Space-aware hearing devices – Making hearing aids smarter

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No permission to take photos

CHAT 2017, Stockholm

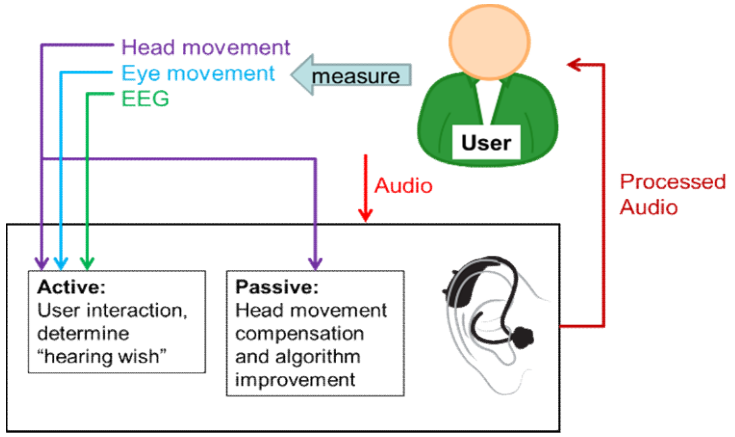
Cocktail-party effect

Problems with acoustic communication in adverse conditions

- Intelligibility
- (Spatial) awareness

Hearing aids help but need improvement

Concept of a „Space-aware“ hearing aid



- Estimate the “hearing wish” from gestures: Defines foreground
- Estimate foreground using a CASA scheme
- Filter signal to enhance foreground

Virtual acoustic environments (VAE)

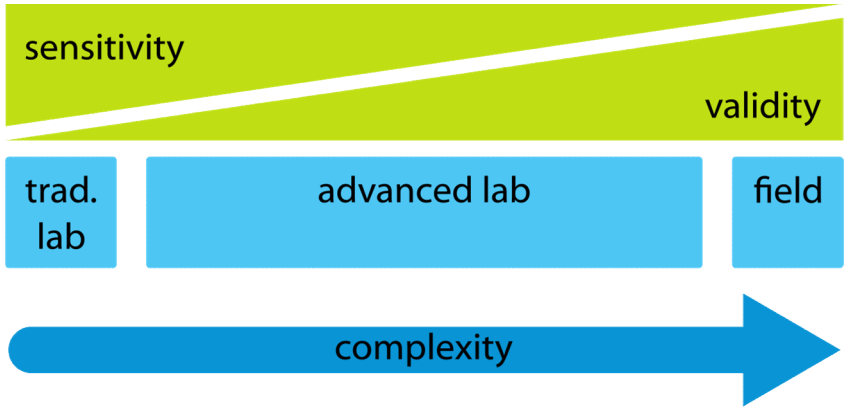
We need more realistic virtual acoustic environments, because…

- Interaction of hearing aids with spatial acoustic environment becomes more complex and cannot be evaluated using standard lab tests
- Simple spatial configurations in the lab may over- or under-estimate hearing aid benefit

We need interactivity (“subject-in-the-loop”), because…

- Hearing aid benefit interacts with the subject‘s behavior, e.g., head motion
- Future hearing aids will adapt to behavior

