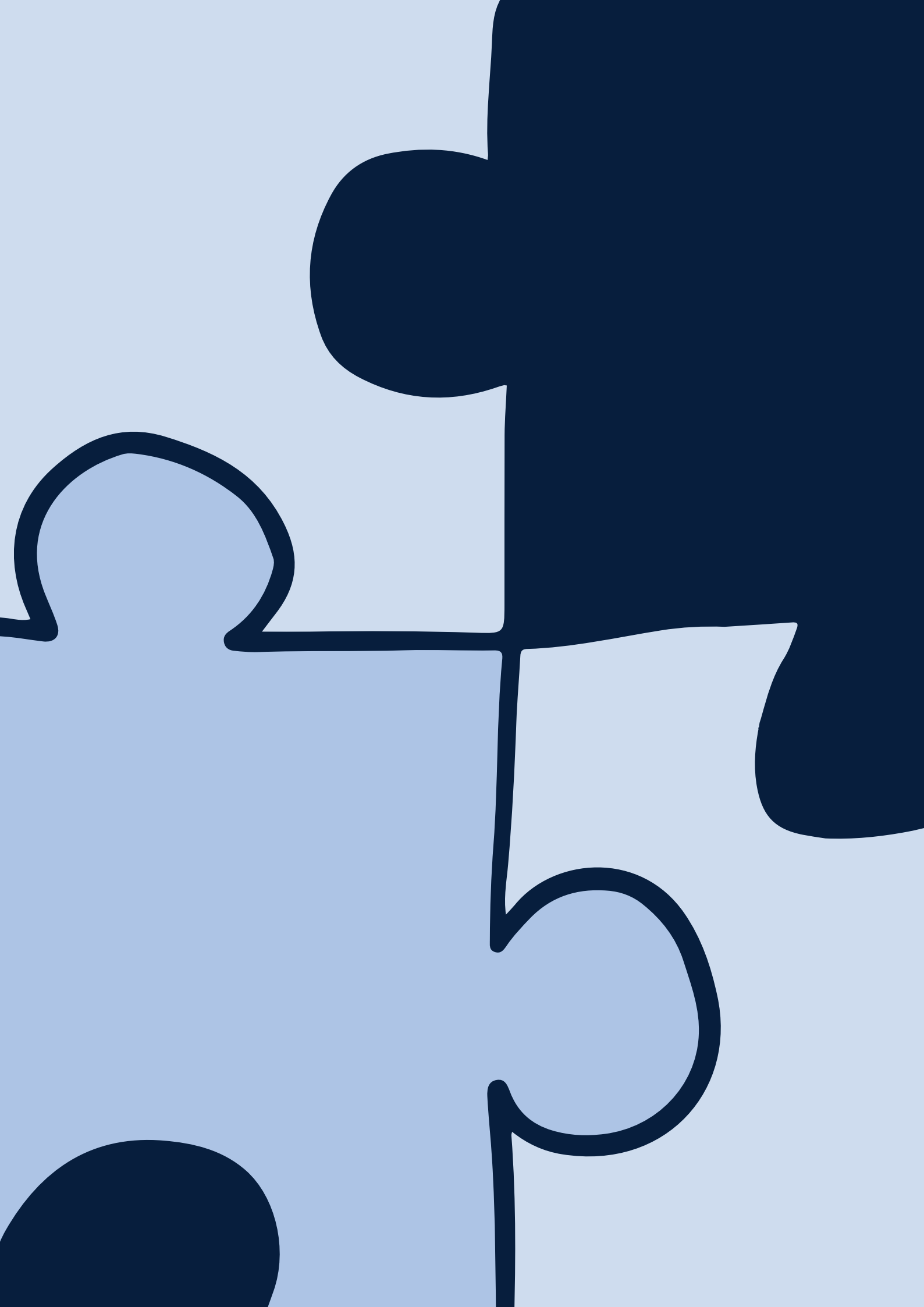

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