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Objective and Perceptual Evaluation of a Virtual Sound Environment System.

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Publication date:
2016

Document Version
Publisher's PDF, also known as Version of record

Objective and Perceptual Evaluation of a Virtual Sound Environment System

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Introduction

Hearing aid (HA) users often have difficulties following a conversation in challenging listening situations involving multiple talkers, background noise, and reverberation. To improve their listening performance, the algorithms in modern HAs have become increasingly complex. Yet, most HA testing is still performed in unrealistically simple setups.

In this study [1], **speech reception thresholds** (SRTs) were measured in a real classroom and its virtual counterpart auralized in the 'Spacelab' (see Fig. 1) to investigate, how well results obtained in a complex **Virtual Sound Environment** (VSE) translate to the corresponding real situation.

Fig. 1: Photograph of the 'Spacelab' at DTU with a spherical array of loudspeakers for the playback of VSEs.

Method

Auralization technique

- Simulation of the classroom (Room 019, V= 180m^2, T_{30} = 0.5s) in ODEON
- Calibration of the room model to the measured reverberation time T_{30} and clarity C_{50}, (ISO 3382), see Fig. 4.
- Auralization of the results with a spherical 29 loudspeaker array in the 'Spacelab' using the LoRA toolbox [2], see Fig. 2.
- Rendering method: **Higher Order Ambisonics** (HOA) or **Nearest Loudspeaker** (NLS), where each reflection is mapped to a single loudspeaker.

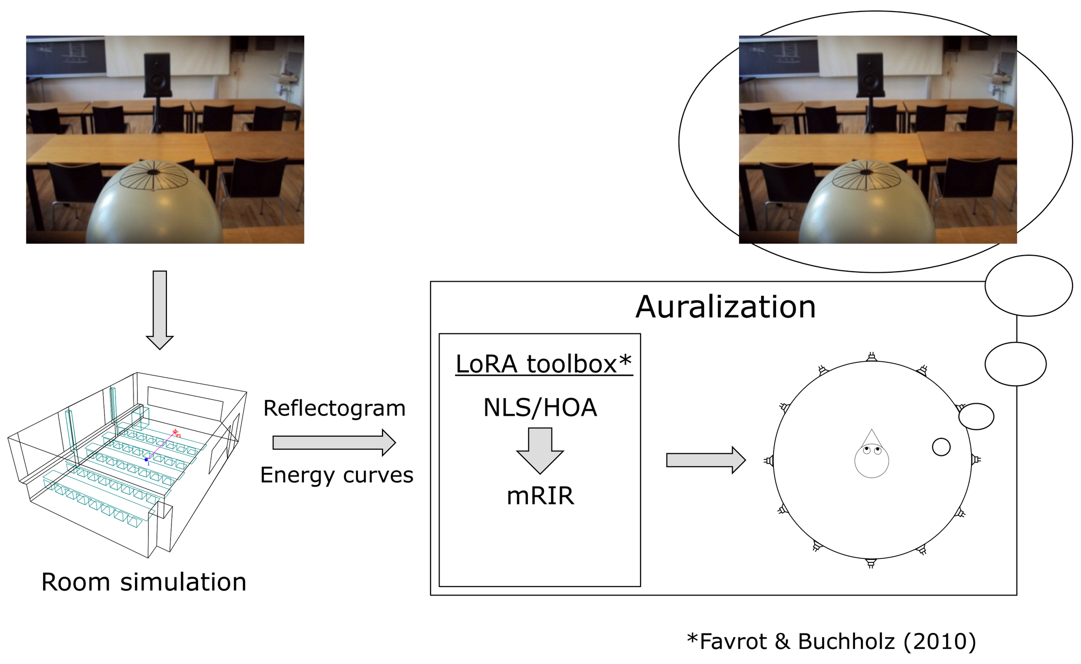

Fig. 2: Overview over the auralization system. The acoustic scenario is simulated in the ODEON room acoustic software, the LoRA toolbox generates a multichannel room impulse response (mRIR) from the ODEON output using either **Higher Order Ambisonics** (HOA) or **Nearest Loudspeaker** (NLS). Convolution of the mRIR with an anechoic signal yields the driving signal for the loudspeakers.

