Examination of Binaural Activity Patterns

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Introduction

A computational model of binaural auditory localization, which simulates the human hearing system qualitatively, is used in this investigation to evaluate the acoustical performance of a room. Head-related impulse responses (HRIRs) were captured by a dummy head and after a preprocessing fed to the model algorithm. Differences in the outcome of the model, which is denominated as 'Binaural Activity Pattern', are visualized concerning head rotation and varying the broadening of the source.

Apparatus and Method

Impulse responses of a 13-loudspeaker setup, arranged in a semicircle in an anechoic chamber, were measured. The diffuse-field-equalised dummy head, which was placed on a manikin, is a custom built one. It consists of the replication of typical natural outer ears, determined in an investigation of Hudde and Schroeter [1]. For the speaker setup see Fig.1.

Figure 1: Measurement manikin and speaker setup in the anechoic chamber.

The manikin was placed on a chair in the middle of the arrangement and all speakers were calibrated. The speaker channels were measured successively while rotating the head in one degree steps from +45° to –45° in the horizontal plane, based on the standard head coordinate system [2].

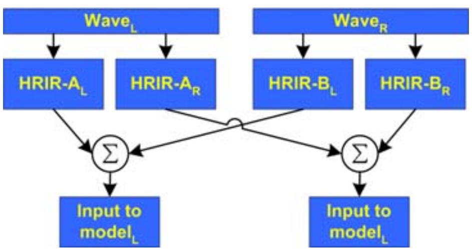

Figure 2: Creation of the model stimuli.

Correlated white noise signals were convolved with HRIRs each measured of two of the speakers at certain angles of head rotation, refer to Fig.2. The generated stimuli were fed to the model algorithm.

The binaural model of hearing used to simulate the human perception of sound qualitatively is based on the well known physiologically-motivated algorithm to estimate interaural time differences (ITDs) by Jeffress [3]. This algorithm, supplemented by Lindemann [4] by an inhibition-stage to estimate the interaural level differences (ILDs) and Gaik [5] by a head related adaption, consists of the following stages: HRTF-adaption to model the outer ears, Gammatone-filter bank for the inner ear transformation, halfway rectification and a 1 kHz lowpass to simulate the haircell transformation, and the central processor, consisting of ITD- and ILD-estimation and a remapping stage. The outcome of this model is a 3-dimensional plot, which visualizes the binaural neural activity over lateralization and time.

Results and Discussion

Fig. 3 depicts the first 100 ms of binaural activity of a noise stimulus (correlation 0.9) in one critical band with a centre frequency of 527 Hz and a bandwidth of 117 Hz. The stimulus signal was reproduced by two speakers at 30° and 330°. The graph at the left side of the figure shows an activity-over-time plot, while the graph located at the bottom of the figure represents activity over lateralization.

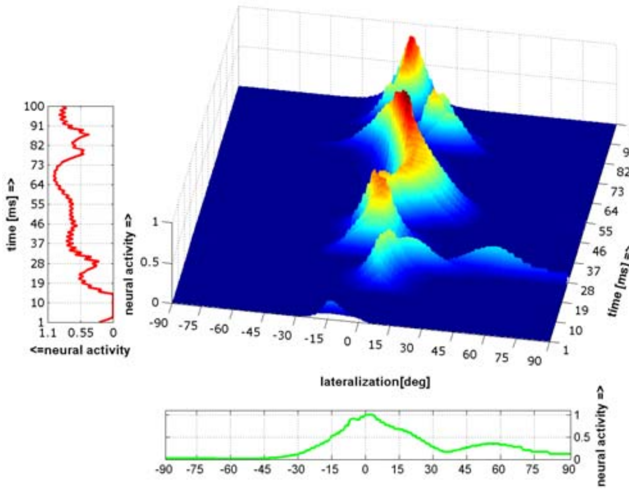

Figure 3: Binaural neural activity, stimulus reproduced by speakers at 30°and 330°, head rotation 0°.

Due to the fact that there is a high degree of correlation, the neural activity is focused in the middle of the lateralization axis. The maximum over lateralization is clearly at 0°.

Continuing with Fig. 4, the head was rotated to 345° (15° to the right). The maximum of the binaural activity changes to 15° lateralization, since the position of the observer is in this way, that he or she is looking out of the 3-dimensional plot. The whole structure with its ridges and dithering is now shifted to the left. Only fractional changes and a lateral broadening are noticeable.

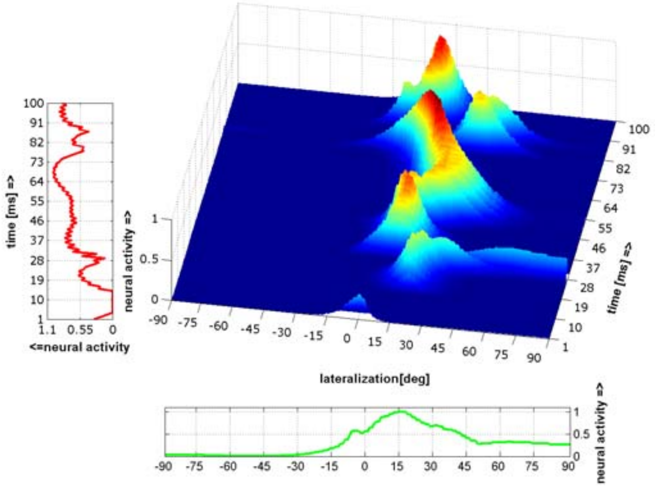

Figure 4: Binaural neural activity, head rotated to 345°.

