Perception of scattering coefficient in auralized concert halls

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Introduction

The subjective impression of a listener has always been a focal point in room acoustics. It is not surprising that the interest of researchers strongly moved towards the understanding of relations between objective and subjective parameters. A common reason for that is the need to support architects and engineers during the planning stages of new concert halls, where a clear statement between acoustic measurements and human perception is necessary.

Unfortunately, it was already shown that it is very difficult to find a direct connection between architectural planning criteria, objective acoustical descriptors and subjective response from listeners [1]. It was also proved that no existing acoustic parameter is well correlated with overall acoustic impression for musicians for halls with suitable level of acoustic response from the auditorium [2].

This paper aims to contribute to the understanding of the relations between human perception and objective parameters by investigating the perception of scattering coefficient (*s*) [3]. In particular, the just noticeable difference for different scattering coefficients associated to lateral walls of a simulated closed space will be investigated.

Audibility of scattering coefficient

Suppose that a listener is sitting next to a side wall in a concert hall during a concert. If the scattering properties of the side wall change, will the listener be able to perceive a difference in the performed music? A previous study [4] tried to answer to this question, showing that the perceived differences were clearly dependent on the input signal and that diffusion was affecting mainly coloration and spaciousness. However, no statement about JNDs was done.

A first attempt of the present study included acoustic simulations of a real concert hall. However, such a closed space is highly complex and the wide amount of surfaces generate additional effects, so that it turns difficult to isolate the influence due only to the scattering coefficient. For this reason, the easiest configuration possible was chosen (Fig.1): one shoebox-like room with one receiver located next to a side wall and one source located in the position where a music ensemble is supposed to be. By means of simulations, several binaural room impulse responses corresponding to different room configurations were obtained. In the simulation, the number of reflecting walls as well as the scattering coefficient was changed. Afterward, each binaural impulse response was convolved with three different anechoic music samples (choir, piano and orchestra). The auralized signals were used in listening tests. Finally, psychometric functions showing the JND for scattering coefficient were obtained.

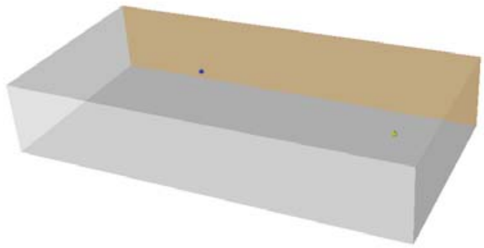

Figure 1: Room configuration under investigation. The source-receiver is distance is 10 m, the receiver side-wall distance is 2 m.

Simulation

Acoustic simulations have been executed with the hybrid room acoustics simulation software RAVEN [5]. The idea is that only one, two or three walls respectively of the room are scattering (values for *s* given in Tab.1), while the remaining ones are completely absorbing (α=*0*). A binaural room impulse response for each scattering value has been determined.

Room-acoustics computer simulations which utilize Lambert-modelled scattering are essentially simulations with stochastic/random mechanisms. In those simulations, differences are sometimes audible between responses with the same scattering coefficient and therefore may be difficult to compare responses with different scattering coefficients. In RAVEN, the late part of the RIR is synthesized by means of a noise process based on a Poisson distribution [6]. In order to avoid possible influences on perception given by this random process, the Poisson sequence is maintained constant with also a constant sequence number.

Listening Tests

A 3 alternative forced choice test was chosen, in which the participants were asked to choose the music sample which was different among a sequence of three. Twenty people attended the test, which lasted almost 15 minutes. The test structure is summed up in Tab.1. A binaural impulse response corresponding to 6 different values of scattering coefficient has been generated. The value 0,9 has been adopted as reference value. No replay of sounds was allowed. Participants could optionally specify which kind of differences they detected, if it was in coloration, spaciousness or something else.