Advanced lab



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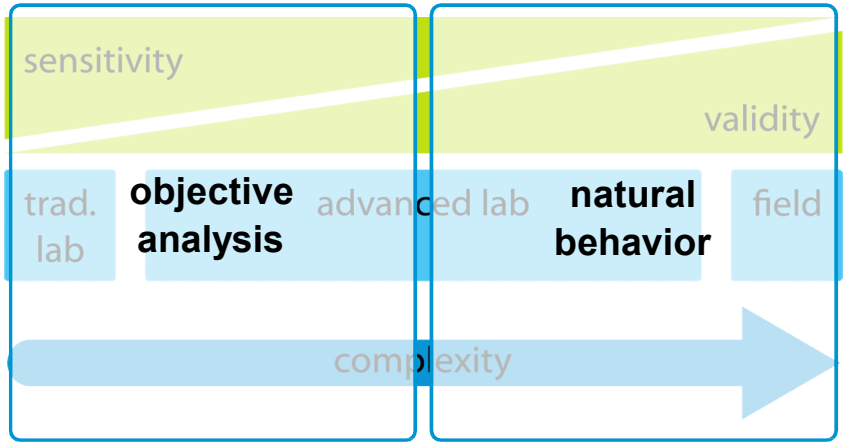
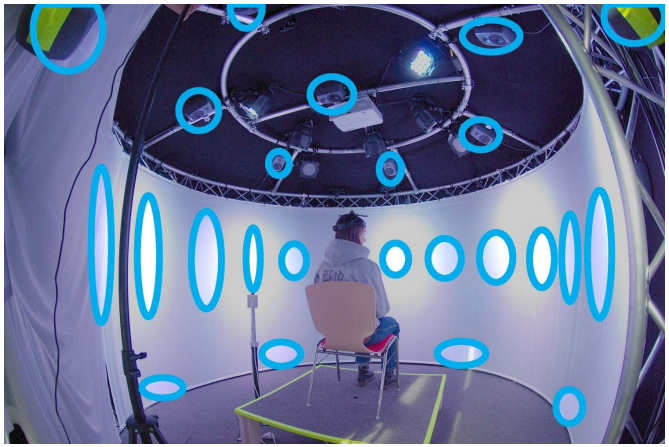


Advanced lab
Setup: The “Gesture lab” in Oldenburg

Stimulus presentation

Sensors

Advanced lab
Setup: The “Gesture lab” in Oldenburg



Stimulus presentation

Audio: 29 channels, 4 subs

Sensors

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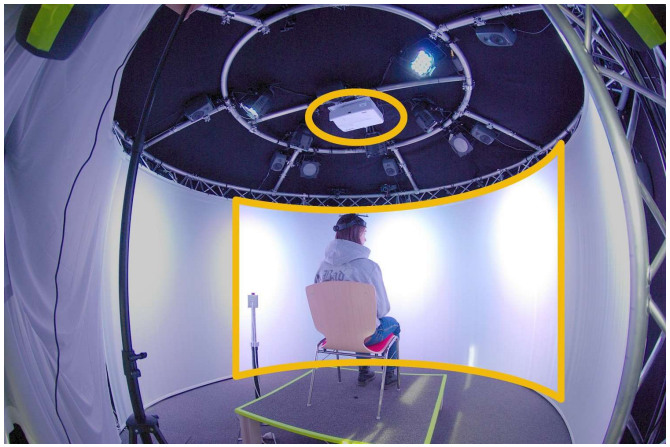

Stimulus presentation

Audio: 29 channels, 4 subs

Video: 120° FOV

Sensors

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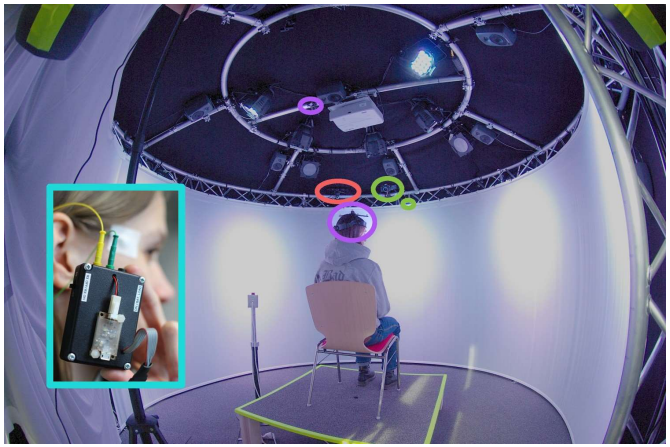