Listening experiments

- **Dantale II** test [3] with **8 normal hearing**, native Danish speaking listeners.
- Receiver-in-the-ear HAs with power domes providing **flat, linear gain of 15 dB.**
- **Omnidirectional** (Omni) microphone and **static beamformer** (BF).

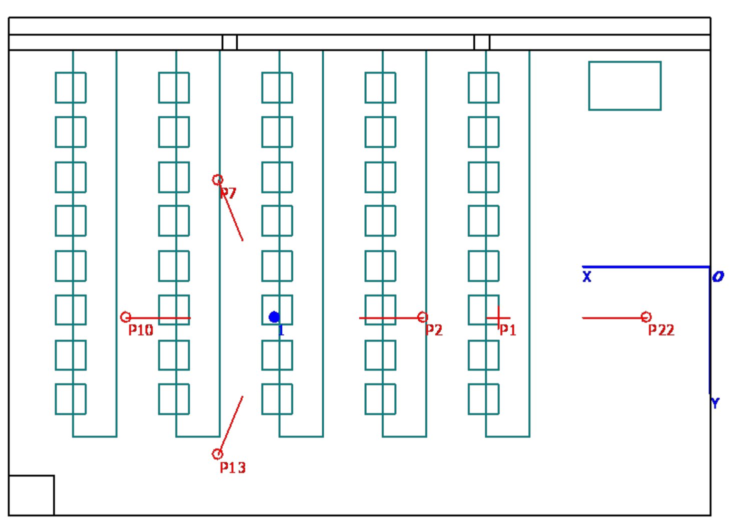

Fig. 3: Top view of the listening test setup with the listening position (1), the three noise sources (P7, P10, P13) and the target speech sources at 2 m (P2) and 5 m (P22).

Results – Physical evaluation

Room acoustic parameters (ISO 3382)

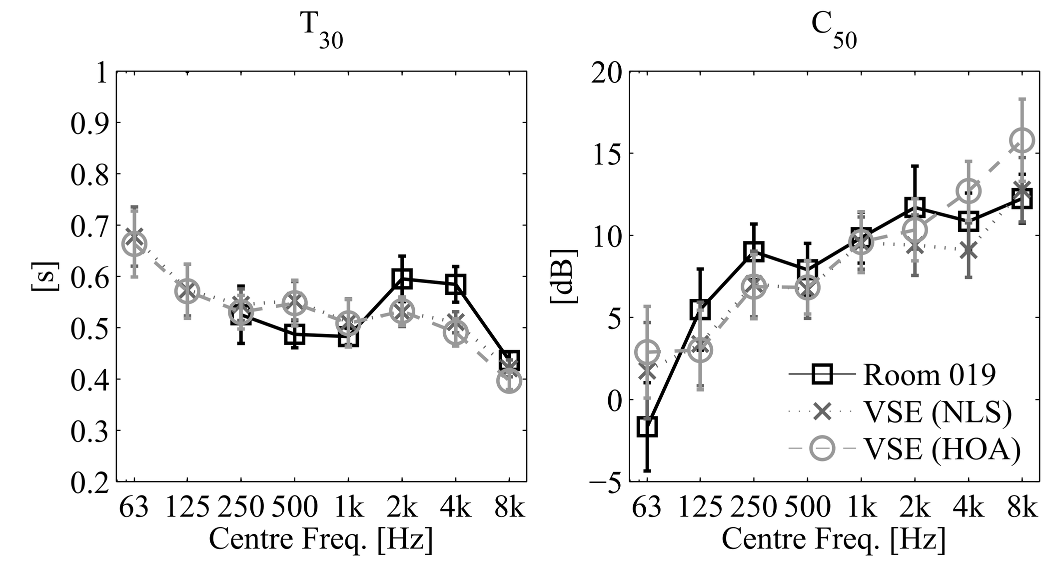

Fig. 4: Average Reverberation time T_{30} and Clarity C_{50} measured for 30 source positions in the real Room 019 (squares), the VSE with NLS (crosses) and HOA (circles) rendering.

