SUBJECTIVE EVALUATION OF DIFFERENCES IN CONCERT HALL SHAPE USING A MULTISOURCE ORCHESTRA ANECHOIC RECORDINGS AURALIZED IN 3D COMPUTER MODELS

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By means of auralizations created by the ODEON software, the present study aims towards testing whether such auralizations are capable of revealing systematic subjective differences between two topologies of concert halls shapes (shoebox and arena). Anechoic multisource orchestra recordings were used as signal input in the auralization of Brahms music in 6 concert hall models and 27 subjects with and without musical background evaluated the halls with respect to general preference in paired comparisons tests. The paper discusses the results regarding the subjects' detection of differences in room shape.

Keywords: auralization, preference, concert halls, shoebox, vineyard

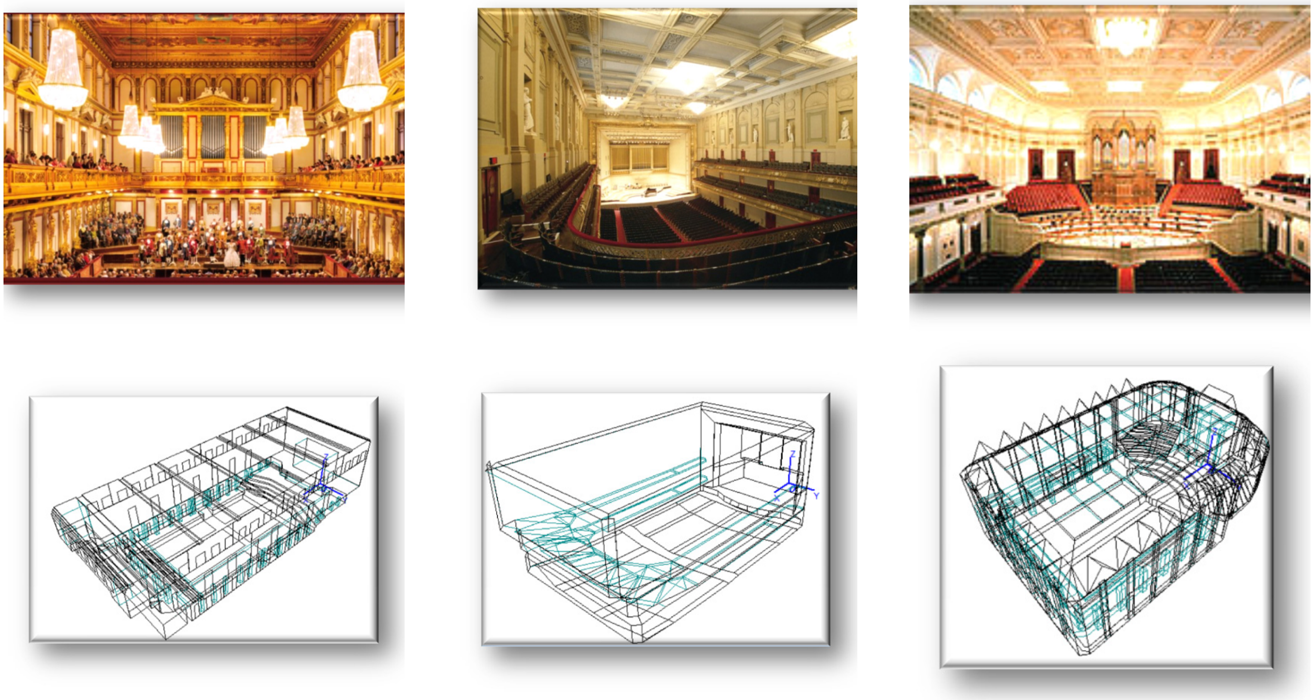
1. Introduction

The current trends in concert hall design seem to concentrate on two basic hall shapes:
1). the rectangular "shoe box" with one or more balconies
2). arena shape with vineyard terraces (and sometimes balconies).

By means of auralizations created by the ODEON 14.05 software, the present study aims towards testing whether such auralizations are capable of revealing systematic subjective differences between these two topologies.

