Loudness in the field and laboratory

An experiment with vehicle noise

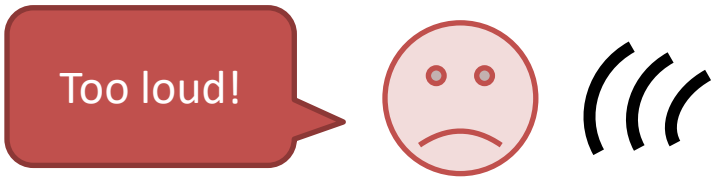
International Hearing Instruments Developer Forum 2019

Gerard Llorach, Dirk Oetting, Melanie Krüger, Matthias Vormann, Giso Grimm, Christina Fitschen, Michael Schulte, Volker Hohmann, Markus Meis

Hörzentrum
Hörtech
Cluster of Excellence Hearing4All
Medizinische Physik, Universität Oldenburg

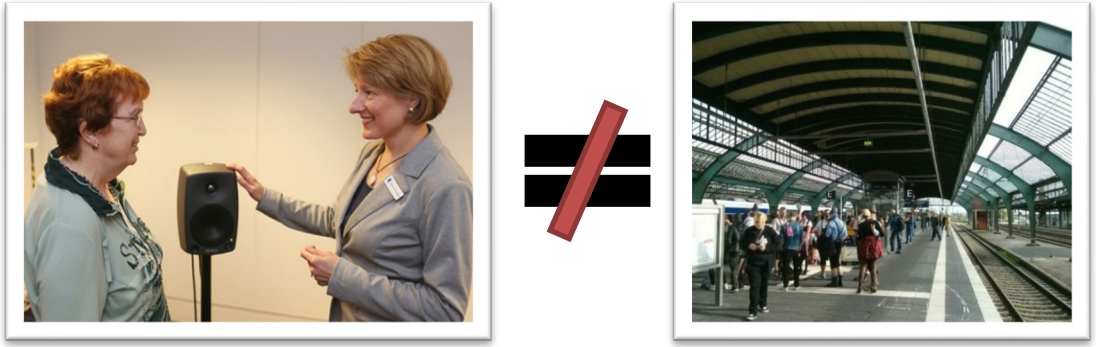
Motivation
Loudness Discomfort

- Hearing aid users complain about loudness



- Clinical audiological methods don't reflect real-life situations

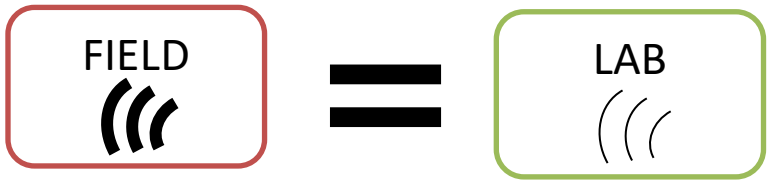
Mueller, G.H. and Bentler, R.A., 2005. Fitting hearing aids using clinical measures of loudness discomfort levels: An evidence-based review of effectiveness. *Journal of the American Academy of Audiology*, *16*(7), pp.461-472.



Related Work
Loudness in the Laboratory

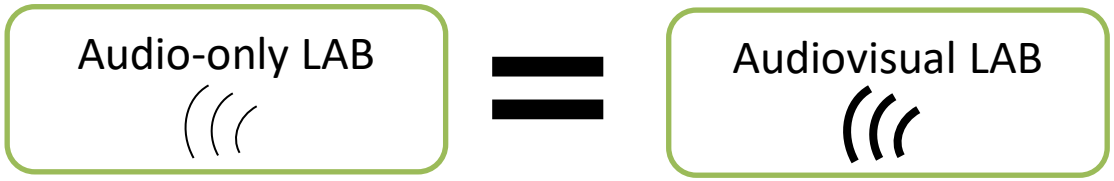
- Lower loudness preference in the laboratory than the field

Smeds, Karolina, Gitte Keidser, Justin Zakis, Harvey Dillon, Arne Leijon, Frances Grant, Elizabeth Convery, and Christopher Brew. "Preferred overall loudness. II: Listening through hearing aids in field and laboratory tests" *International Journal of Audiology* 45, no. 1 (2006): 12-25.



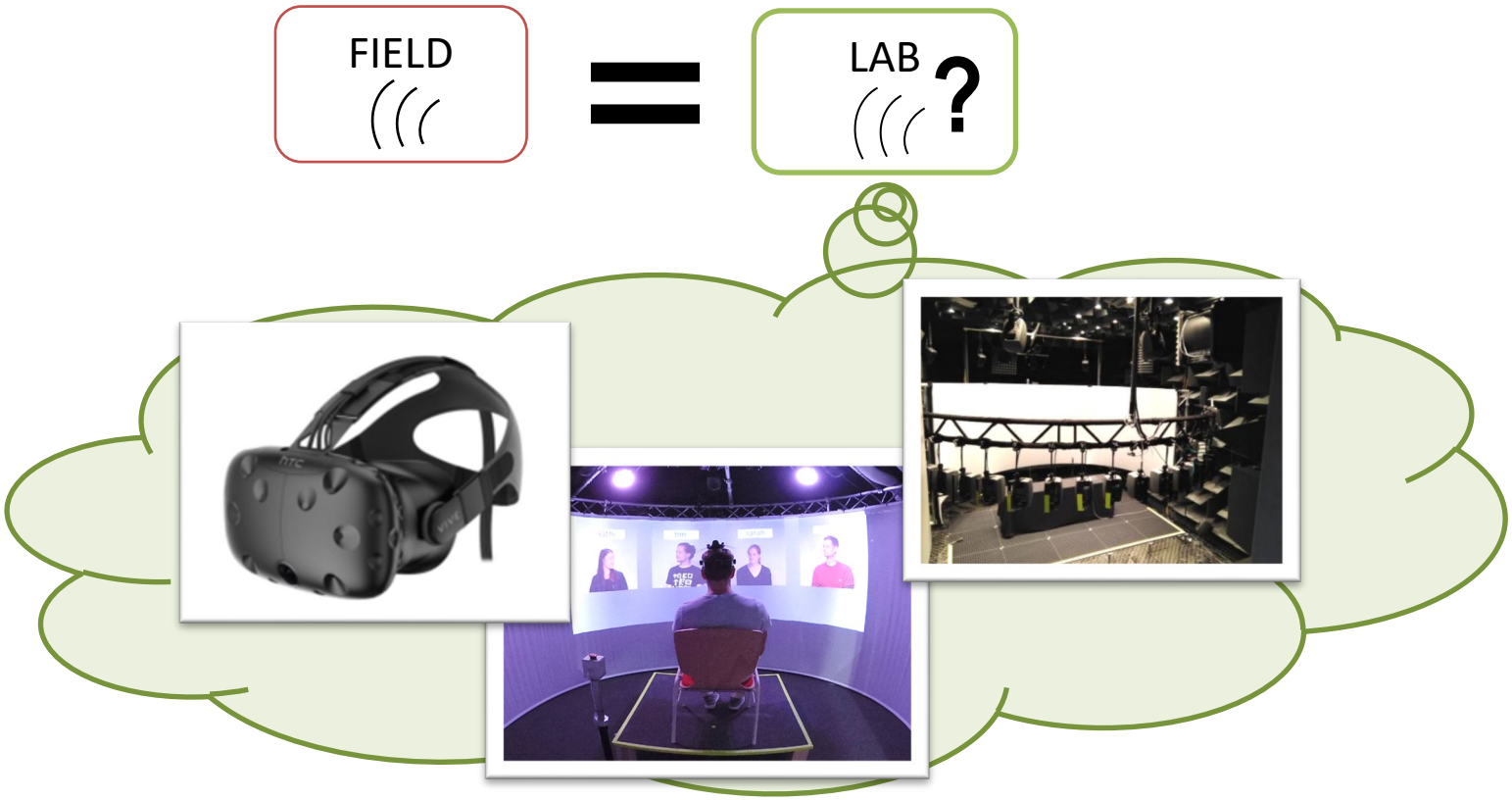
- Visual cues play a role in the laboratory. Sounds are perceived less loud with visual cues

Fastl, H., 2004. Audio-visual interactions in loudness evaluation. In Proc. Int. Congress on Acoustics ICA 2004, 18. Intern. Congress on Acoustics, Kyoto, Japan.



Research Question
Problem

- What do we need in the lab to achieve the same loudness?