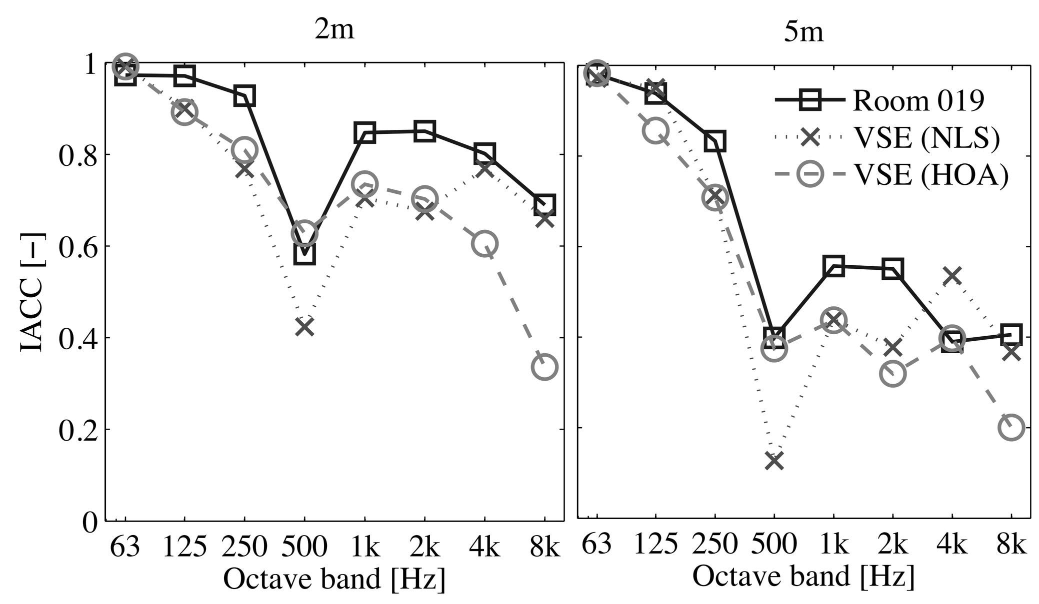

Fig. 5: Interaural cross correlation coefficients measured in the real Room 019 (squares), the VSE with NLS (crosses) and HOA (circles) rendering.

