Subjective evaluation of diffuse sidewall reflections in a concert hall model

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Introduction

This paper presents some conclusions about the ability of a group of subjects to perceive any audible differences in side wall reflections, using different degrees of scattering values for these surfaces.

The research was done in two parts: First we did a computer simulation of a simple shoebox shaped model, equivalent to Vienna Musikvereinssaal in dimensions and reverberation characteristics; we made full calculations of acoustical parameters and the obtained impulse responses were convolved with anechoic files to render audible the sound in the hall. Secondly we prepared and presented to a group of subjects listening tests using a stereophonic reproduction of music, both binaurally processed for headphone presentation.

Computer simulation

The Vienna Musikvereinssaal, in its most simple geometry, a shoebox with a volume around 15000m^3, was chosen to be our model. The hall was considered fully occupied and audience absorption was chosen according to Kuttruff (average occupied audience [1]). For all the other surfaces, absorption coefficients were adjusted to obtain the reverberation time of the real room according to Beranek's data [2]. Two different sound source configurations were applied (figure 1): 1) a monophonic source representation of a trumpet player in the middle of the stage (A0), using trumpet directivity. 2) A stereophonic reproduction of orchestral music, represented by two omnidirectional sources (A1, A2) located symmetrically on both sides of the stage. Three receiver positions were chosen from the audience area: central line, first and second half of audience area (R1, R8); R3 close to a balcony. Simulations were done with (LB) and without lateral balconies (NB) and for three scattering value configuration: frequency independent, representing totally specular reflections (s10), totally diffuse reflections (s99) and estimated frequency dependent rough values between 30 and 80 % (s30-80).

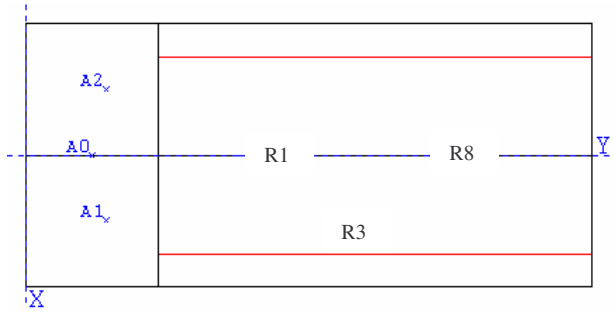

Fig. 1: source and receiver positions in the model

Auralization was done using the first 7.8s of Purcell's Trumpet Voluntary anechoic file. For the stereophonic orchestral music, we select a sample of 10.6s from Bruckner´s 4th Symphony, first movement, and a sample of 11s from Johann and Josef Strauss's Pizzicato Polka.

Listening tests

To evaluate the subjective preferences, an attempt to define a cause-effect relationship between some physical parameters and subjective responses was done using listening tests. The possible questions were presented according two different ways: 1) by discrimination: Can subjects perceive any difference? 2) by affectivity: Which sound stimuli are preferred?

Evaluations were done for only one physical parameter change at a time, by a group of subjects: experts, trained and untrained listeners, males and females, ages between thirties to seventies**,** most of them with some degree of knowledge on music and/or acoustics. The tests were randomized to avoid adaptation, expectation, and habituation. The order of presentation of the music samples and possible combinations was done by the software PATS (Synotec, Germany). Results were obtained just counting the chosen answers: First sample (A), second sample (B) and a null hypothesis was also considered (wn) meaning no clear difference was found or not possible to say which one was preferred. A total of forty five comparisons were evaluated for Purcell's and Bruckner's and thirty six for the Strauss files.

Some results

Seat comparisons: Subjects show a clear preference for sound at R3, for all the six considered cases when compared with R1. R8 is preferable against R1 and R3 for high scattering coefficients (s99), while for lower scattering values, R3 is preferable to R1 and R8. In no case R1 shows to be a good place to hear differences in audibility by changing the scattering values (see figures 2- 4)

