On Early Reflection Thresholds in the Median Plane

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Introduction

Early reflections play an important role in room and virtual acoustics. They are important for the localization of sound events as well as for spatial impression. Thence research in majority focused on the influence and the perception of these kind of reflections on the horizontal plane. This work focused on the perception of single early reflections in the median plane combined with a direct sound arriving from the front of the listener. A listening experiment has been conducted to determine the reflection masked threshold for single reflections in the median plane. The observations are helpful, e.g. to determine positions of loudspeakers in spatial audio systems for auralization. Furthermore the results can be used as an criterion in room simulations to control computational effort.

Test parameters

For the listening experiment a special loudspeaker setup was installed in a reference listening room. The setup enables the reproduction of direct sound in the frontal direction of the subject and reflections from variable directions in the frontal median plane. The reflections were delayed with 20 ms, 50 ms and 80 ms relative to the direct sound with angles of incidence at 30°, 40°, 50°, 60° and 75° in the front median plane. The loudspeakers used for the reflections were mounted at the ceiling 2 meters above the listeners' heads. The direct sound was reproduced by a speaker in front of the listening position at a height of 1.20 meters. Time and level differences have been compensated. The direct sound was reproduced with 55 dB(A) during the whole test [3]. For each combination of direction of incidence and delay the reflection masked threshold was determined.

Test design

To determine the reflection masked threshold a "Yes/No" algorithm with a PEST (Parameter Estimation by Sequential Testing) paradigm was used. Thereby the listener got two test signals: The direct sound and a combination of direct sound and early reflection. The sequence of this combinations was randomized for each listener. Furthermore, the test was done with two signals, a dry male speech and a short snare drum hit. The test started with a randomly chosen combination of delay and angle of incidence for the simulated reflections. The sound pressure level (SPL) of the reflection was set on 50 dB(A) measured at the listening position at the beginning of each test run. As a consequence of the testers' choices whether a difference of the two signal was perceived or not, the level of the reflections was decreased or increased. The PEST algorithm instructed in which step sizes to change the level of the reflection [4] [5]. After a sequence of identical answers, e.g. four times a detection of the reflection the stimulus changed in greater steps. After many changes of the answers, i.e. insecurity whether the reflection was present or not, the step sizes got smaller. One test run was terminated when the step size reached a defined minimum, in this test design this matched with a change of the reflection´s level of less than ±1 dB. A single test run took about 20 minutes for all combinations of delays and incidence angles of the reflection. After a short break the test was repeated with the second test signal. The subjects were advised to look at the direction of the loudspeaker of the direct sound. During the listening test the room illumination was reduced to a minimum in order to minimize visual bias. The participants of the listening experiment were students of Ilmenau University of Technology and employees of Fraunhofer IDMT. At the beginning of each listening test, the subjects got written instructions about the test procedure. 12 subjects participated in the experiment with an age spread from 20 to 29 years and an average age of 24 years. 6 listeners already had experience with listening tests.

Results

The results of this test are plotted in Figure 1. The ordinate shows the level difference of the reflection compared to the direct sound for a given delay and angle of incidence. The abscissa shows the delays, at which the perceptual thresholds were tested. The mean and the 95% confidence intervals of the two signals and all combinations of angles of incidence are grouped for a certain delay. For both test signals a decrease of the threshold for increasing delays can be noticed. The thresholds for the speech signal are over those of the snare signal. For all tested data combinations there is just a marginal variance of the means but a highly overlap of the confidence intervals for different angles of incidence.

Discussion

In the results of this test effects which are known from similar experiments in the horizontal plane can be found. The decrease of the threshold with lengthen delays as well as the fact, that the threshold of the snare signal (an impulsive signal) is below the one of the speech signal agrees with findings of Olive and Toole [1]. An explanation could be seen in postmasking effects which become less important with increasing delays. Durand R. Begault et. al. also ascertained a dependency of the signals in the horizontal plane which seems to be valid in the median plane with regard to the results of this test, too.