HA directivity

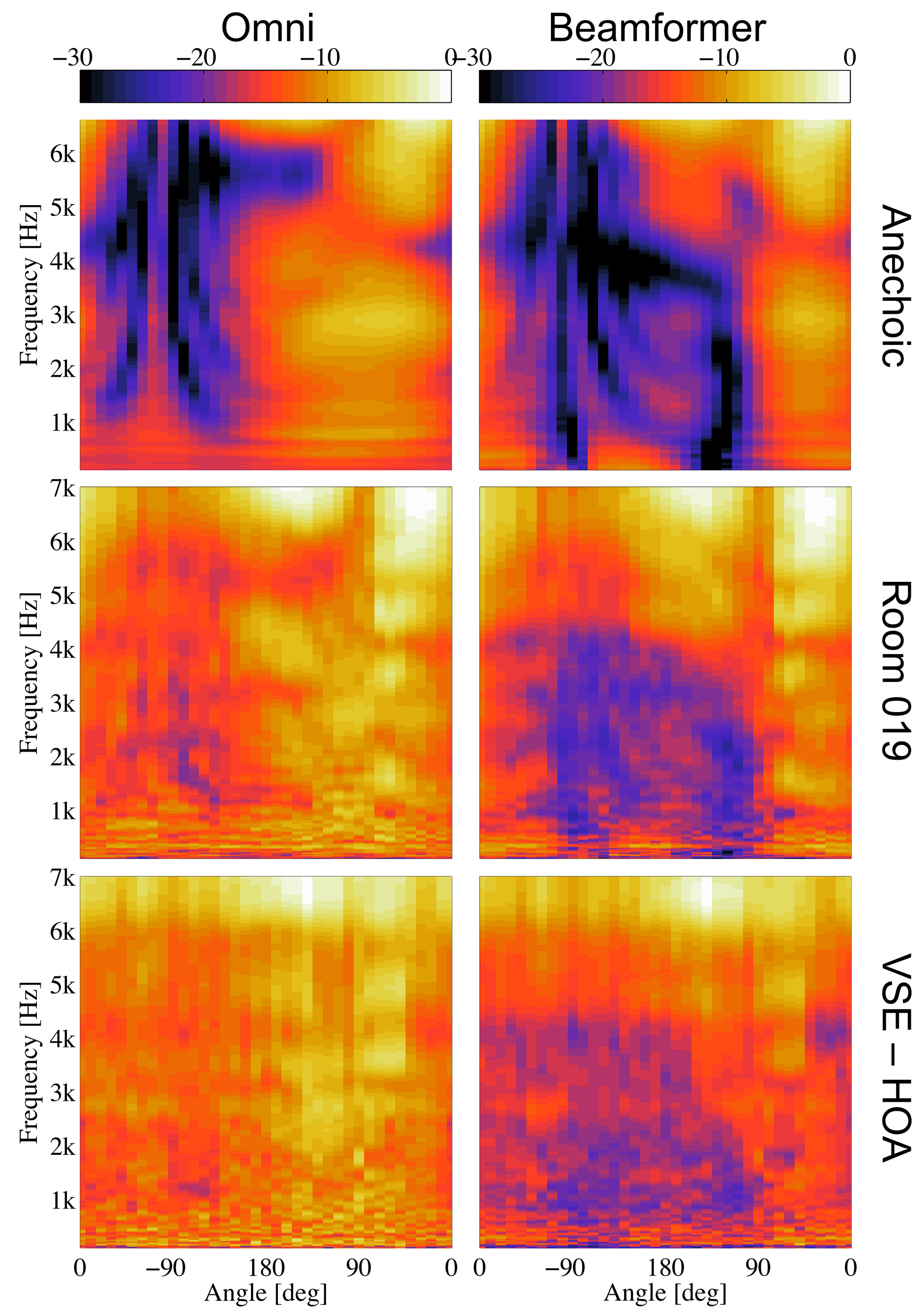

Fig. 6: Transfer functions of the hearing aid measured on the right ear of a B&K HATS for all azimuth angles in steps of 10 degrees in the omnidirectional program (left column) and the BF program (right column). The rows show the results measured in an anechoic chamber (top), Room 019 (middle), and the VSE with HOA coding (bottom).