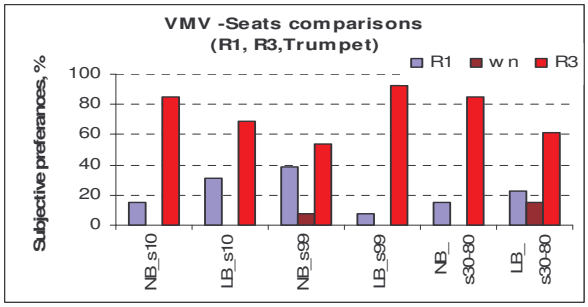

Fig. 2: Seat preferences R1 versus R3

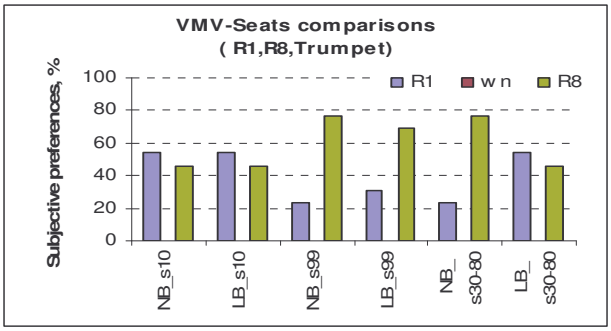

Fig. 3: Seat preferences R1 versus R8

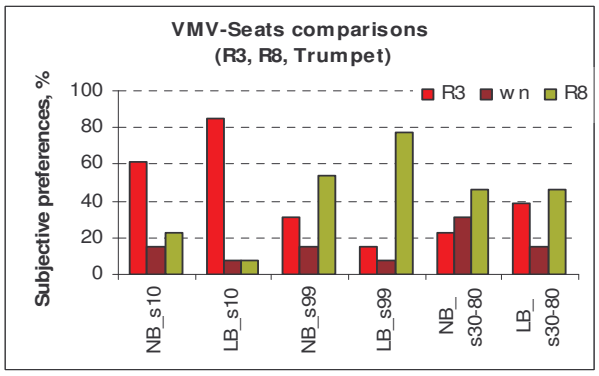

Fig.4: Seat preferences, R3 versus R8

Scattering effects: Changing scattering values without lateral balconies does not influence audibility in R3 (fig.5) and R1. The values s30_80 are preferred to s10 for seat R8. With lateral balconies, the situation s30_80 is preferred to s99 for seat R1 (see fig. 6), while for the other places there's no significant difference.

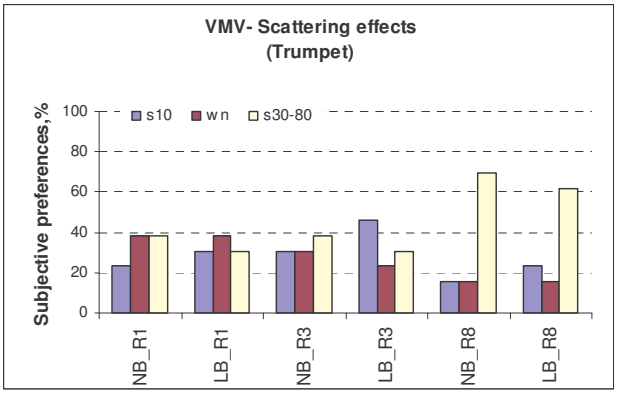

Fig.5: Comparing s10 to s30-80, for Trumpet

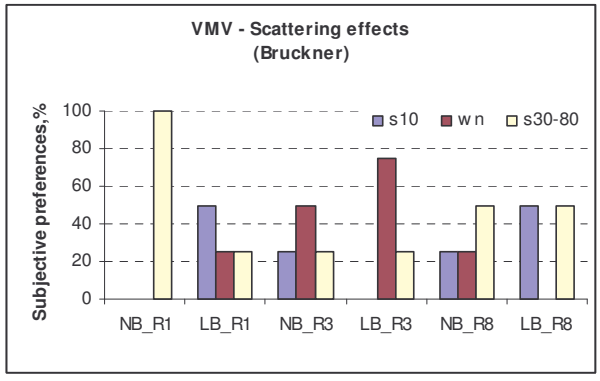

Fig.6: Comparing s10 to s30-80, for Bruckner

Geometry influence: Figure 7 shows the influence of lateral balconies at the three seats for the audibility of the three scattering settings. A most significant in effect is found at R3 for low scattering (s10), while for high scattering (s99) the effect of the balconies seems inaudible. For s30_80 the audibility only at R1 and R3 is clear. For the stereophonic orchestra examples the corresponding results (fig.8) are evidently less significant.

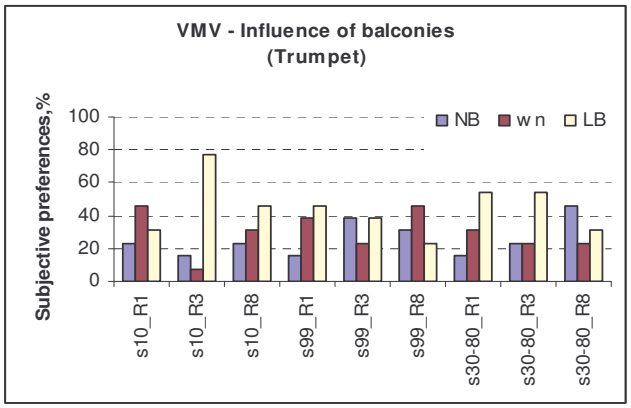

Fig.7: Influence of balconies for the trumpet

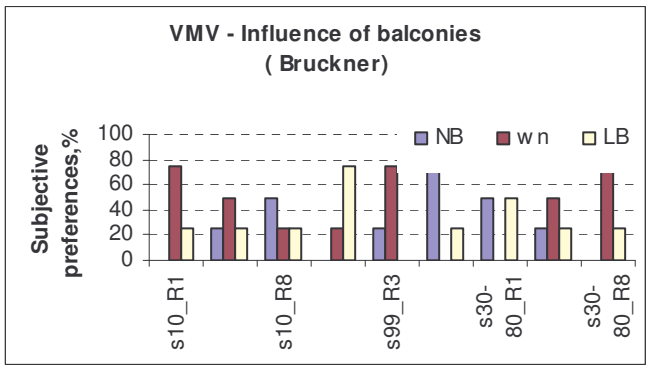

Fig.8: Influence of balconies for Bruckner's

Conclusions

Listening test with a simple computer model showed that the audibility of side wall scattering is depending on geometrical conditions: Listener position, wall structure, source configuration.

The effects of the degree of scattering on the two source signals was significantly different: while for the solo trumpet the variation of scattering was clearly audible, the stereophonic source configuration (orchestra) showed only small changes in sound quality (e.g. apparent source width). The reason for this can be explained by the higher density of early reflections in the case of two sources in contrast to the single source arrangement.

Literature

[1] Kuttruff, H.: Room Acoustics, Spon Press 2000.

[2] Beranek, L.: Concert Halls and Opera Houses, Music Acoustics, and Architecture, Springer 2004.