Accompanying Dataset for [1]: On the Perceptually Acceptable Noise Level in Binaural Room Impulse Responses

Wiebke Hahne, Vera Erbes, Sascha Spors

2019

Abstract

The practical measurement of binaural room impulse responses (BRIRs) is impaired by equipment and background noise. The noise level in the BRIR depends amongst others on the duration of the excitation signal. With the increasing use of fast measurement techniques, e.g. for the measurement of individual BRIRs, the question arises which level of noise is perceptually acceptable. This paper presents a perceptual study on the threshold of detecting noise in BRIRs. As reference, a set of BRIRs is measured resulting in a high peak-to-noise ratio (PNR) by long-term averaging. In order to generate the stimuli, these BRIRs are impaired by additive white Gaussian noise of different levels. The BRIRs are convolved with a speech stimulus and presented in a 3AFC listening test with a 2Up-1Down rule to the subjects. The results of perceptual experiment are statistically analysed and discussed.

1 General Information

Experiment title	On the Perceptually Acceptable Noise Level in Binaural Room Impulse Responses
Experiment id	noise-detection-brir
Principal investigators	Wiebke Hahne, Vera Erbes, Sascha Spors
Affiliation	Institute of Communications Engineering, University of Rostock, Germany
E-Mail	{wiebke.hahne, vera.erbes, sascha.spors} @uni-rostock.de
Date	March 2019
Type	data measurement, data analysis

Location	Richard-Wagner-Str. 31 (Haus 8), 18119 Rostock
Keywords	noise detection, virtual acoustics, binaural room impulse response, noise floor
Language	English
Rights	CC BY 4.0
DOI Data	10.18453/rosdok_id00002434

1.1 Objective

Detection of the perceptual threshold of noise artefacts in a noisy BRIR convolved with a speech signal.

1.2 Problem Statement

Every measurement captures undesired noise of the environment or of the measurement equipment. Therefore every measured BRIR is contaminated with a noise floor. The resulting question is at which noise floor level a listener cannot detect the noise in a stimulus convolved with the noisy BRIR.

2 Description

2.1 Data format

The dataset has been obtained based on the BRIR-processing described in "On the Perceptually Acceptable Noise Level in Binaural Room Impulse Responses" by W. Hahne, V. Erbes and S. Spors [1].
For the processing of the BRIRs, Jupyter Notebooks with Python 3.6.4 were used. The realization of the listening test was done in the Matlab based software package 'WhisPER' [2].
The published dataset contains the averaged BRIR with a high PNR level, the artificially impaired BRIRs with different PNR levels and the results of the listening test.

- **BRIR_mean**:
  long term averaged BRIR, two channel WAV-File, channel 0: left ear, channel 1: right ear, 24bit, 44.1 kHz

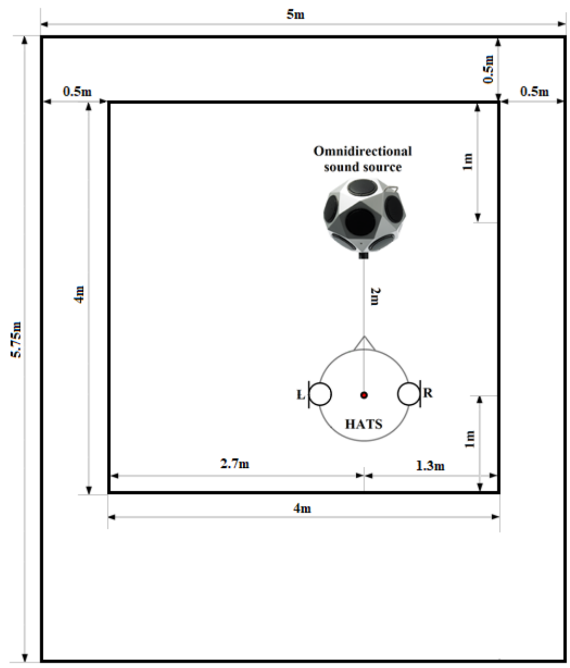
- **BRIR_PNR**N:
  artificially impaired BRIRs with an PNR of N dB, two channel WAV-File, channel 0: left ear, channel 1: right ear, 24bit, 44.1 kHz