Loudness in the field and laboratory

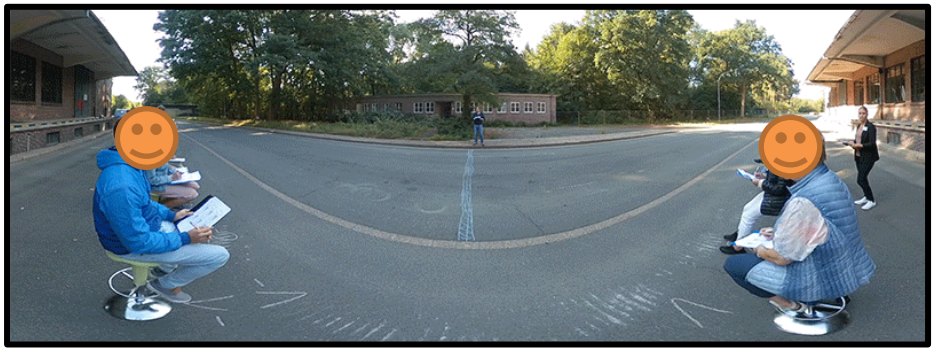
Method

Vehicle noise in the field

Immersive simulations in the laboratory

Research Question
Our approach

- Stimuli
  - Vehicle noise (different vehicles and driving actions)
- Participants
  - **19 Normal Hearing (NH)**
  - 20 Hearing Impaired (HI) with NAL-NL2 and trueLOUDNESS fittings
- Measures
  - Loudness ratings (categorical scale of loudness)
  - Annoyance (ICBEN numerical annoyance scale)
- Field vs Laboratory
  - Field
    - **For NH: test and retest**
    - For HI: NAL-NL2 and trueLOUDNESS
  - Laboratory conditions:
    - HMD and stereo audio
    - Desktop display and stereo audio
    - Audio-only and mono audio



Field Experiment Stimuli

- Loudness perception of vehicles

- Recorded with a 360º camera and a tetrahedral microphone during field experiments

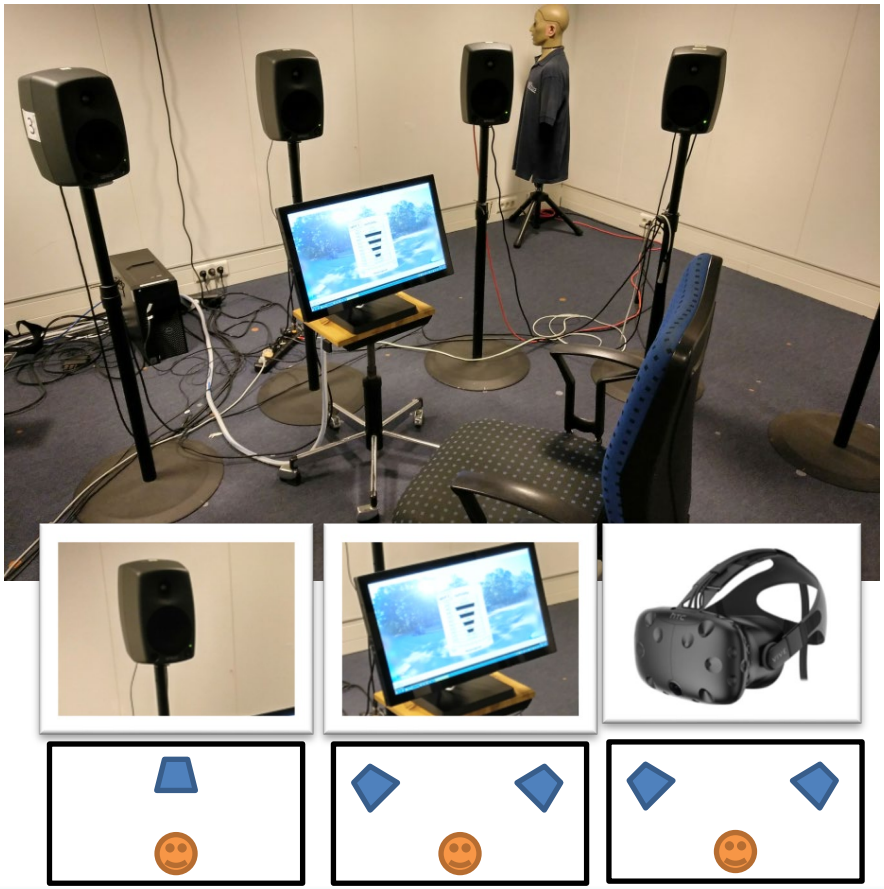
https://www.youtube.com/playlist?list=PLgon04MLXpQpN53hYwTZRmDp0ZSsmnHXB

https://gerardllorach.weebly.com/work.html

Or type “gerard llorach” on google and go to my personal webpage.

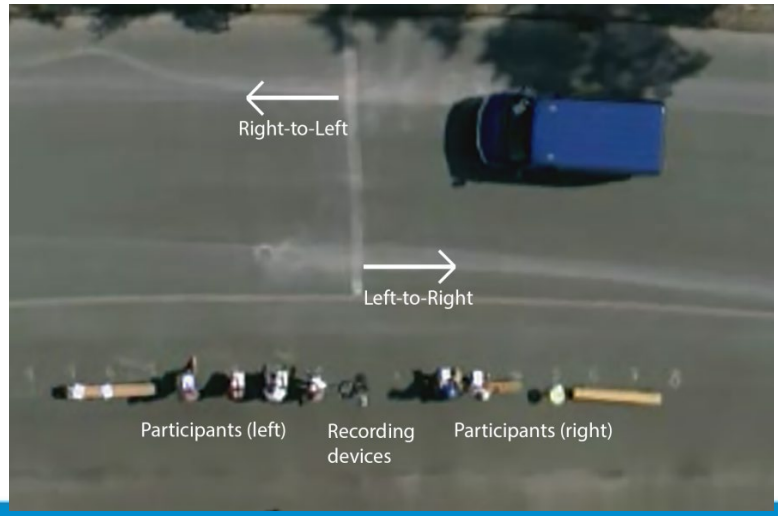
Laboratory experiment
Stimuli

- Recordings of the field experiment (360º Camera and Tetrahedral Microphone)
- Conditions
  - HMD (360º video) with stereo (+-60º loudspeakers)
  - Desktop display with stereo (+-60º loudspeakers)
  - Audio-only mono (frontal loudspeaker)



Experiment
Stimuli - Driving actions

- 10 driving actions with the car, motorbike and van:
  - Stand by close
  - Accelerate close
  - 30 km/h far
  - 50 km/h close
  - Break and stop far
  - Stand by far
  - Accelerate far
  - 30 km/h close
  - 50 km/h far
  - Break and stop close
- 6 driving actions with the street sweeper
  - Stand by close
  - Brushes on close
  - Brushing forward close
  - Stand by far
  - Brushes on far
  - Brushing forward far
- 36 driving actions in total



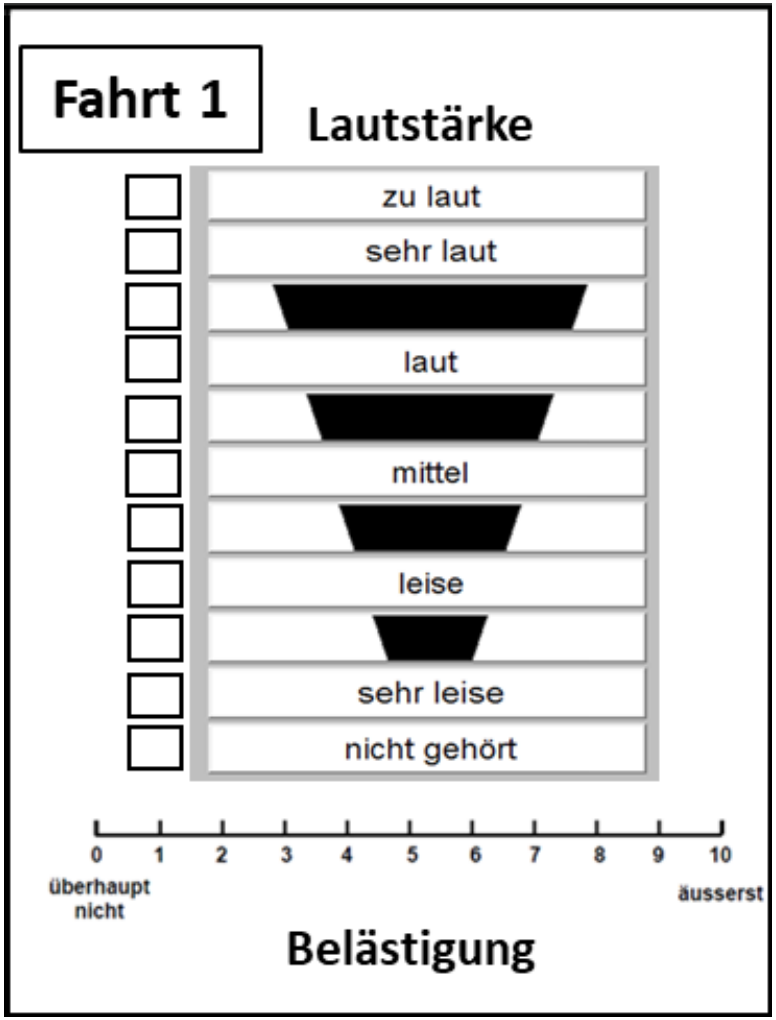
Experiment
Measures – Questionnaires

- Categorical Units of Loudness (CU)
  - From “nicht gehört” to “zu laut”

ISO, 2006. “Acoustics Loudness scaling by means of categories” (ISO 16832:2006). International Organization for Standardization.

- ICBEN annoyance scale (0-10)

ISO, 2003. “Acoustics Assessment of Noise Annoyance by Means of Social and Socioacoustic Surveys” (ISO/TS 15666:2003). International Organization for Standardization.