A head rotation of further 15° to the right shifts again the whole structure to a center of gravity at 30°, see Fig. 5.

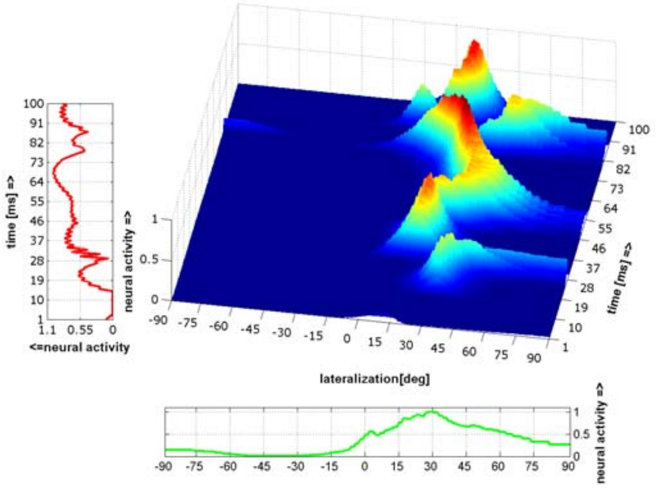

Figure 5: Binaural neural activity, head rotated to 330°.

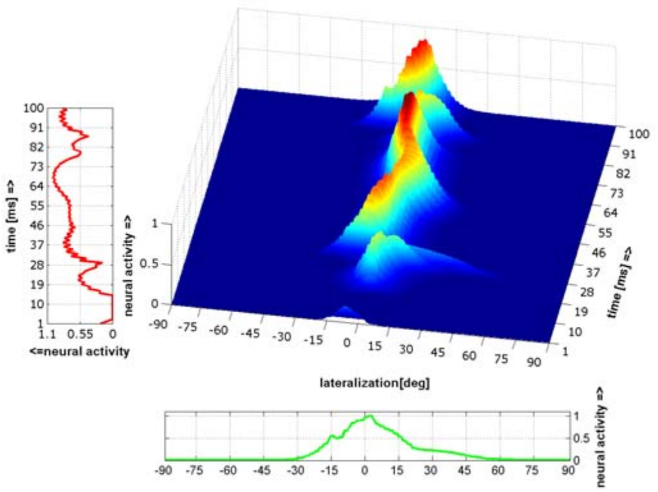

Figure 6: Binaural neural activity, stimulus reproduced by speakers at 15°and 345°, head rotation 0°.

To get an indication for source broadening, the opening angle of the two speakers was changed to 30° (see Fig. 6), and 90° (see Fig. 7). The structure of the 30° opening is a very homogeneous, continuous stream in binaural activity.

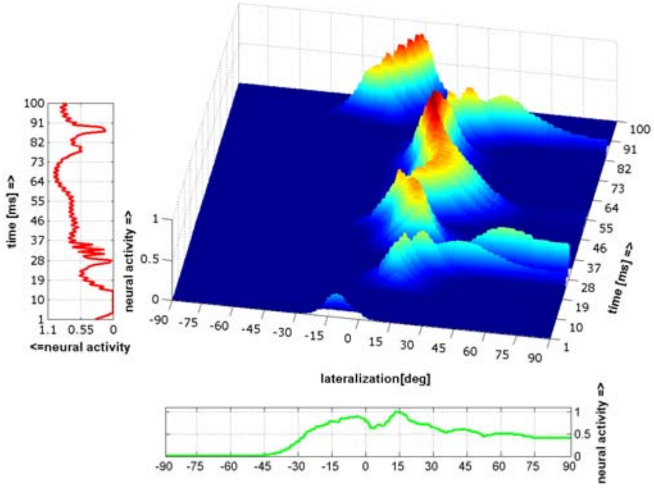

Figure 7: Binaural neural activity, stimulus reproduced by speakers at 45°and 315°, head rotation 0°.

In contrast, the wider dispersion of the sources causes a drifting apart of the activity stream's temporal structure. Interestingly the groups of activity peaks stay connected.

Conclusions and Outlook

The outcome of the model algorithm acts like follows: A rotation of the head causes only a shift of the whole neural activity structure to the opposite side. As can be seen in the structure, the axis transformation provides the correct position of the crests and peaks. Furthermore a variation in broadening of the source causes a dilation and compression in the dithering of the binaural activity ridges, which Lindemann characterized as an indicator for spaciousness [6]. Hence the edges of a floating temporal integration window could indicate the perceived broadening of the source, in literature called auditory source width (ASW) [7].

References

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