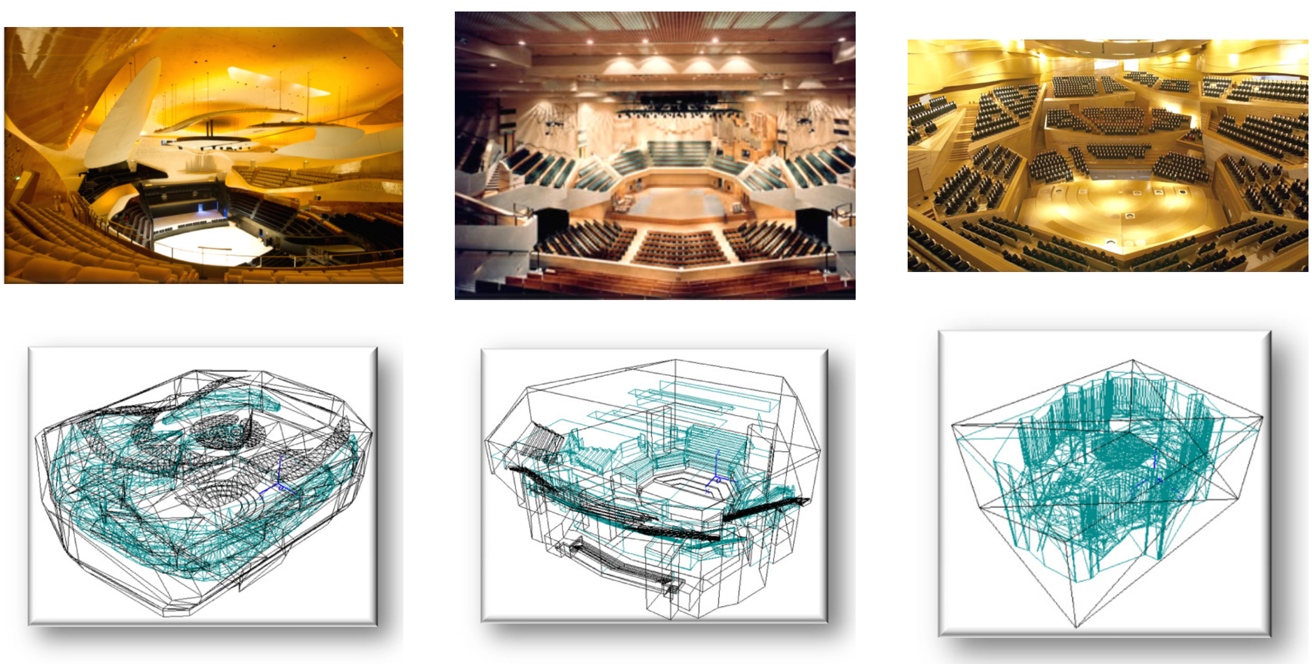
The procedure was to create 3D model auralizations from two listener positions in each of three classical shoeboxes and three modern "vineyard" halls.

Then evaluation of the listeners preferences was made with the use of paired comparison test, using headphones. Examples of real halls and their Odeon room models used for the study are shown on Fig.1 and Fig. 2



Musikvereinssal, Vienna | Symphony Hall, Boston | Concertgebouw, Amsterdam

Figure 1: Acoustical Odeon scale models for three classical shoebox concert halls:



Philharmonie Paris, Paris | St. David's Hall, Cardiff | Danish Radio, Copenhagen

Figure 2: Acoustical Odeon scale models for three arena (vineyard) type concert halls:

2. Method

Odeon auralizations with multisource orchestra was made in Odeon [3], for two positions on the audience. This paper only covers results for position R2, located approx 14m from stage front on the right side of the stalls (Fig.3). Three halls were traditional rectangular shaped, the so-called shoebox halls, while other three are more modern designs in which the audience surrounds the orchestra. Brahms Symphony No. 4, 3rd movement Odeon anechoic recordings were used (Fig.4), as Brahms seems to have the most rich instrumentation among Odeon and Tapio Lokki recordings. For each position a 42sec excerpt of Brahms recording was made, with 1sec. fade in and fade out. Unfortunately, Brahms recording is very unsynchronised in first part (most interesting musically), so a later part was used (where strings play more synchronized). Orchestra was simulated as multisource orchestra [1, 2] on stage, and set up identically in all models.

In Odeon models, only 3 materials from Odeon database were used:
Material 1 - orchestra with instruments on podium (mat.11000)
Material 2 - audience on lightly upholstered seats (mat.11009)
Material 3 - average total residual absorption (mat.2354)
To reduce the influence of reverberation, the Reverberation Time (T_{30}) in all models was set to ~2,0 sec (125-4kHz) by adjusting absorption coefficient of Material 3. Results of absorption coefficients for Material 3 before and after adjustments are shown in Fig.5

Scattering was set at 0,7 for audience and orchestra, and 0,1 for other surfaces.