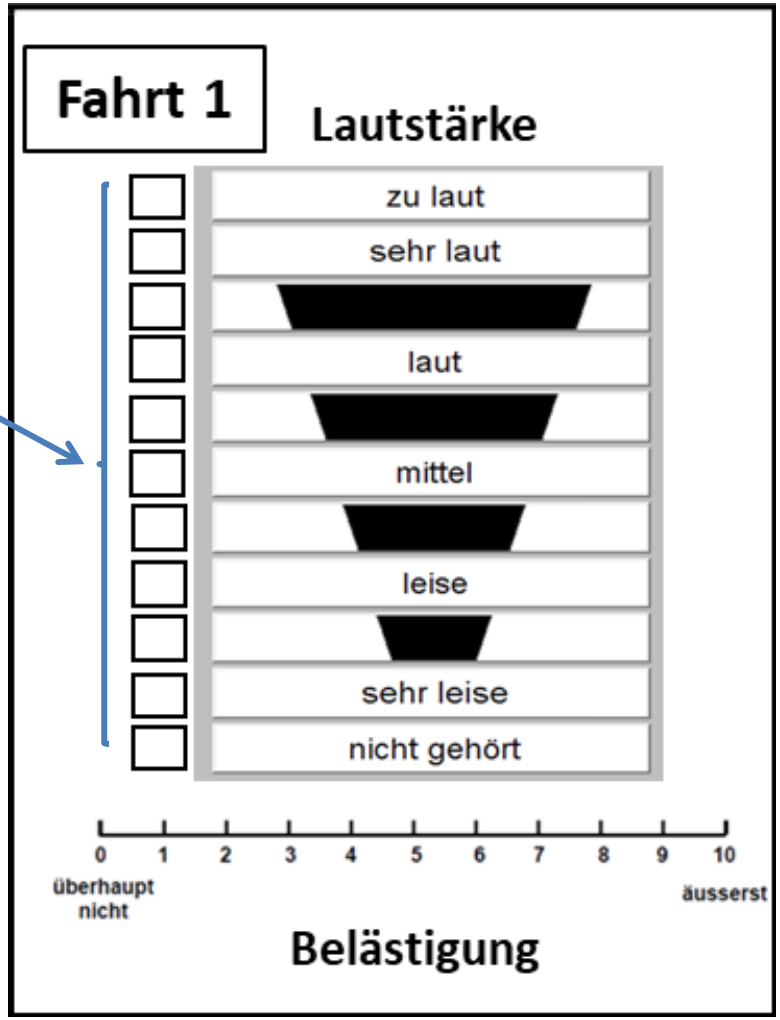
Experiment
Measures – Questionnaires

- Categorical Units of Loudness (CU)
  - From “nicht gehört” to “zu laut”

ISO, 2006. “Acoustics Loudness scaling by means of categories” (ISO 16832:2006). International Organization for Standardization.

- ICBEN annoyance scale (0-10)

ISO, 2003. “Acoustics Assessment of Noise Annoyance by Means of Social and Socioacoustic Surveys” (ISO/TS 15666:2003). International Organization for Standardization.



Field results (Normal Hearing)

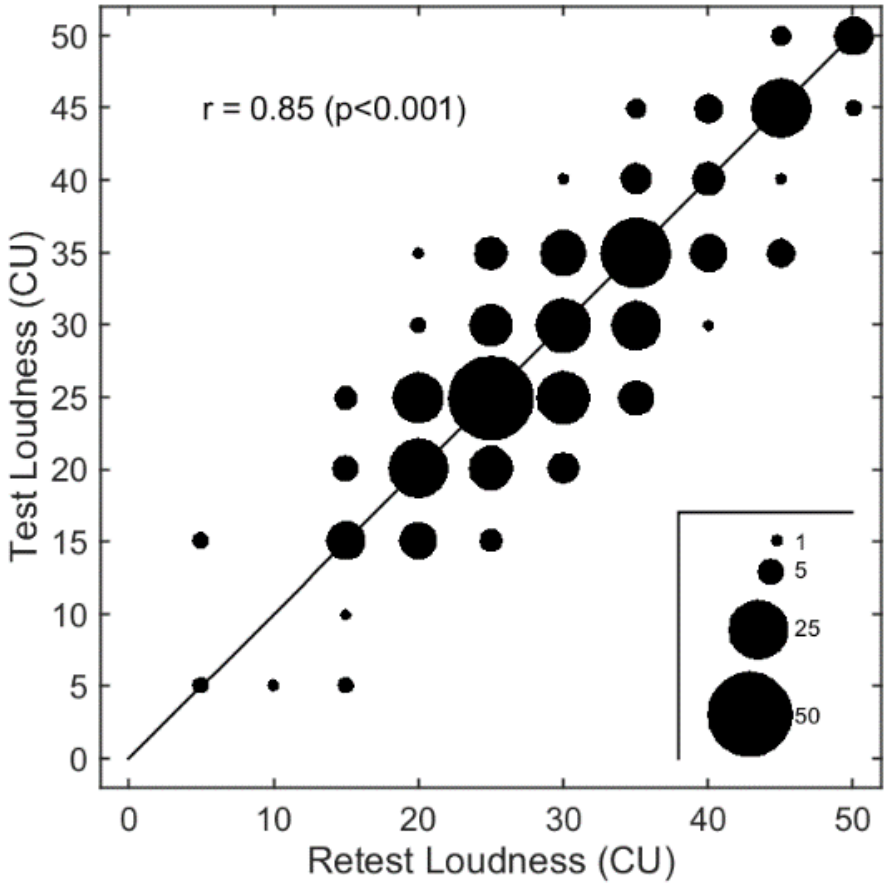
Loudness perception and models

G. Llorach, D. Oetting, M. Krüger, M. Vormann, C. Fitschen, M. Schulte, V. Hohmann, M. Meis, Vehicle Noise: Loudness Ratings, Loudness Models and Future Experiments with Audiovisual Immersive Simulations, to appear in Internoise 2019

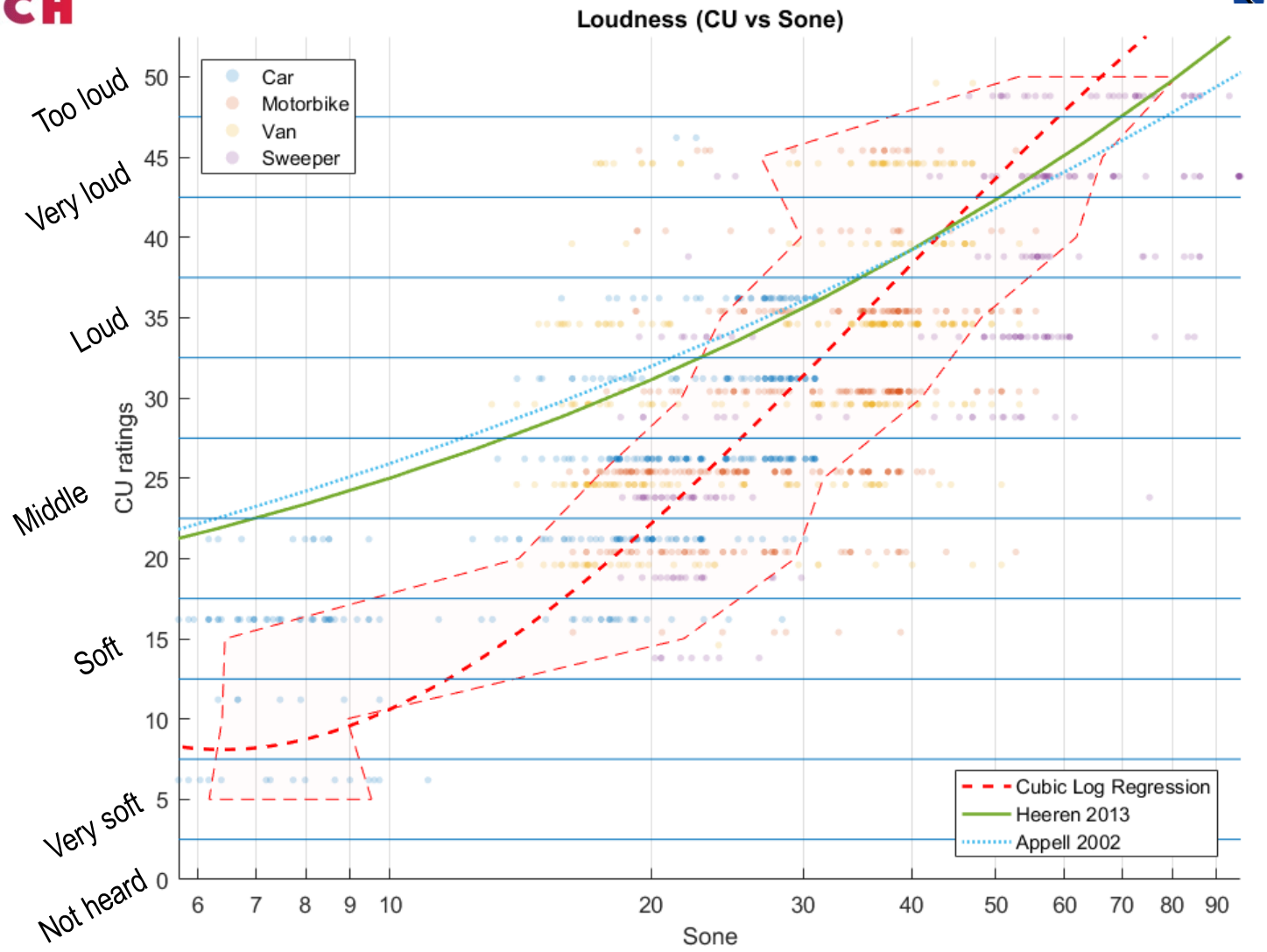
Field Experiment
Measures – Loudness rating variability

- Variability and range of the loudness ratings between test and retest (NH)

- 0 CU = “nicht gehört”
- 50 CU = “zu laut”



Field Results
Loudness perception (NH)

