Aspects of Hearing and Reproduction of Extended Sound Sources and Diffuse Sound Fields

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Abstract

A diffuse sound field was created in a reverberation chamber. Broadband impulsive sounds with different temporal density of the impulses were employed. Tests were performed with listeners in the reverberant chamber as well as with the binaural recordings of the reverberant chamber tests.

The results of these tests showed a strong lateral concentration of the auditory events when a low temporal density of the impulses was employed. The presentation of the binaural recordings to the subjects over headphones produced qualitatively similar results, although a higher variability was observed. Similar results were obtained for tests performed in an anechoic chamber employing eight uncorrelated sound sources uniformly distributed in a horizontal circle.

These results suggest that the lateral concentration of the auditory events evoked by impulsive sounds in a diffuse sound field is an intrinsic characteristic of the human auditory system.

1. Introduction

In an extensive study Damaske [1] showed that under specific conditions the presentation of two decorrelated sound sources at different angles to the listener elicits the formation of an extended auditory event. Further studies have investigated this relationship (e.g [2], [3] and [4]). Damaske’s study also showed that the extension of the auditory event does not increase indefinitely with increasing angle between the sound sources. Exceeding a threshold results into the formation of two separate auditory events. Investigating these thresholds was the object of a study reported in a previous publication [5].

In the tests reported in [5] two incoherent sound sources formed out of 4 different talkers each, were simultaneously presented in free-field conditions to the listener at different azimuths. A head-tracked binaural system was employed. The four subjects participating in the test were asked to draw the horizontal angle occupied by the auditory event. Although the head-tracking system allows tracking for any head movement, the listeners were asked to limit their head rotation to small angles (approx. +10 degrees).

The thresholds obtained from the previous tests regarding the maximum angle between two sound sources that still elicits a continuous auditory served as basis for a further test. This time eight decorrelated sound sources surrounding the listener were employed. The sound sources were located at 0 degrees (frontal direction) +30 and -30 degrees, 90 and 270 degrees and at 135, 180 and 225 degrees. It is observed that despite the above mentioned distribution of the sound sources the location of the auditory events is predominantly to the sides of the listener.

2. Tests

To investigate whether the observed results were due to the use of non-individual HRTFs, or any artefact generated by the binaural system, further tests were performed. To this purpose a 3-dimensional diffuse sound field was created in a reverberation chamber. The set-up consisted in 8 loudspeakers located in a 2m radius, 1.2m high, separated by 45 degrees, facing outwards, as shown in figure 1. The listener seated in the centre of the circle in a chair with head rest. The test signals consisted of three types of rain sounds, each with a different temporal density of impulses. For each rain sound type, each loudspeaker was fed with the same signal but delayed 10s between subsequent loudspeakers. The SPL was approx. 75 dB and five test subjects have taken part in the experiments. Each sound signal had duration of 40s followed by a 10s pause. The listeners were presented to the sounds before the tests. The tests themselves consisted in a random presentation and each sound was presented four times. The listeners were asked to perform only minimal head rotations (approx. +10 degrees) and to draw the horizontal angle occupied by the auditory event. The tests were performed for two orientations in order to guarantee the independence of the results on the subject orientation. Furthermore, binaural recordings were performed, which were subsequently presented to the subjects.
3. Results

Figure 1 a) to f) presents the results obtained in the experiments for sounds #1, #2 and #3. Figures a), b) and c) show the results obtained with the subjects in the reverberant room and figures d), e) and f) show the results obtained with the corresponding binaural recordings being presented to the subjects. Sound #1 has the lowest temporal density of impulses and the results of figure 1 a) show that the associated auditory events are predominantly localized to the sides of the listener (the darker the grey, the higher the concentration of reported auditory events). Sound #3 has the highest temporal density of impulses (almost no impulses are perceived in this sound) and the results relative to this sound, depicted in figure 1 c), shows an almost homogeneous distribution of auditory events around the listener. The binaural recordings presented over headphones produce results qualitatively similar to those obtained in the reverberant room although a higher variability is observed (figure c), d) and f)).

Further tests were performed with pink noise bursts in the reverberant chamber and in an anechoic chamber (employing eight loudspeakers equally distributed in a circle). Each burst had a duration of 100ms and a $\cos^2$ envelope. The temporal density of the noise bursts could be adjusted at will. The results obtained further support the results presented in figure 1a)-c).

4. Conclusions

Sound sources surrounding the listener were presented both in an anechoic chamber and in a reverberant chamber and employing binaural recordings of the sound fields presented in the reverberant chamber. The signals presented to the subjects consisted in rain drops and pink noise bursts of different temporal density of impulses. For both signals the auditory events associated with the sound field showed a strong concentration to the sides of the subject for low temporal density of impulses. The auditory events tended to become more homogeneous distributed around the listener as the temporal density of the impulses increased.

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6. References