Stimulus presentation

Audio: 29 channels, 4 subs

Video: 120° FOV

Sensors

Eye tracking: EOG bluetooth

Head tracking: marker crown

Body tracking: depth camera

Video observation

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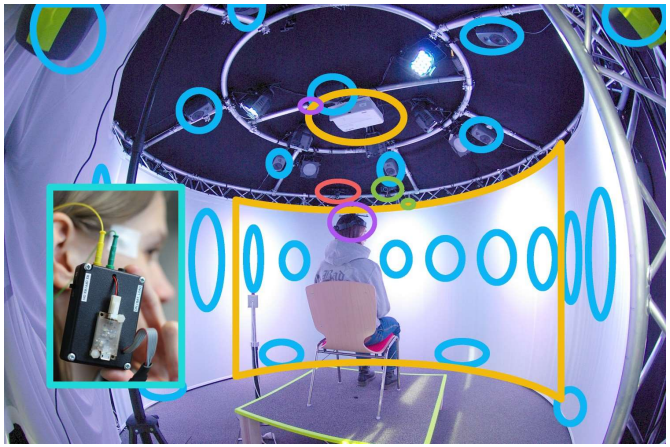

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Sensors

Eye tracking: EOG bluetooth

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Body tracking: depth camera

Video observation

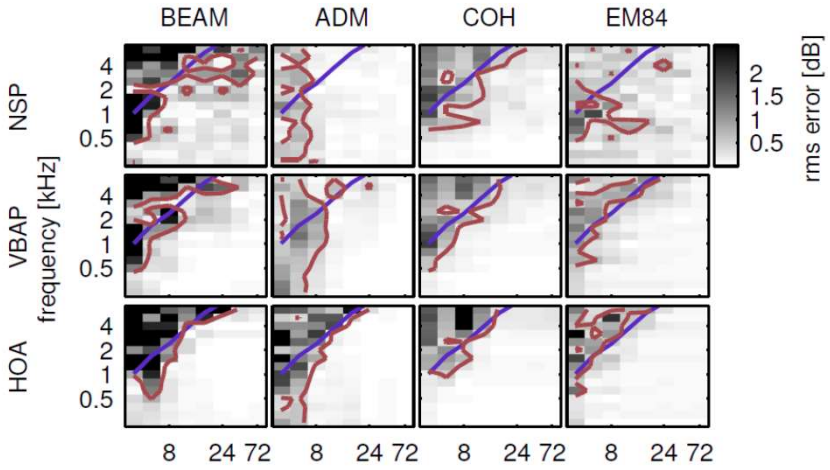
Data logging: time aligned

Evaluation of spatial audio reproduction schemes

- Interaction between spatial resolution and hearing aid performance
- Influence of reproduction method and array size
- Representative hearing aid algorithm classes:
  - Static beamformer 'BEAM'
  - Adaptive differential microphone 'ADM'
  - Binaural noise reduction 'COH'
  - Single channel noise reduction 'EM84'

Grimm, Ewert, Hohmann (2015). *Evaluation of spatial audio reproduction schemes for application in hearing aid research.* Acta Acustica united with Acustica, 101(4), 842-854.

Is Multi-channel Loudspeaker Reproduction valid for Hearing Aid Evaluation?