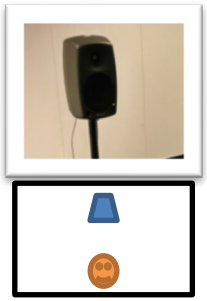


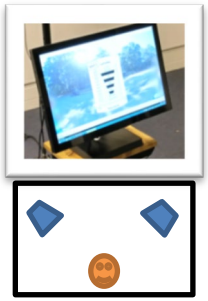
Laboratory results

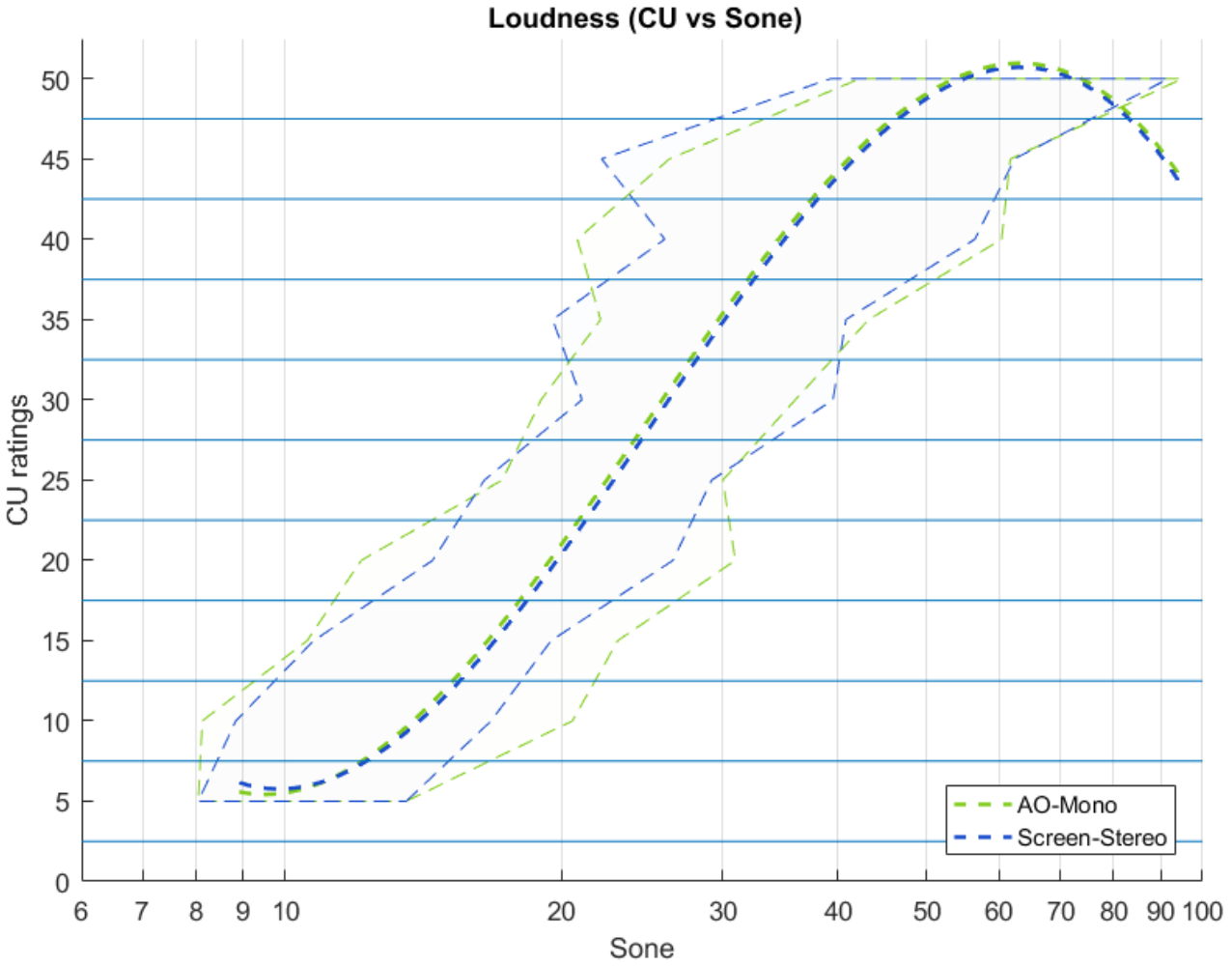
Loudness perception in the laboratory

Laboratory Results
Loudness perception (NH=10)