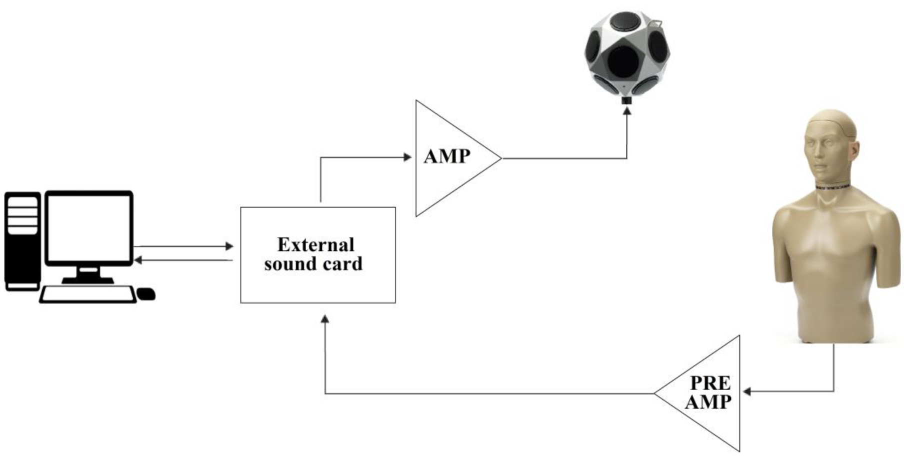
- **results**:
  results of every subject of the listening test using PNR-dependent stimuli generated with the BRIRs, PDF- and CSV-file, including same information

2.2 Dataset recording

BRIR Measurement

Measuring a whole night, 600 measurements of a BRIR with a specific geometric setup have been done. The schematic measurement setup and the positioning in the room are shown below [3].



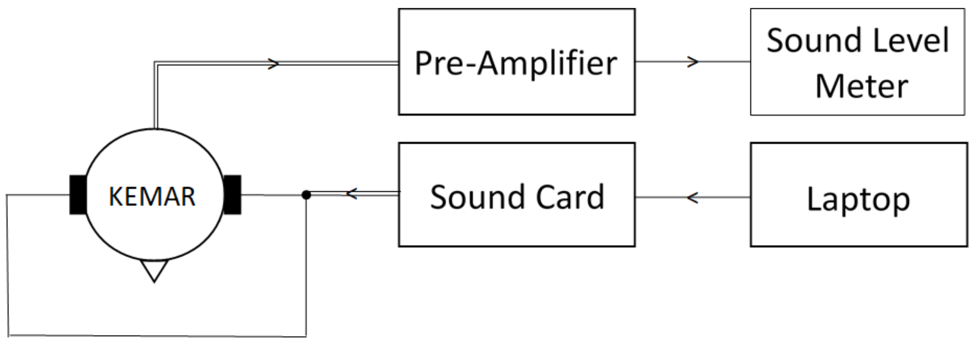


Room:	Audio Laboratory University of Rostock (Germany) Size: 5.75 m × 5.0 m × 3.0 m acoustically treated, low reverberation time $T_{60} \approx 0.3$ s
Software:	Matlab Version R2015a

Excitation Signal:	Exponential Sine Sweep duration $T \approx 47.6\,\mathrm{s}$ start frequency 20 Hz, stop frequency 20 kHz $f_s = 44.1\,\mathrm{kHz}$
Sound Card:	RME Fireface UC
Power Amplifier:	Brüel & Kjær, Type 2734-A
Loudspeaker:	omni power sound source Brüel & Kjær, Type 4292-L 12 drivers in a dodecahedral configuration
Dummy Head:	KEMAR manikin 45BA G.R.A.S. large pinnae (type KB0065 and KB0066) pressure microphones 40AO G.R.A.S.
Pre-Amplifier:	Lake People C360

Sound Pressure Level Measurement

A schematic setup of the sound level measurement is shown below. The Amplifier (Lake People) is additionally in the setup because the sound level meter (NTi) detects automatically the sensitivity of the connected microphones of the dummy head. However, these are two different manufacturers and the sensitivity is detected incorrect by the sound level meter. Therefore the Amplifier with Gain 0 is between microphone and sound level meter to set the sensitivity manually.

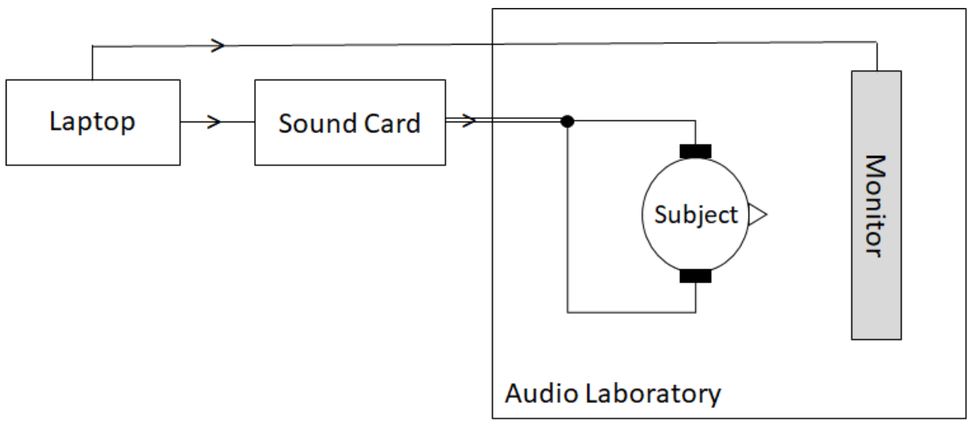


Test Signal:	German speech signal convolved with a BRIR with a PNR = 90 dB
Sound Card:	RME Hammerfall DSP Multiface II Hardware: rotary control Position 5 Software: Main Mix of RME at a level of $-16,5\,\mathrm{dB}$
Headphone:	AKG K601 SN: 14539