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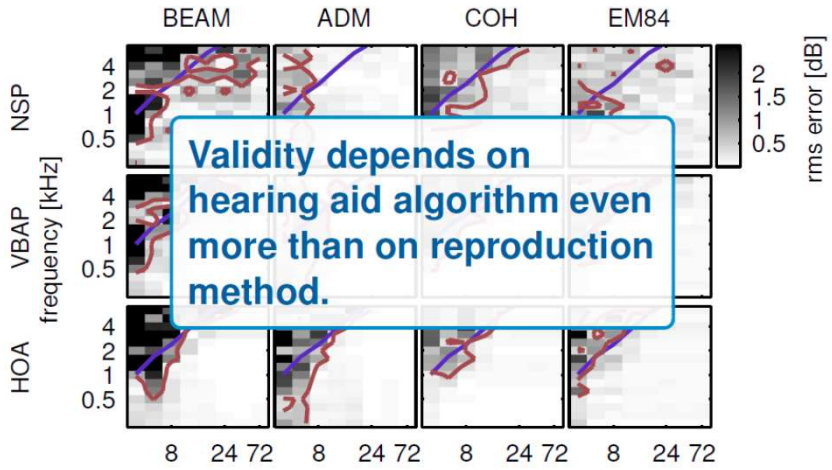
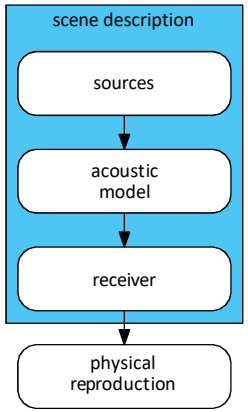
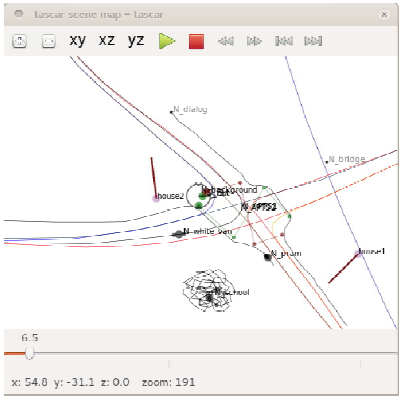


Validity depends on hearing aid algorithm even more than on reproduction method.

Simulation method: Interactive Virtual Acoustic Environments in Hearing Aid Evaluation





TASCAR

Toolbox for acoustic scene creation and rendering

- interactive
- dynamic sources and receivers
- real-time audio processing

Grimm, Luberadzka, Herzke, Hohmann (2015). *Toolbox for acoustic scene creation and rendering (TASCAR): Render methods and research applications.* Proc. Linux Audio Conf.

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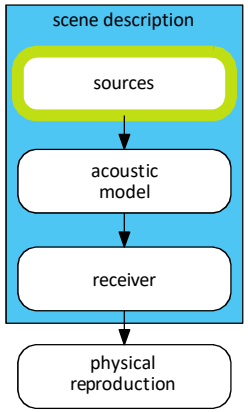

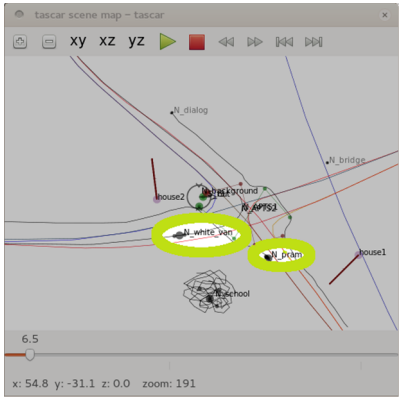

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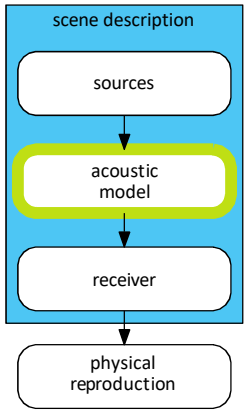

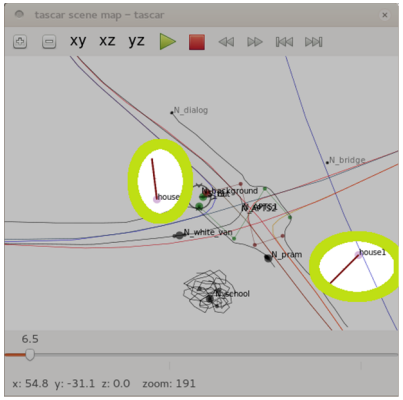

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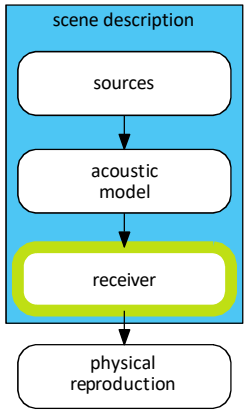