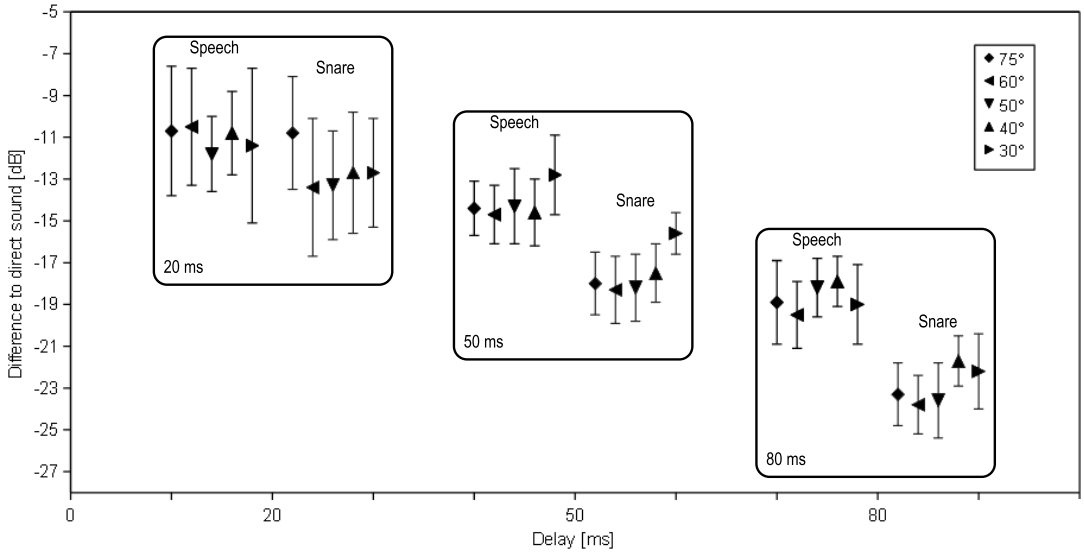

Figure 1: Test results (means and 95% confidence intervals) of the identification of early reflections in the median plane for given angles of incidence and delays for the speech signal as well as for the snare signal

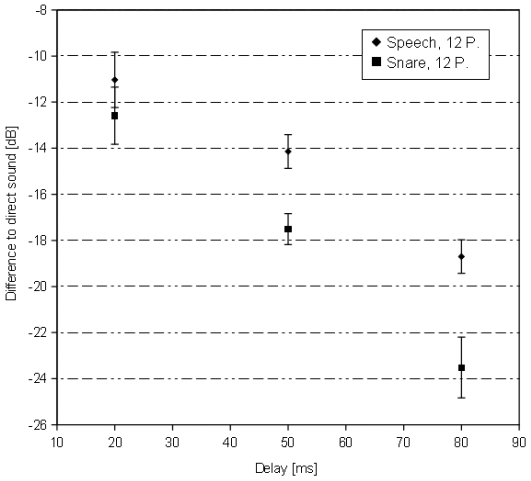

Figure 2: Mean results of the listening test (means and 95% confidence intervals) concerning the detection of early reflections in the median plane

Furthermore a stronger descent of the threshold of the snare signal with an increasing delay could be observed in this current results. On the basis of the highly overlap of the confindence intervals at each delay in Figure 1, the results of all angles of incidence for a given delay and signal were combined in Figure 2. Durand R. Begault et. al. showed that the threshold of early reflections in the horizontal plane depends on the angle of incidence [2]. This effect seems not to be valid in the median plane when considering the results of this test. Further experiments on the perception of the angle of incidence of the reflection can extend the given results to prove this hypothesis.

Summary and Future Work

In this paper a listening experiment on the threshold of single early reflections in the frontal median plane was presented. A "Yes/No" test design with a PEST algorithm was used to determine the reflection masked threshold. The main findings are comparable to those of previous observations in the horizontal plane. An interesting tendency is the independence of the angle of incidence on the threshold. The results of this experiment lead to a variety of future work. For comparison tests in an anechoical room could be done. Additionally it is important to know in which way the reflecton masked threshold in the median plane changes, when the direct sound is reproduced not in front of the listener but from variable directions in the horizontal plane. The results of the current experiments deliver important insights on the perception of reflections in the median plane which can be applied in the design of spatial sound design systems.

References

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