- Screen-Stereo and AO-Mono have similar curves

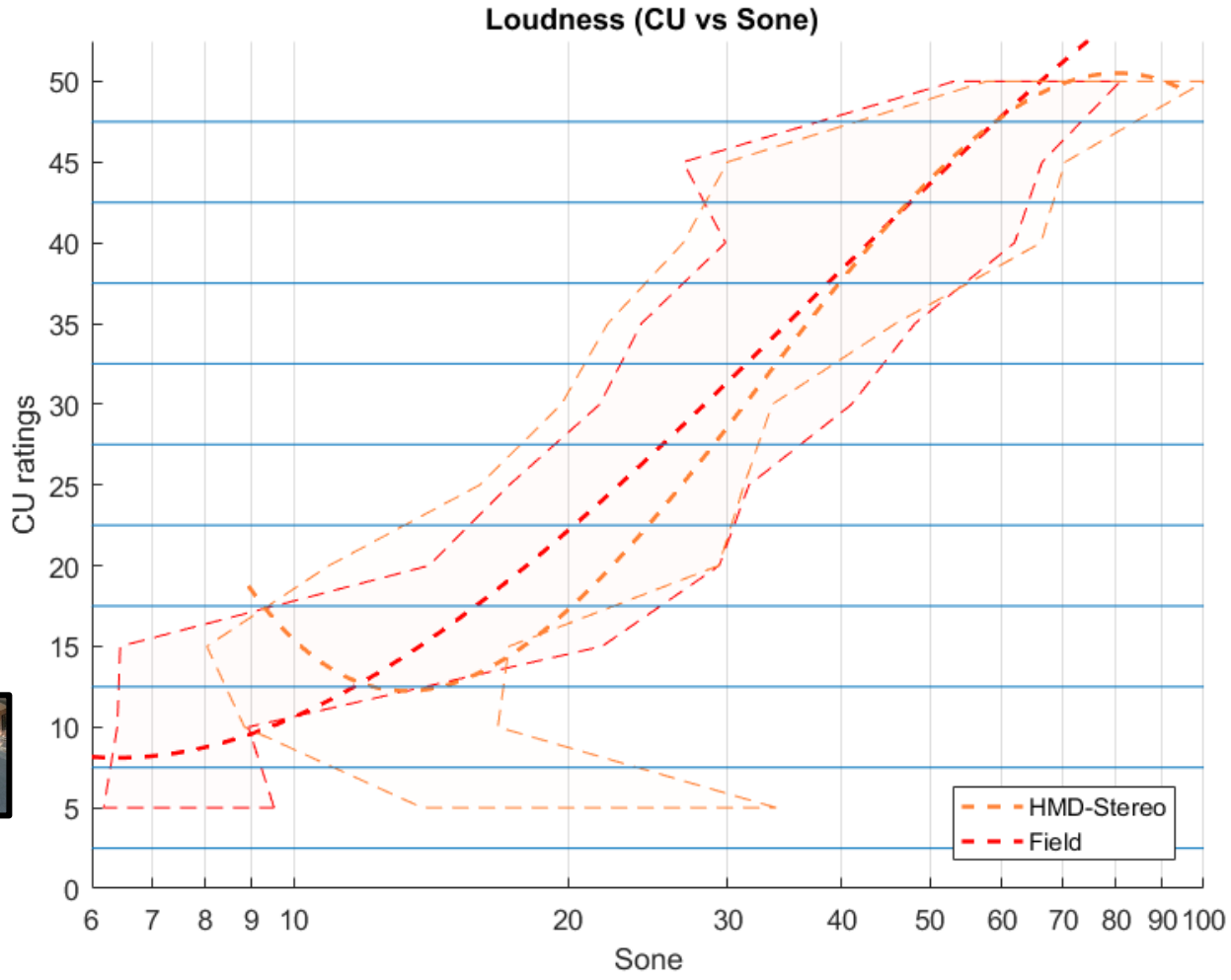






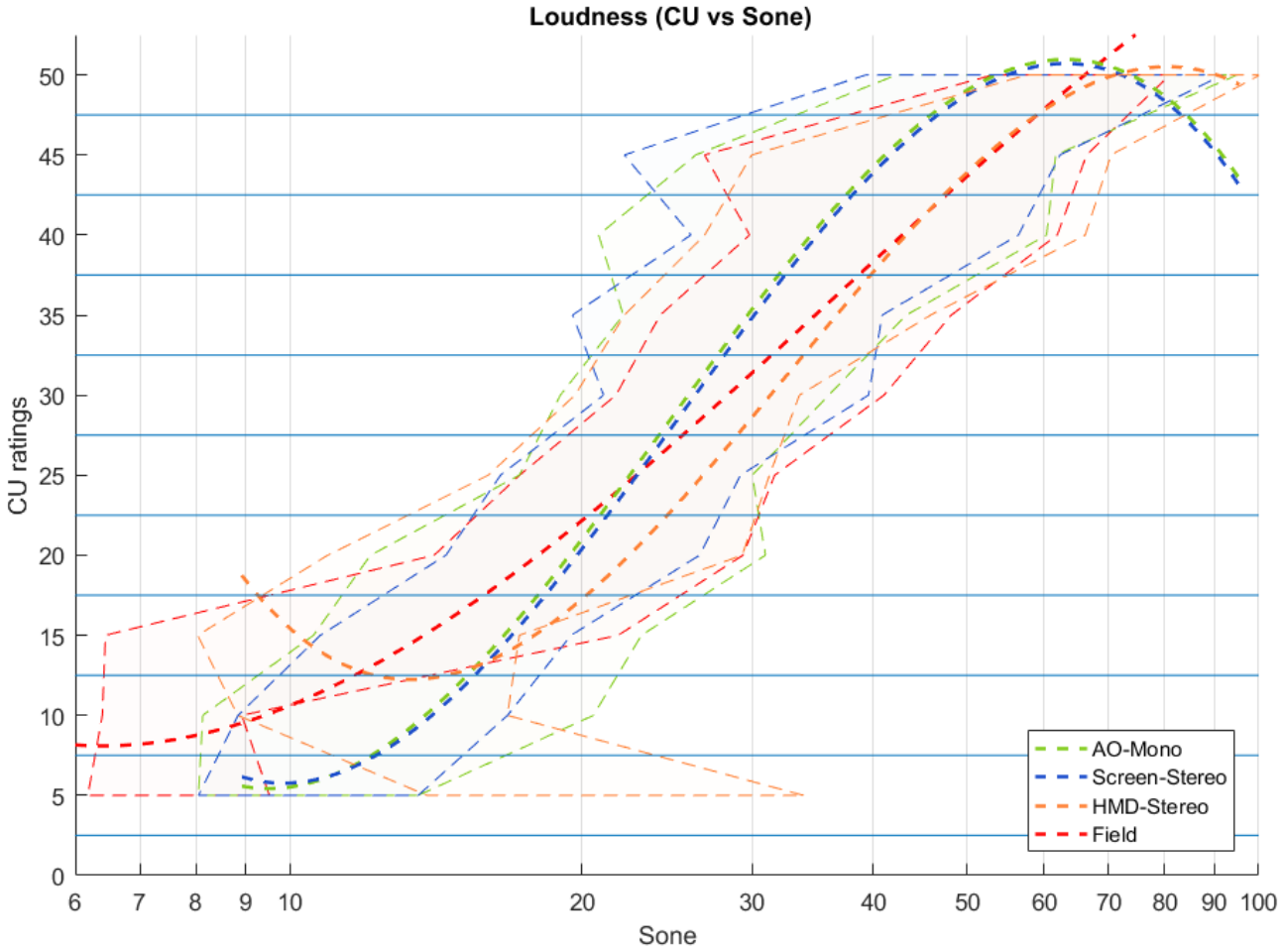
Laboratory Results
Loudness perception (NH=10)

- Field and HMD-Stereo curves more similar with louder stimuli (>40 sones)



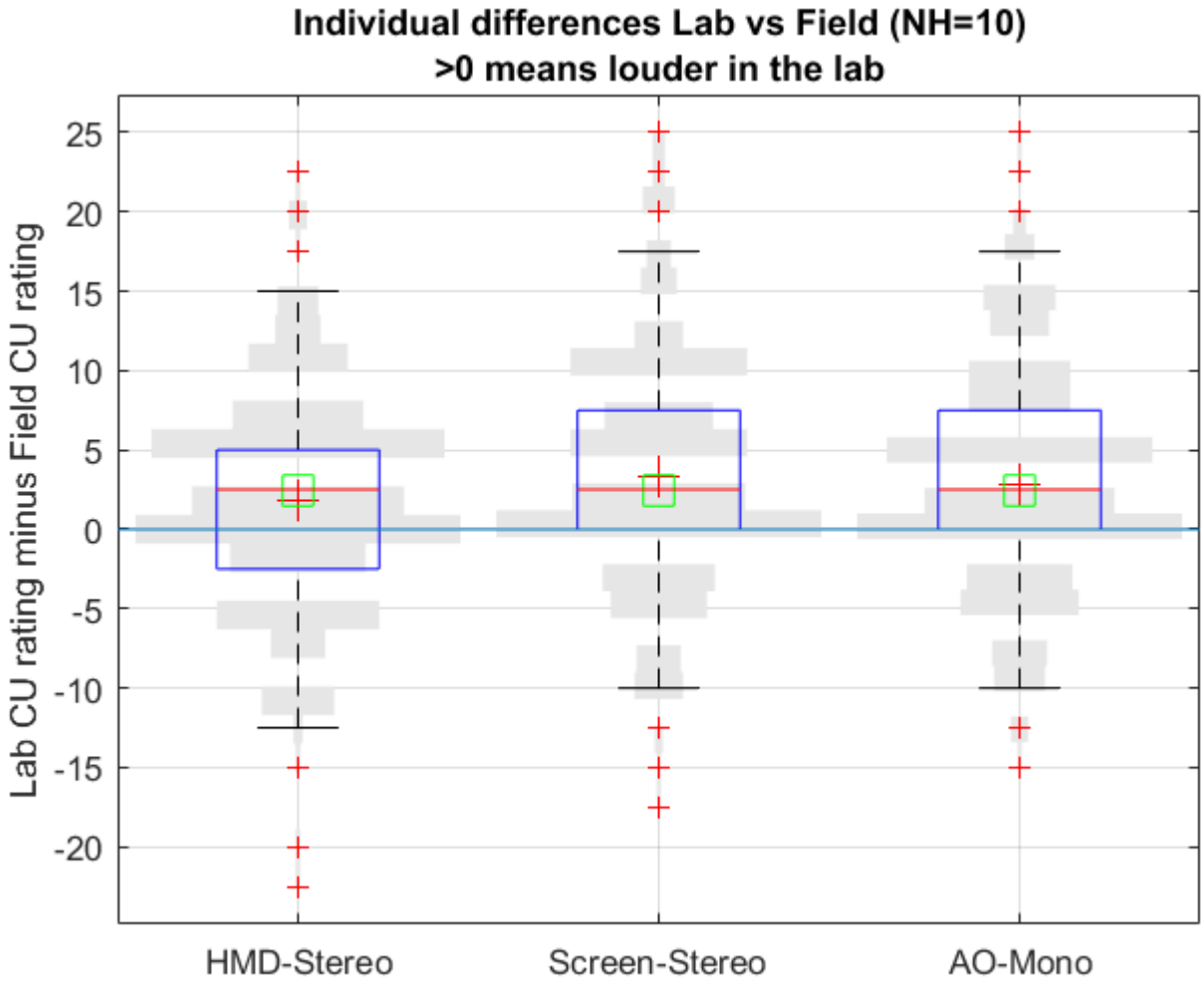
Laboratory Results
Loudness perception (NH=10)

- AO-Mono and Screen-Stereo:
  - Higher ratings for stimuli above ~20 sones
  - Lower ratings below ~20 sones
- Participants almost cover all CU range (very soft – too loud)



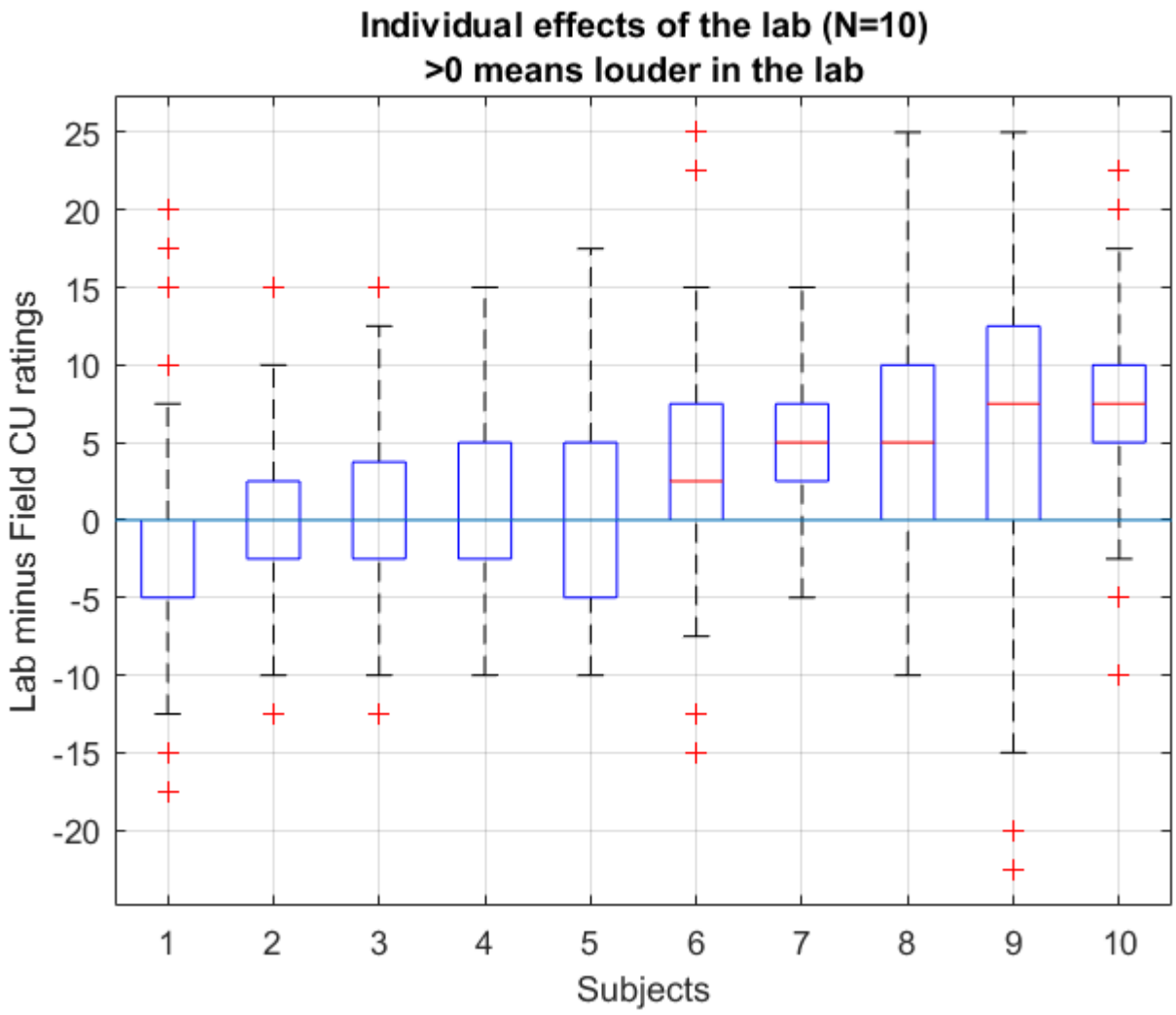
Laboratory Results
Individual differences (NH=10)