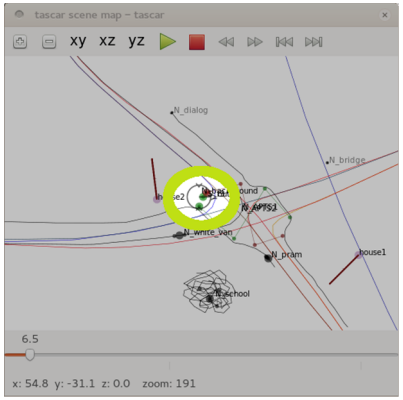

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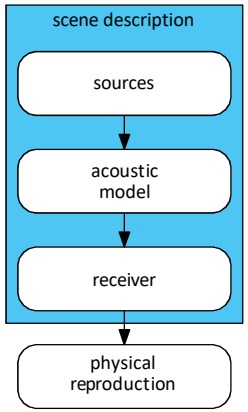

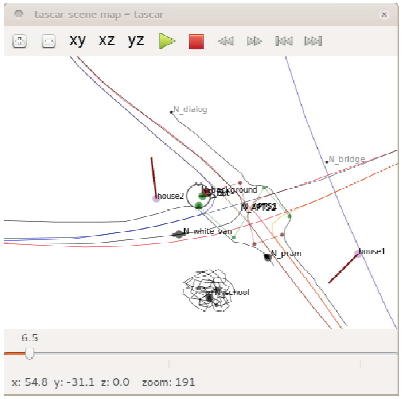

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Applications: Virtual walks with virtual or real hearing aids (Movie)

Prediction of HA benefit in more realistic environments

Benefit from directional microphones

Can be huge in the lab	**Often not found in real-life**
with low spatial complexity	based on field tests and user reports

⇒ **Improve prediction of hearing aid benefit by using virtual acoustic environments**

Grimm, Kollmeier, Hohmann (2016). *Spatial acoustic scenarios in multichannel loudspeaker systems for hearing aid evaluation.* Journal of the American Academy of Audiology, 27(7), 557-566.

Prediction of HA benefit in more realistic environments

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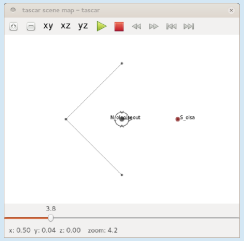

Virtual laboratory

$S_0N_{90}N_{180}N_{270}$

More realistic environments

Prediction of HA benefit in more realistic environments

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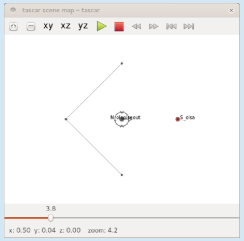

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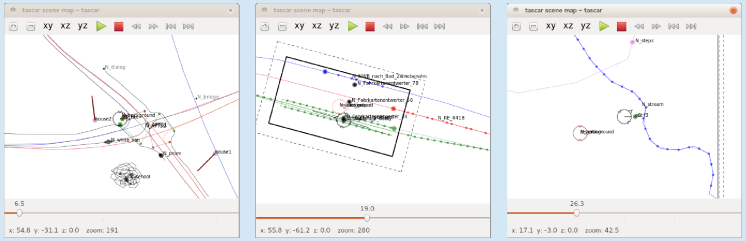

Outdoor and traffic: Street, train station, nature

Prediction of HA benefit in more realistic environments

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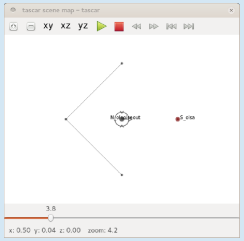