Table 1: Listening test structure

Walls	Scattering Coefficient					Anchor
1/2/3 – sides	0,1	0,3	0,6	0,7	0,8	0,9
					Music samples: Piano, Choir, Orchestra	

Results

Results from listening tests allowed the determination of psychometric functions, which is a curve that relates an observer's ability to detect a stimulus (or differences between two or more stimuli) to the intensity of the stimulus (or to the size of the difference). Its range is a probability measure, namely the probability with which the listener can correctly identify the target stimulus in comparison with others. Psychometric functions were fitted using *psignifit*, a software package which implements the maximum-likelihood method described by Wichmann and Hill [7]. For the choir sample a JND of 0.27 was detected. It means that the scattering coefficient needed to be lowered at least of 0.27 in order that a difference could be heard by the listeners. For the orchestra sample a JND of 0.37 was detected, while for the piano sample a JND of 0.45 was detected. The piano sample appeared to be particularly difficult, as suggested from the psychometric function slope. The reason may be found in the nature of the piano music signal, which was fast, articulate and with a high note density. The complexity of the sample decreased the ability of the listeners in detecting the differences.

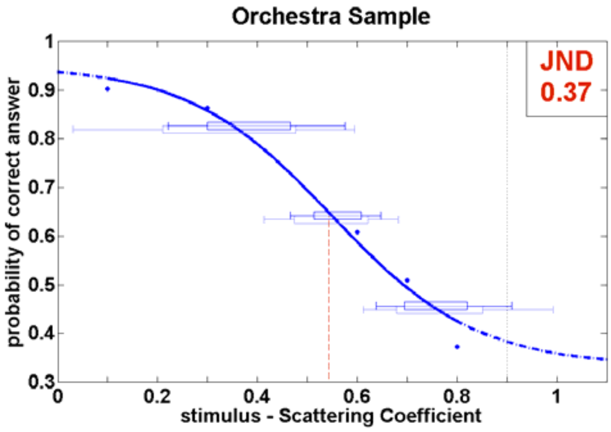

Figure 2: Psychometric function for the orchestra sample.

In order to understand how the variations of scattering is influencing the JND, psychometric functions were obtained also for different room configurations. Results showed that if only one wall is scattering, it was very difficult for the listeners to perceive differences (a JND of 0.49 was detected). In case two walls are scattering, the slope of the psychometric function appeared more reliable, even though there was an extensive dispersion of the values. The JND in this case was found to be 0.42. A clear improvement in the ability of detecting a difference in the musical samples by the listeners was achieved in the room configuration with three scattering walls: the variance of data decreased and the measured JND was 0.27.

Figure 3 shows that differences in spaciousness were more audible than differences in coloration, independently from music samples and room configurations. Other aspects were also described, like difference in loudness or reverberation. Results slightly diverges from [4], where for a static organ chord more differences in coloration where detected. However, as soon as the music content is more articulated, such as in the string quartet sample used by Torres or in the samples used in this study, spaciousness plays a major role.

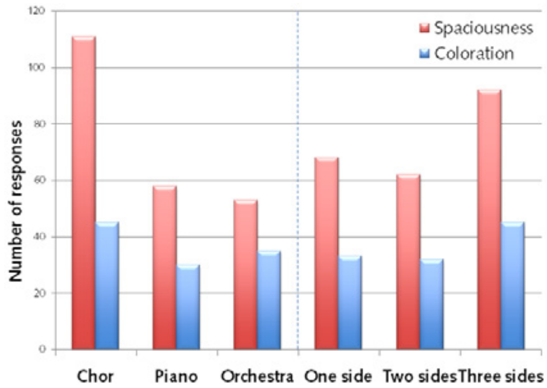

Figure 3: Perceived differences by the listeners.

Conclusions and future perspectives

A first investigation for determining the JND of scattering coefficient has been successfully performed. By using a reference value of 0.9 for the scattering coefficient, JNDs between 0,27 and 0,49 have been found. An increase in the scattering surface corresponds to an increase in the listeners ability to detect differences. The music texture plays a major role in the perception of scattering, which seems to be more related to spaciousness than coloration.

Future works include frequency-dependent scattering tests as well as evaluation of JND for different reference values. The high dependence of perception from the musical content, suggests the idea of investigating the relation between scattering coefficient and specific cues in music. It may also be interesting to perform listening tests with the same music sample played by different instruments. The complexity of the room geometry shall be increased, and testing with realistic reverberation conditions shall be done.

Acknowledgments

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