- High variability in the ratings
- Slightly higher loudness perception in the laboratory
- HMD-Stereo closer to field ratings



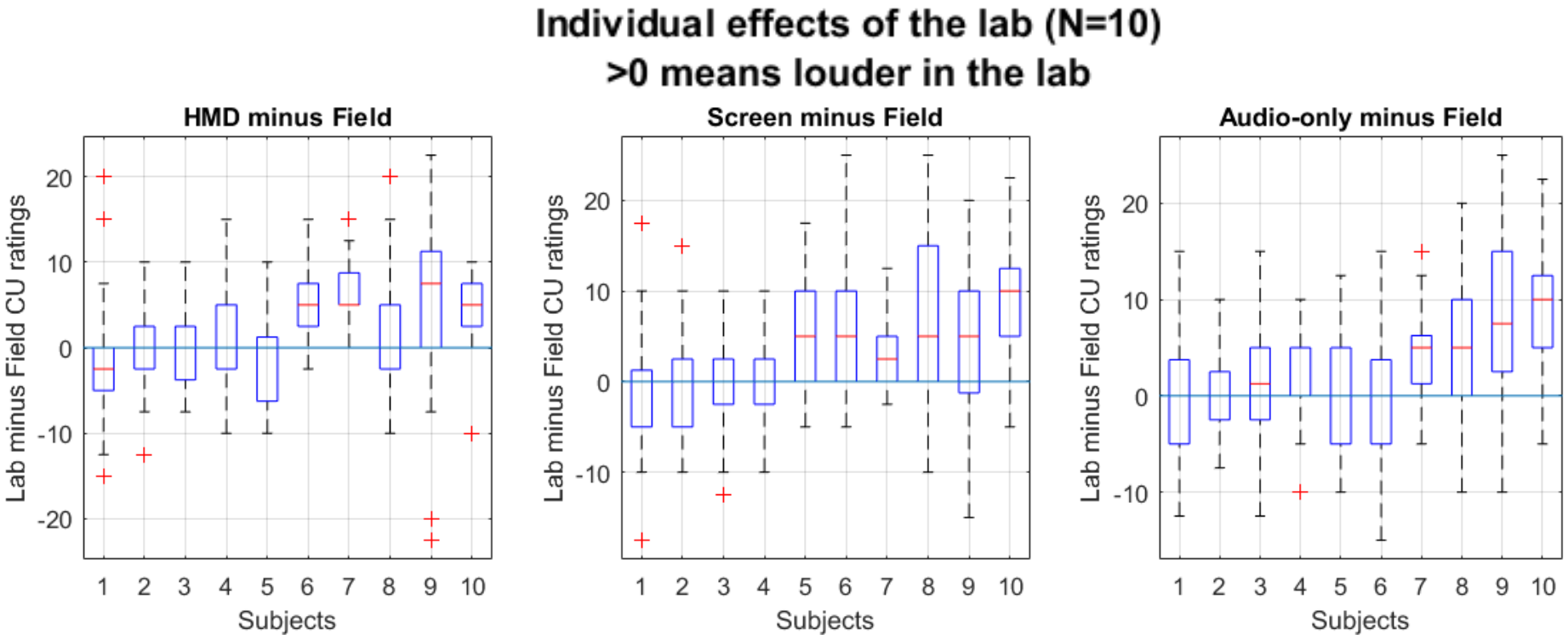
Laboratory Results
Individual effects (NH=10)

- Different effect size of the laboratory across subjects



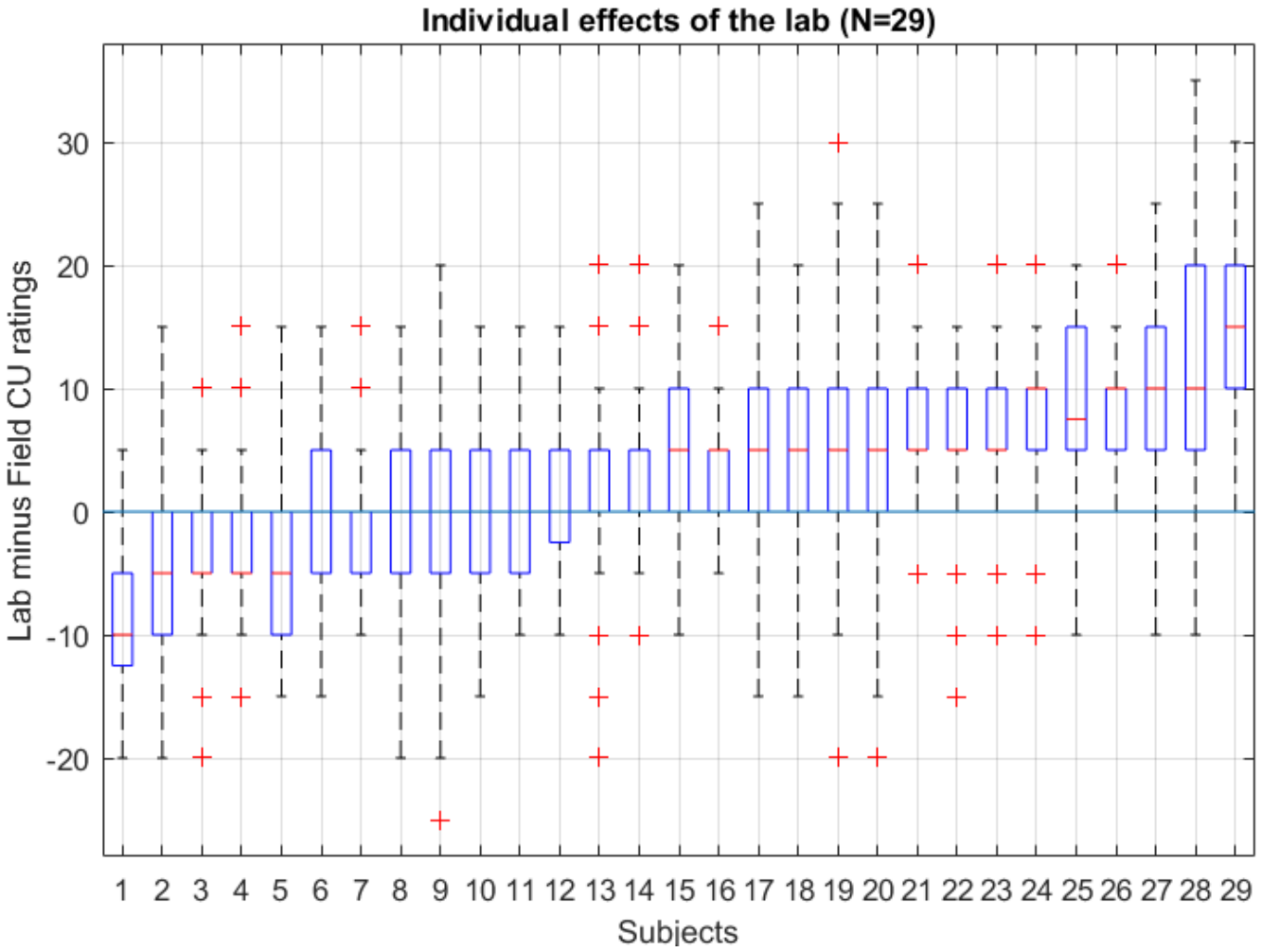
Laboratory Results
Individual effects (NH=10)

- Small individual variations between laboratory conditions



Laboratory Results
Individual effects (NH and HI)

- Individual laboratory effect size (HI and NH included)



Conclusions

- More immersion/realism gets slightly closer results to the field
- Effects of the laboratory are individual
- Loudness models and transformation functions are not predictive when using vehicle noise