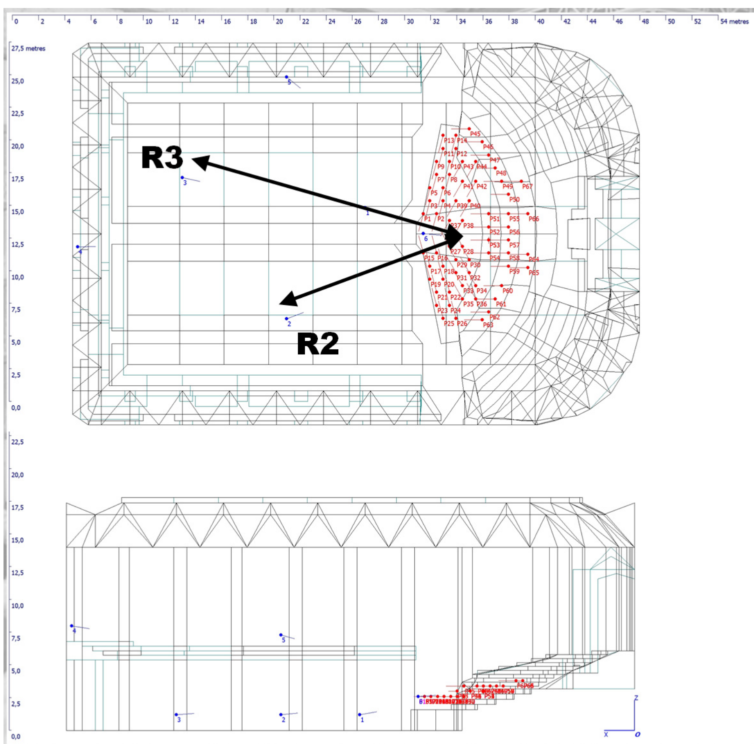


Figure 3: Orchestra layout and receiver positions. In this paper only results for R2 position were presented.

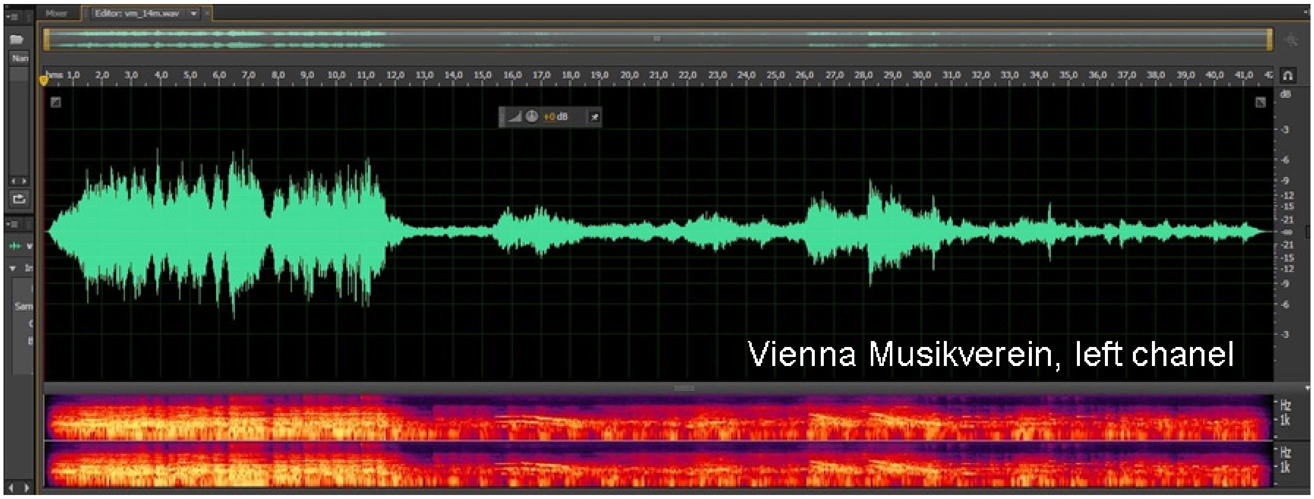


Figure 4: Auralized music used in paired comparison test (example for Vienna model)