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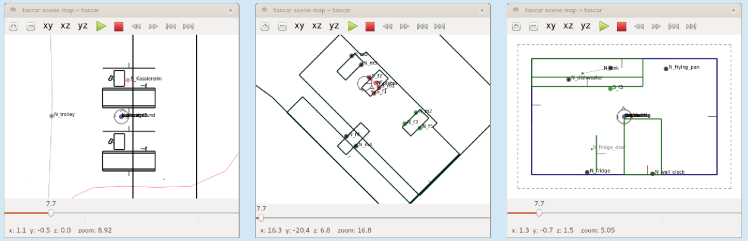

Outdoor and traffic: Street, train station, nature
Active communication: Supermarket, cafeteria, kitchen

Prediction of HA benefit in more realistic environments

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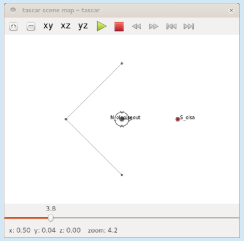

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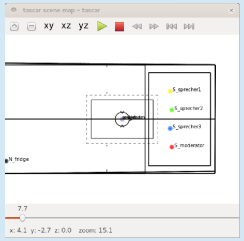
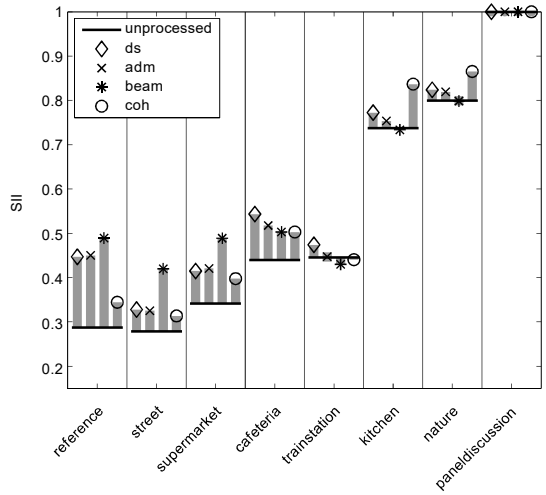


Outdoor and traffic: Street, train station, nature
Active communication: Supermarket, cafeteria, kitchen
Passive listening: Panel discussion

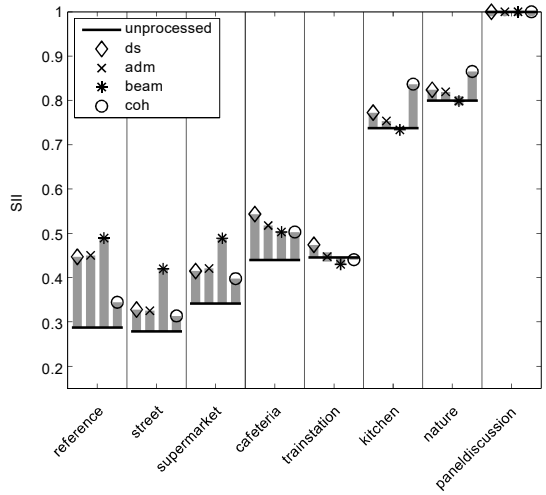
Prediction of HA benefit in more realistic environments



Algorithm benefit

- Large benefit in reference condition
- Smaller benefit in more realistic environments

Prediction of HA benefit in more realistic environments



Algorithm benefit

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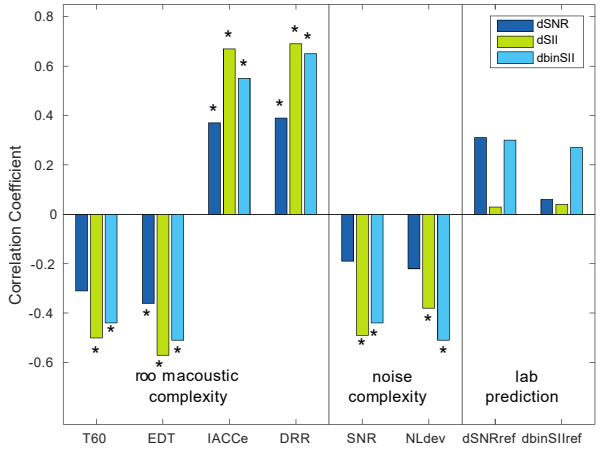
Which properties of the environments can predict HA benefit?