Results – Listening experiments

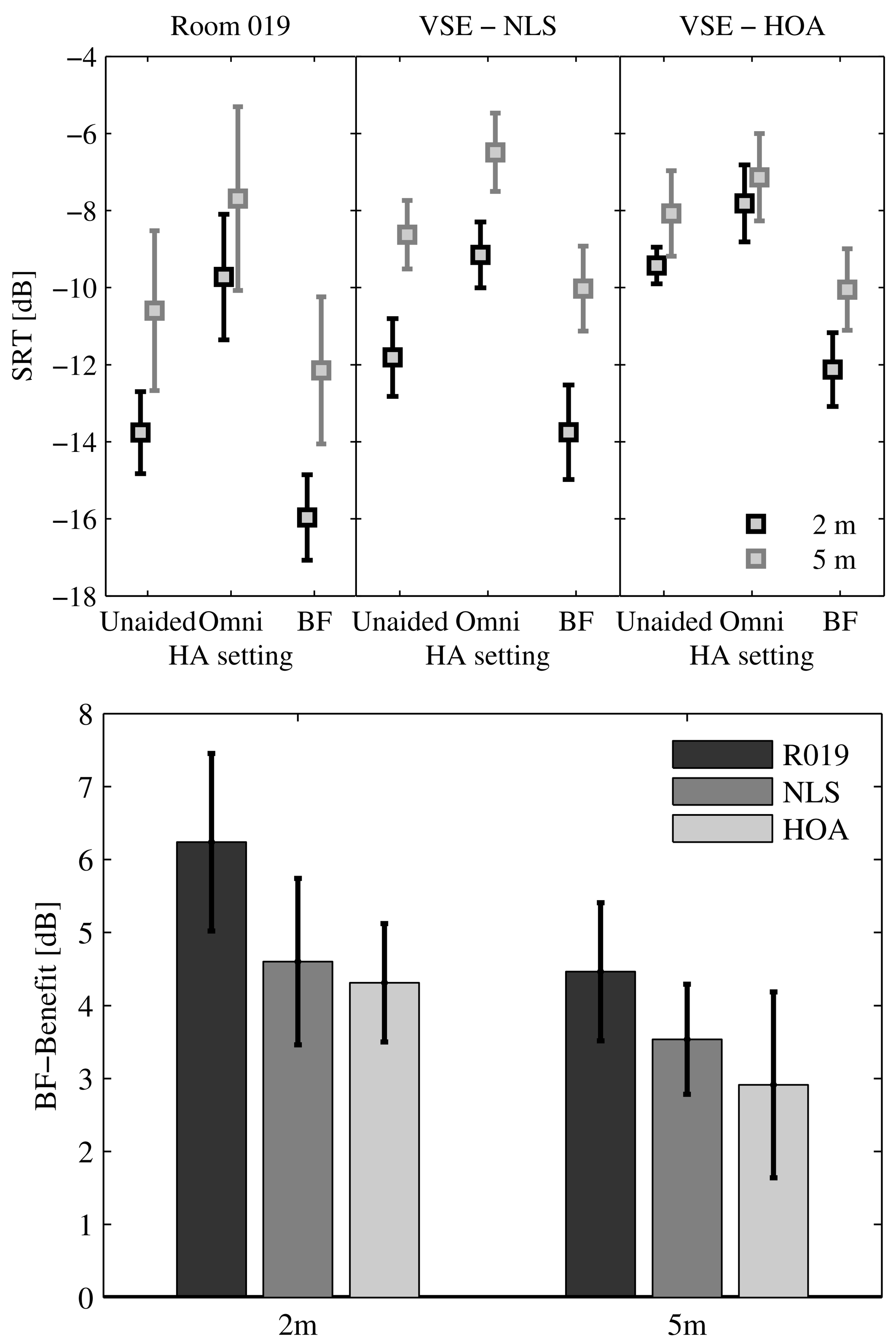

Fig. 7: Average Speech reception thresholds measured in Room 019, the VSE with NLS coding and the VSE with HOA coding (upper panel) and benefit from the BF program compared to the omnidirectional microphone (lower panel). The error bars indicate +/- one standard deviation.

Discussion – Physical Evaluation

- LoRA processing transparent with respect to T_{30} and C_{50}.
- IACC lower in VSE than in Room 019, i.e., more diffuse sound field in the VSE.
- Reduced dynamic range of the directivity pattern over azimuth angle in VSE compared to Room 019, indicating a more diffuse sound field in the VSE.
- Effectiveness of the beamformer reduced in the VSE due to the higher diffuseness.

Discussion – Listening experiments

- SRTs higher in the VSE than in Room 019, probably due to higher diffuseness compared to Room 019.
- However, the SRT benefit from BF over omnidirectional microphone is similar in the VSE and Room 019.
- Higher SRTs with HOA compared to NLS coding, consistent with [4].
- Standard deviations are smaller in the VSE than in Room 019, consistent with the subjective description of the listeners.
- With NLS, SRT differences between 2m and 5m are almost identical to Room 019. Generally: NLS results are closer to reality.
- NLS preserves the dependence of the SRT on the target source distance.

Conclusion

The tested VSE seems to capture many acoustical features of a real environment (an existing room) that might be crucial for speech intelligibility, even though the resulting sound field in the VSE seems to be slightly more diffuse. The SRTs measured in the VSE were higher than those in Room 019. However, the differential outcome measure, BF benefit, was the same in the simulated and real environment.

VSEs could provide a powerful tool for testing HA algorithms, since very different acoustic conditions can be tested flexibly in a controlled and repeatable way. Array microphone recordings and screen projection could provide additional flexibility, for example, in the case of dynamic acoustic scenes.

References

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[3] K. Wagener, J. Josvassen, R. Ardenkjær: Design, optimization and evaluation of a Danish sentence test in noise. International Journal of Audiology **42** (2003),10–17.

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