Dummy Head:	KEMAR manikin 45BA G.R.A.S. large pinnae (type KB0065 and KB0066) pressure microphones 40AO G.R.A.S.
Pre-Amplifier:	Lake People C360 Gain: 0
Sound Level Meter:	NTi XL2 Set to $\mathrm{dB}_{\mathrm{LA\,eq,T=60}s}$

Listening Test

20 subjects participated individually in the listening test. The supervisor was outside the room. A schematic setup of the measurement is shown below. The results of the subjects can be found either in the PDF- or CSV-file



Room:	Audio Laboratory University of Rostock (Germany) Size: $5.75\,\mathrm{m} \times 5.0\,\mathrm{m} \times 3.0\,\mathrm{m}$ acoustically treated, low reverberation time $T_{60} \approx 0.3\,\mathrm{s}$
Software:	Matlab Version R2015a WhisPER Version 1.9.1 [2]
Audio Signal	speech, German, 4 sentences ($\sim 8\,\mathrm{s}$)
Sound Card	RME Hammerfall DSP Multiface II Hardware: rotary control Position 5 Software: Main Mix of RME Position $-16.5\,\mathrm{dB}$
Headphone	AKG K601 SN: 14539
Sound Level	$58.4\,\mathrm{dB(A)}_{\mathrm{eq}}$, $T = 60\,\mathrm{s}$

2.3 Dataset processing

The data processing is performed with Anaconda3 (64-bit) in Jupyter notebooks using Python 3.6.4

Mean BRIR

Automatic detection of outliers:	Moving system distance reference measurement: previous measurement defined Threshold: 0.017 24 Measurements as outliers
Mean calculation [4]:	total number of measurements: $I = 576$ resulting PNR: 101.9 dB

BRIR Processing

Additive Noise:	white noise variance: PNR level dependent
Bandpass Filtering:	Distortions around Nyquist Frequency and 0 Hz through division of excitation signal in frequency domain $f_{low} = 20\,\text{Hz}$, $f_{high} = 20\,\text{kHz}$, $f_s = 44.1\,\text{kHz}$, numtaps = 8193 filter = signal.firwin(numtaps, [f_{low}/f_s*2, f_{high}/f_s*2], window='nuttall', pass_zero=False)

BRIR truncation

truncation point:	10 dB beneath intersection of the noise level and the decay curve
Noise Level:	estimated using the last 10% of the 1 s long impulse response
Decay Curve:	linear regression of the smoothed decay curve by Schroeder integration
Schroeder Integration[5]:	Interval $[k_{max}; k_I]$ k_{max}: maximum value of impulse response k_I: intersection point of noise level and decay curve, estimated by Lundeby algorithm [6]
Lundeby Algorithm [6]:	(2) Estimate background noise level using last 10% of the tail (3) Estimate slope of decay from 0 dB to 5 dB above noise level (5) Find new local time interval length using 5 intervals per 10 dB decay

	(7) Estimate background noise level: Allow a safety margin from crosspoint corresponding to 10 dB decay (8) Estimate late decay slope: A dynamic range of at least 20 dB are evaluated. From 25 dB until 5 dB above noise level.

Stimuli Generation

Headphone compensation:	headphone filter for AKG K601 serial number 14539
Fade-in & fade-out:	0.01 s Blackman window
Normalization:	by the maximum value of all stimuli with the different PNR levels and of left and right channel

References

[1] Wiebke Hahne, Vera Erbes, and Sascha Spors. On the perceptually acceptable noise level in binaural room impulse responses. 45. DAGA, March 2019.

[2] TU Berlin. Whisper. DOI: 10.14279/depositonce-31.3, Version 1.9.1.

[3] Bassim Zaitoon. Threshold of detection of noise in a binaural room impulse response. Master's thesis, University of Rostock, March 2018.

[4] Nara Hahn and Sascha Spors. Comparison of continuous measurement techniques for spatial room impulse responses. In *Signal Processing Conference (EUSIPCO), 2016 24th European*, pages 1638–1642. IEEE, 2016.

[5] Manfred R Schroeder. New method of measuring reverberation time. *The Journal of the Acoustical Society of America*, 37(3):409–412, 1965.

[6] Anders Lundeby, Tor Erik Vigran, Heinrich Bietz, and Michael Vorländer. Uncertainties of measurements in room acoustics. *Acta Acustica united with Acustica*, 81(4):344–355, 1995.