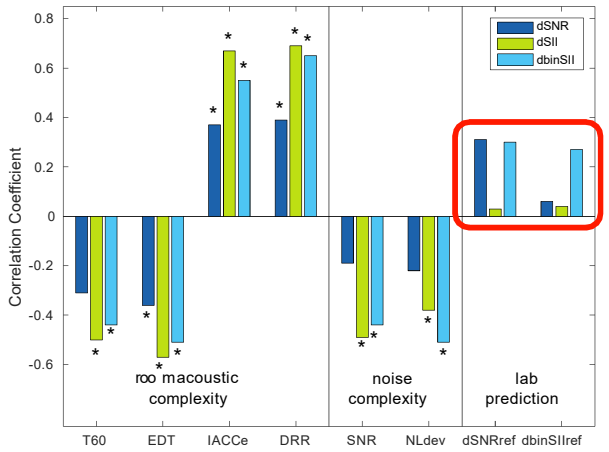
Prediction of HA benefit in more realistic environments



Correlation coefficients between HA performance and

- Room acoustic measures
- Noise properties
- Lab benefit

Prediction of HA benefit in more realistic environments



Correlation coefficients between HA performance and

- Room acoustic measures
- Noise properties
- Lab benefit

Benefit in the lab is not a good predictor of benefit in more realistic environments.

Effect of visual cues on user behaviour
Visual conditions

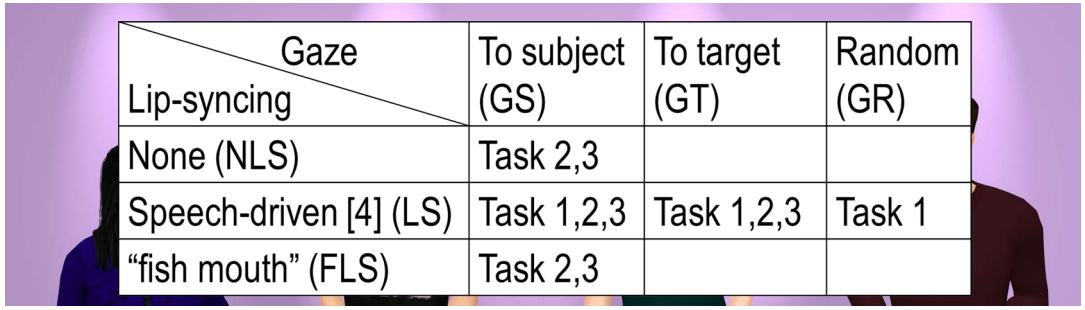
Visual conditions:

no image – video

Effect of visual cues on user behaviour
Visual conditions

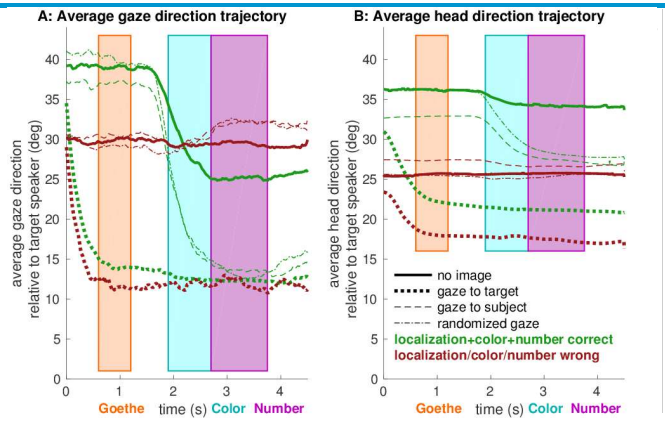
Visual conditions:

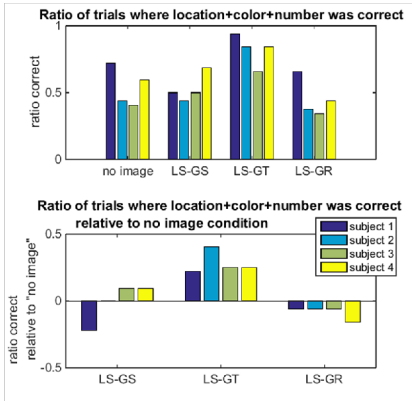
no image – video – animated



Lip-syncing \ Gaze	To subject (GS)	To target (GT)	Random (GR)
None (NLS)	Task 2,3		
Speech-driven [4] (LS)	Task 1,2,3	Task 1,2,3	Task 1
“fish mouth” (FLS)	Task 2,3		

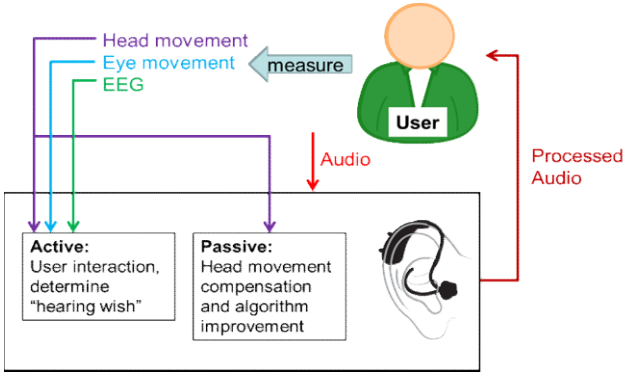
Coordinate Response Measure (CRM)





- Repeat color and number for speaker uttering keyword “Goethe”
- Subjects gaze to target, finding the target required for speech comprehension
- Visual information maybe positive or distracting

„Space-aware“ hearing aid



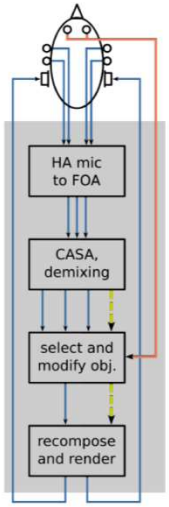
- Estimate the “hearing wish” from gestures: Defines foreground
- Estimate foreground using CASA scheme
- Filter signal to enhance foreground

A simple CASA-based space-aware hearing aid

1. **A simple CASA algorithm**
   which tracks source objects and decomposes the input signal into object signals.

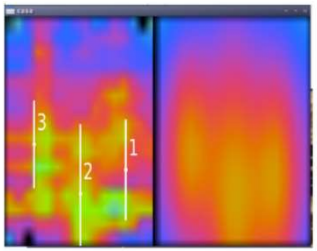
2. **Select objects with eye gestures**
   recorded by a wireless electro-oculography (EOG) amplifier.

3. **Interactive resynthesis to binaural signals**
   using a real-time interactive acoustic simulation toolbox.



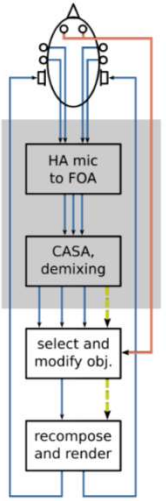
A simple CASA-based space-aware hearing aid

- Decomposition of the acoustic environment into sound objects
- Use First order Ambisonics (FOA) input signal
- Intensity histogram across feature space
- Object model of intensity distribution (Gaussian mixture model)



Feature space (now):
- Direction of arrival
- Frequency

Additional features (future):
- Speech-based features (pitch, modulation)



Virtual conversation with virtual “space aware” hearing aid

- Online CASA algorithm
- Virtual desktop mic
- Yellow: head (cross) and gaze (circle) direction
- Red: Detected hearing wish

Thank you for your attention!

Supported by DFG research unit FOR1732.