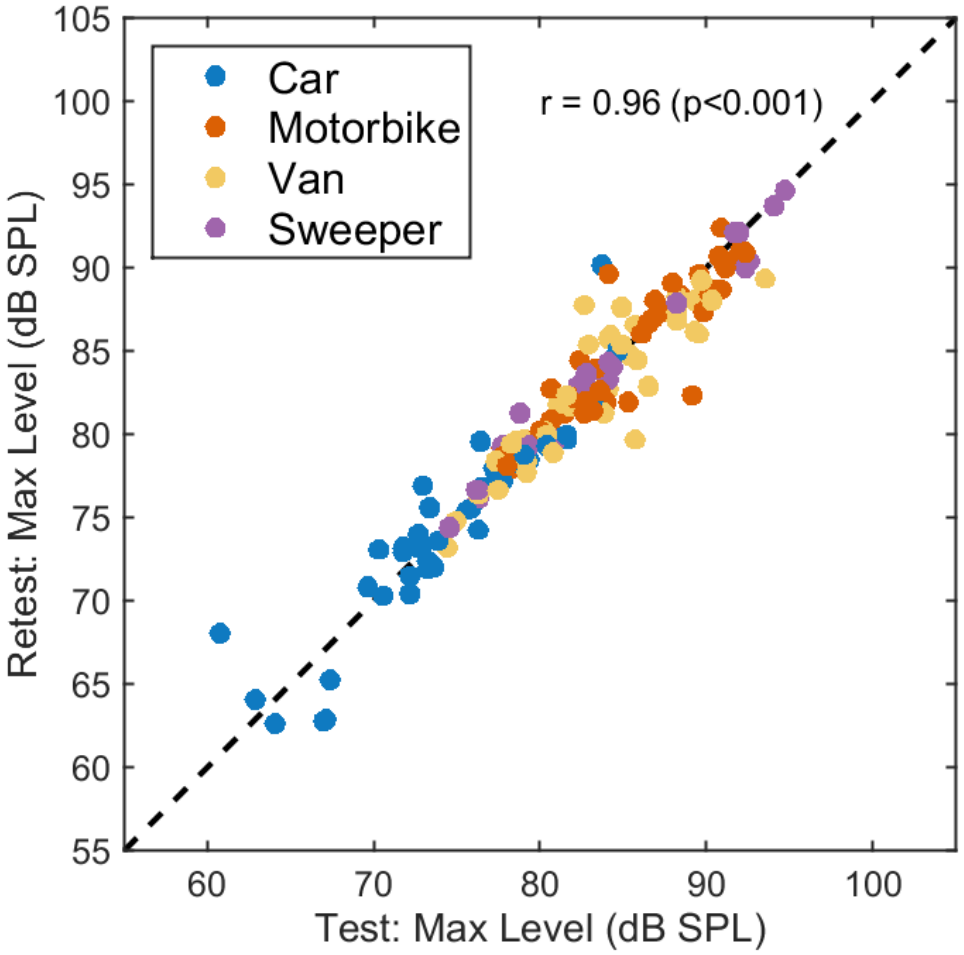
Thanks

This research has received funding from the EU‘s H2020 research and innovation programme under the MSCA GA 675324 (ENRICH ETN) and the Deutsche Forschungsgemeinschaft (DFG, Cluster of Excellence EXC 1077/1 “Hearing4all” and SFB1330 Project B1 and C4).

Extra slides

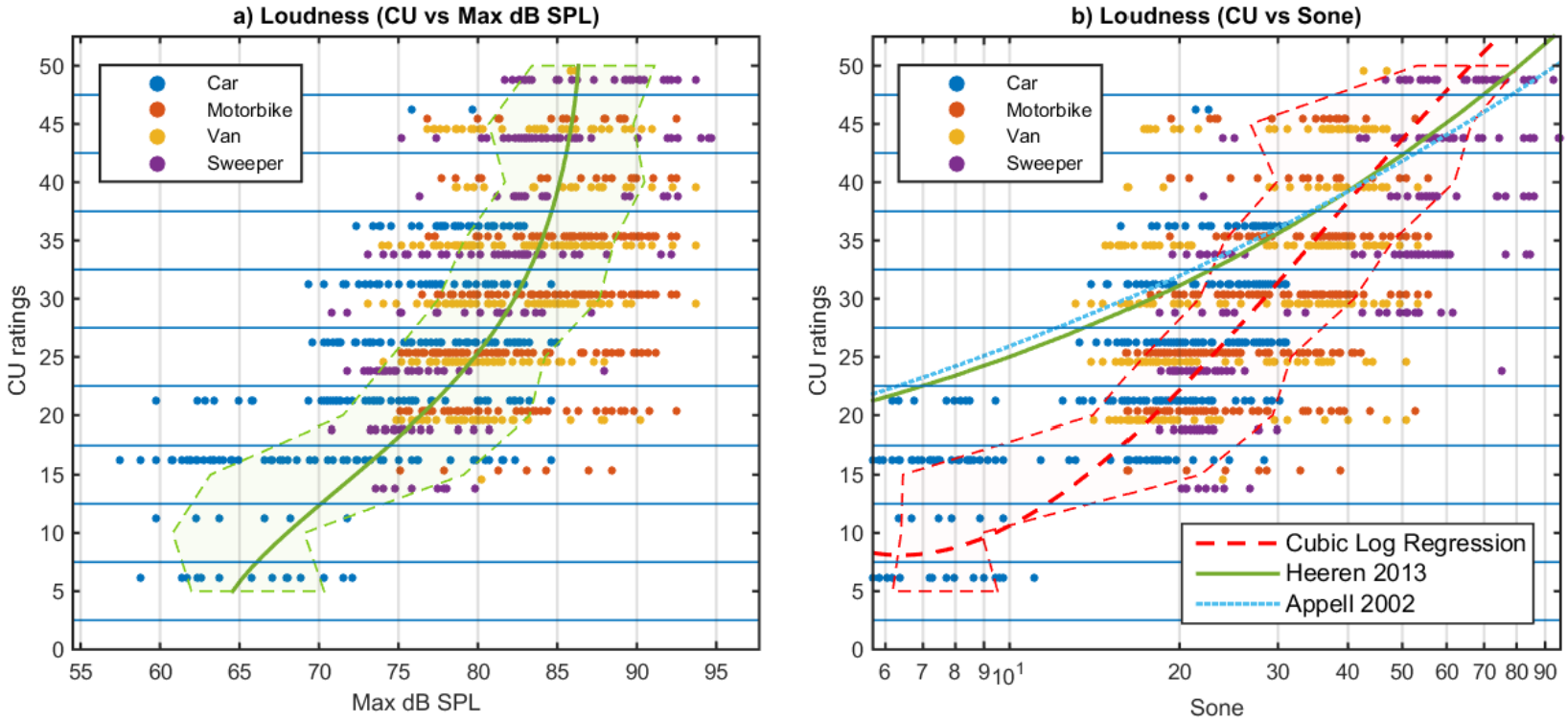
Field Experiment
Stimuli - Driving variability

- 36 driving actions
- From ~65 to ~95 dB SPL
- Low driving variability between test and retest



Field Results
Loudness perception (NH)

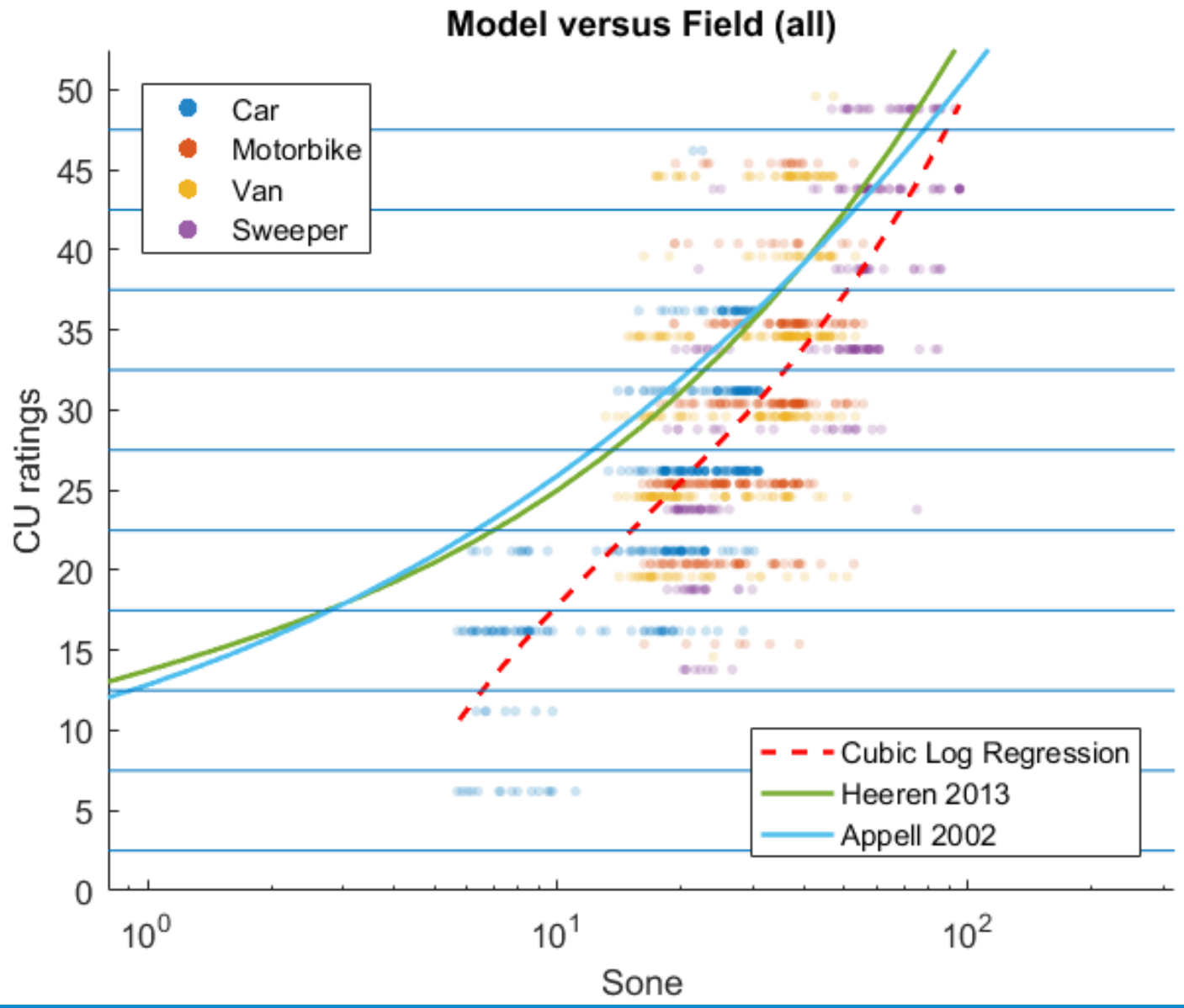
- Sounds are **perceived less loud** in comparison to laboratory loudness models