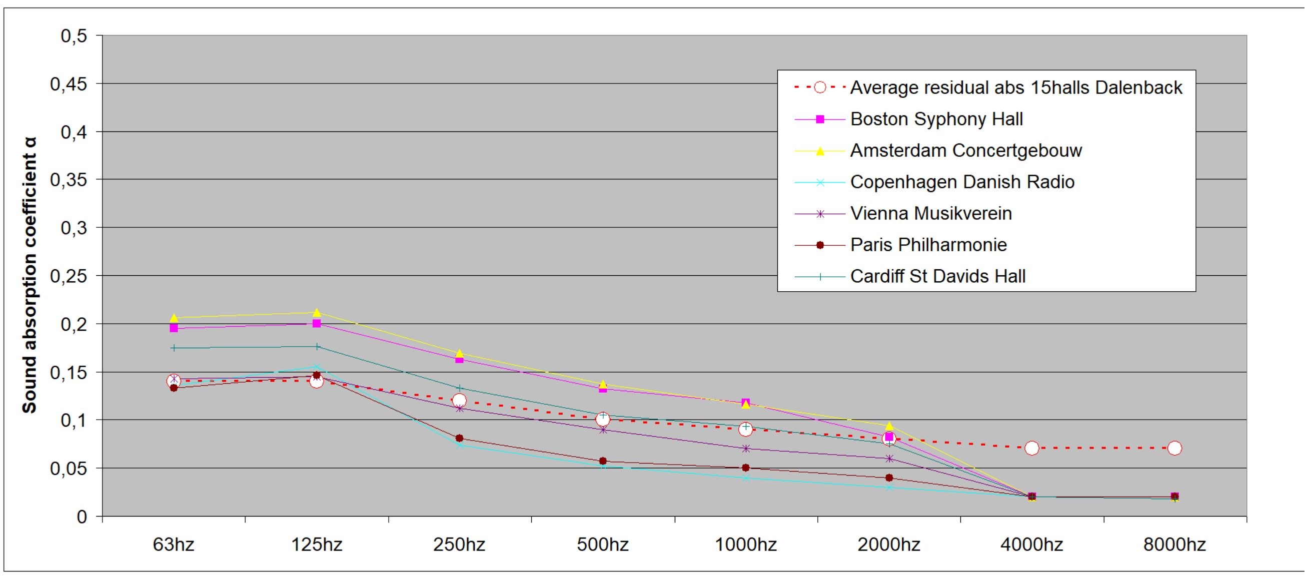


Figure 5: Comparison of Material 3 sound absorption coefficient: average residual absorption and it's value in each model after adjustments for equal reverberation time were made.

All auralization were evaluated by 27 participants (age 18-31years old, average age 24,3 years, 14 female & 13 men, 14 with musical background.) with the Paired Comparison Test. Each participant conducted a training session and two tests (Test 1 and Test 2). Each test included 15 pairs, played in fully random order.

Training session was used so participants can familiarize with the selection process and so they can choose the comfortable level played music. This level could not be later changed during Test 1&2.

All participants were asked the same question: "Your aim is to choose the sound you prefere".

3. Results

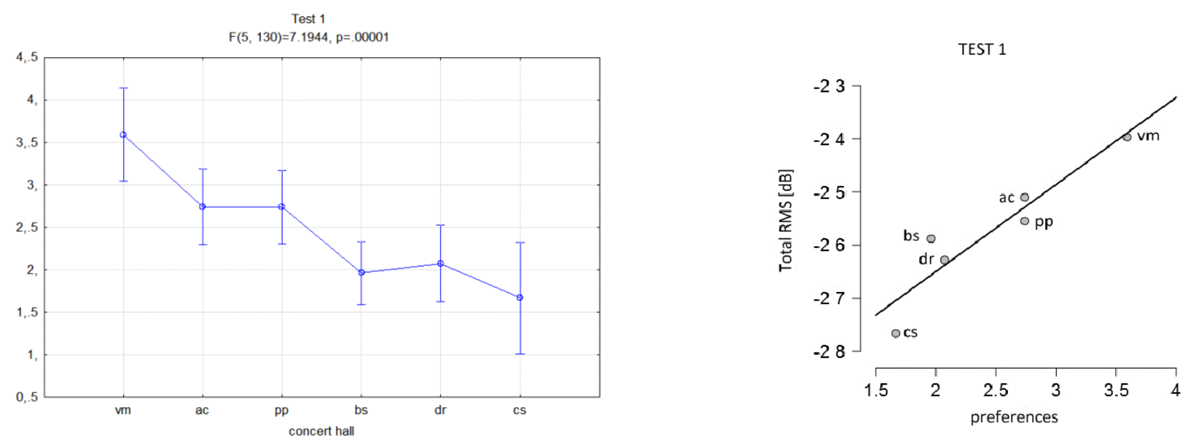
For the clarity of the text, the results of test 1 and then test 2 and their comparison will be presented in order. Both tests were carried out on the same group of subjects in the same order. Statistical analyses were performed with the use of STATISTICA 13 [5] and JASP 0.8.1.2 [6] programmes.