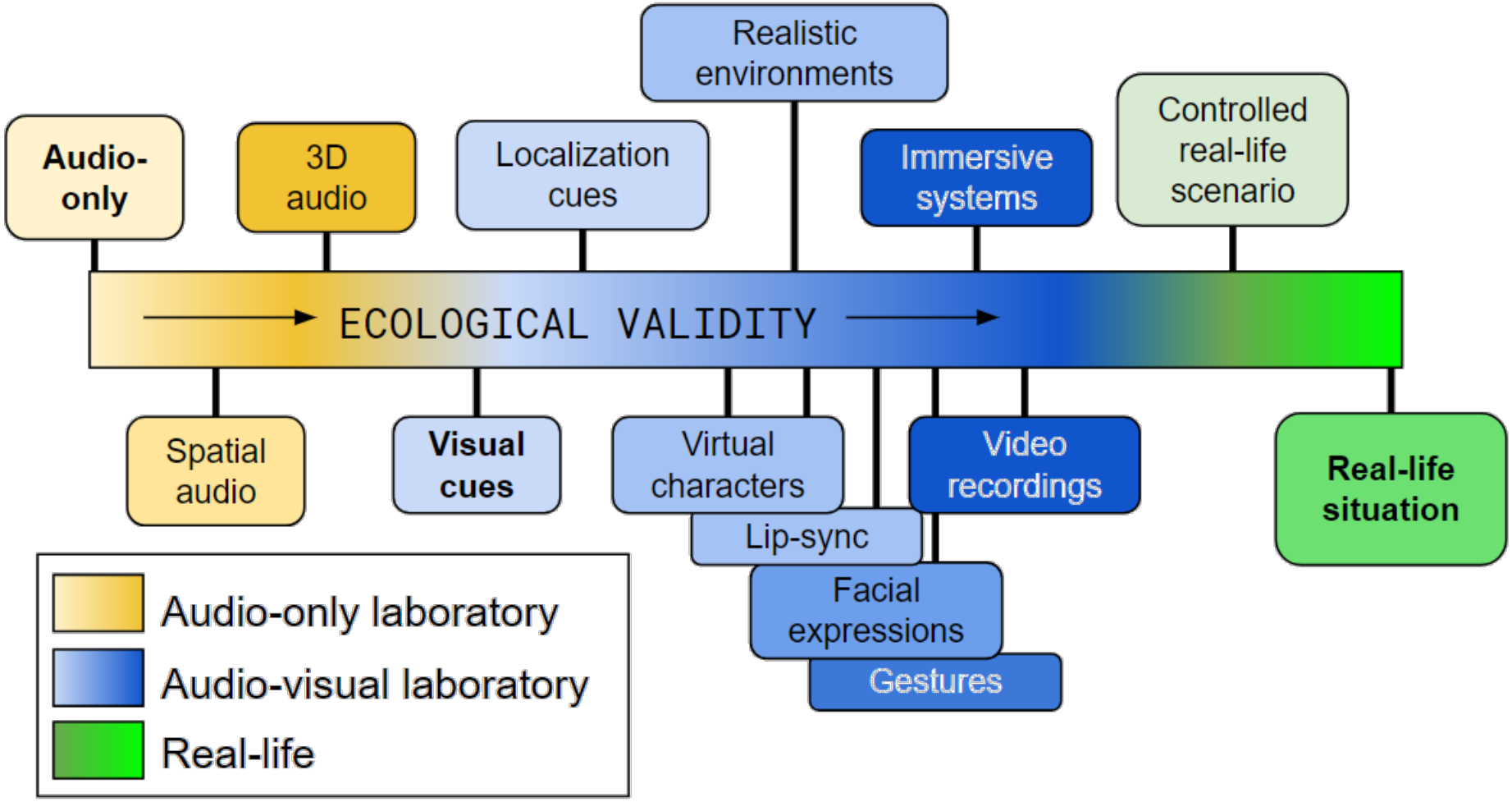
Heeren, W., Hohmann, V., Appell, J.E. and Verhey, J.L., 2013. "*Relation between loudness in categorical units and loudness in phons and sones*". The Journal of the Acoustical Society of America, 133(4), pp.EL314-EL319.

Appell, J.E., 2002. "*Loudness models for rehabilitative audiology*" (Doctoral dissertation, Universität Oldenburg).

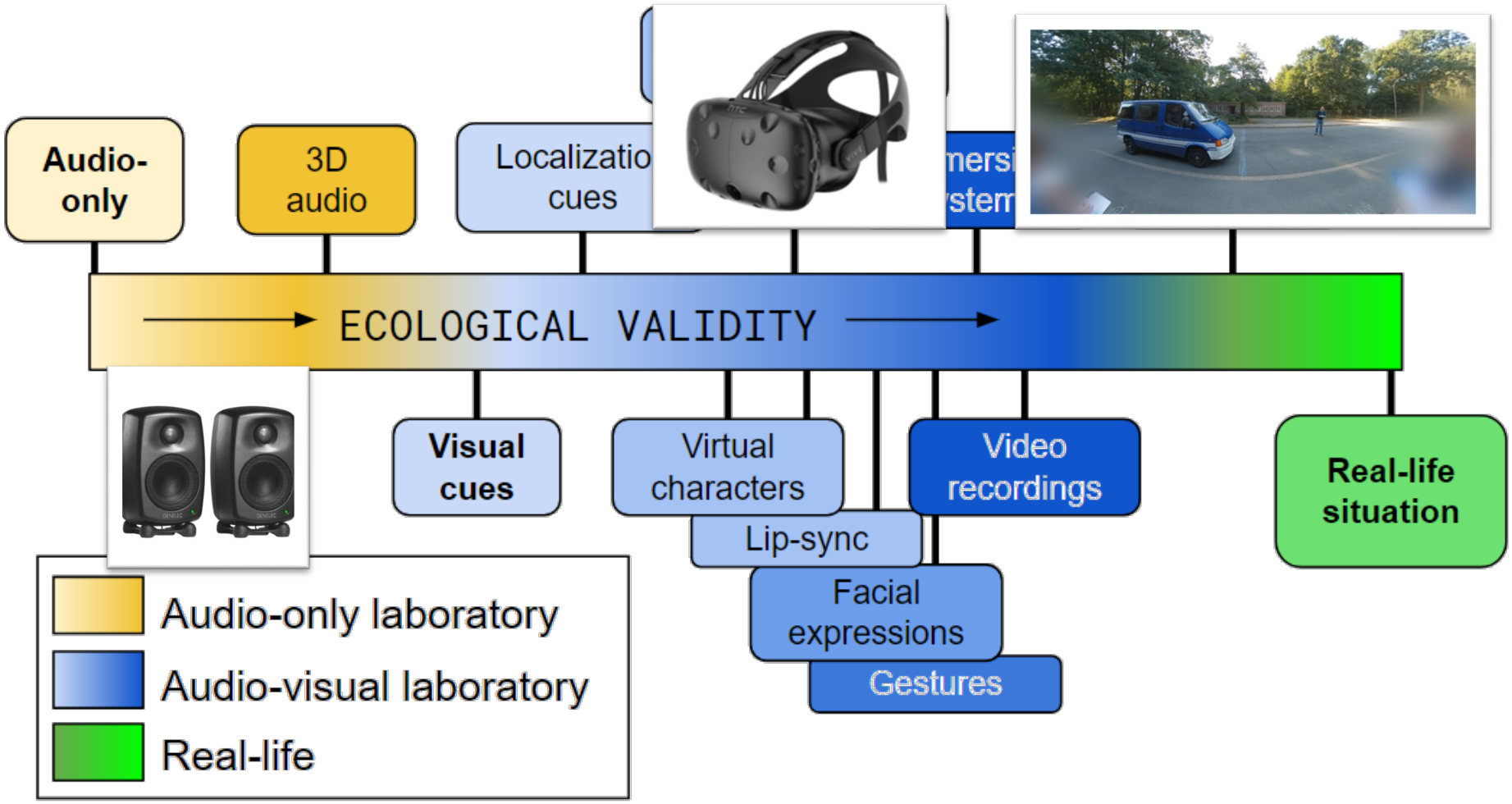
Field Experiment



Laboratory


Realistic environments
Audio-only
3D audio
Localization cues
Immersive systems
Controlled real-life scenario
ECOLOGICAL VALIDITY
Spatial audio
Visual cues
Virtual characters
Video recordings
Real-life situation
Lip-sync
Facial expressions
Gestures
Audio-only laboratory
Audio-visual laboratory
Real-life

Laboratory


Audio-only
3D audio
Localizatio cues
mersi
rstem
ECOLOGICAL VALIDITY
Visual cues
Virtual characters
Lip-sync
Facial expressions
Gestures
Video recordings
Real-life situation
Audio-only laboratory
Audio-visual laboratory
Real-life