Notation and interpretation of Bayes factor (BF) is taken from Wetzels et al. (2011) and Ly, Verhagen and Wagenmakers [7]. The subscript 10 means that the value of BF favours the hypothesis 1 against 0. All Bayes analyses provided here identify hypothesis 1 with the presence of differences between variables, and hypothesis 0 is identified with lack of the differences. We adopted the interpretation of BF suggested by Wetzels et al. [8]. The values of BF10 above 3 are interpreted as substantial or stronger evidence in favour of hypothesis 1, and the values below .33 are interpreted as substantial or stronger evidence in favour of hypothesis 0 and against hypothesis 1. BF values that are between 3 and .33 are not conclusive to infer favour of any hypothesis. We used partial eta-squaed n all refered results.

3.1 Test 1

Box halls were chosen more often than terrace halls. Mean for box halls was 2.77 (SD=.73) and mean for terrace halls was 2.16 (DS=.76). The difference is significant with $F(1,26)=4.64$, $\eta^2=.15$, $p=.041$. Bayes Factor is conclusive with $BF_{10}=9.67$ and favors the differences in preferences between types of hall. This result is consistent with the results presented by Patynen and Lokki (2016).

General effect for the set of concert halls was significant with $F(1,26)=7.19$, $\eta^2=.22$, $p<.001$, $BF_{10}=45324$. Fig.6 (a) presents plot of the preferences. Based on our assumptions regarding the impact of sound level on preferences, we compared preference results with loudness indicator (Total RMS) in the halls. Loudness and preferences were highly correlated, Pearson's r correlation was $r=.934$, $p=.006$, $BF_{10}=8.737$. Fig.6 (b) shows the distribution of preferences depending on the loudness.



a) b)

Figure 6: Preferences (mean of number of choices) of concert hall (a);Dispersion of preferences depending on the music loudness (estimated linear relationship) (b)

3.2 Test 2

Test 2 was carried out on the same group of subjects. The Total RMS volume indicator was reversed, so that the loudest tracks in Test 1 became the quietest in Test 2 and vice versa (see Fig.7). According to our hypothesis, if loudness is an important factor affecting preferences, the preferences should also be reversed after reversing the volume.

In Test 2 terrace halls were chosen more often than box halls. Mean number of choises (preference) for box halls was 1.83 (SD=.75) and mean for terrace halls was 3.1 (DS=.73). The difference is significant with $F(1,26)=21.19$, $\eta^2=.45$, $p<.001$. Bayes Factor is conclusive with $BF_{10}=179790$ and favors the differences in preferences between types of hall. The differences are even stronger than in the case of regular volume. This result is opposite to Test 1 and to Patynen and Lokki (2016), however it is expected in the light of our hypothesis.

General effect for the set of concert halls was significant with $F(1,26)=8.96$, $\eta^2=.26$, $p<.001$, $BF_{10}=1.642e+6$. Fig.8 (a) presents comparison of the preferences in Test 2 and Test 1. Similar to the results of Test 1, loudness (Total RMS) and preferences were highly correlated. Pearson's r correlation was $r=.953$, $p=.003$, $BF_{10}=13.07$. Fig.8 (b) shows the distribution of preferences depending on the volume.

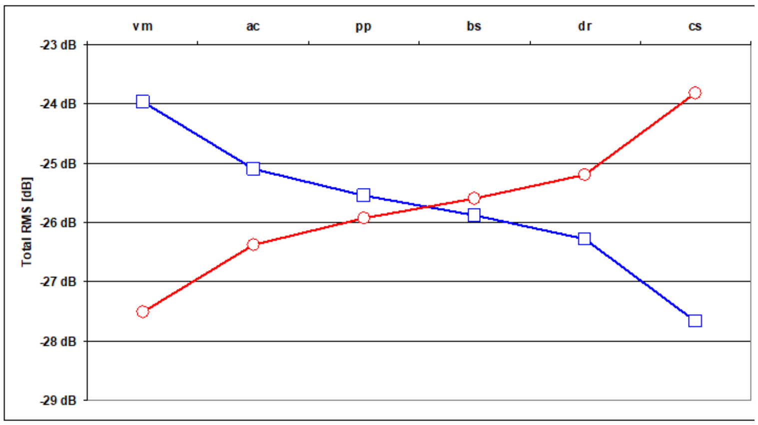
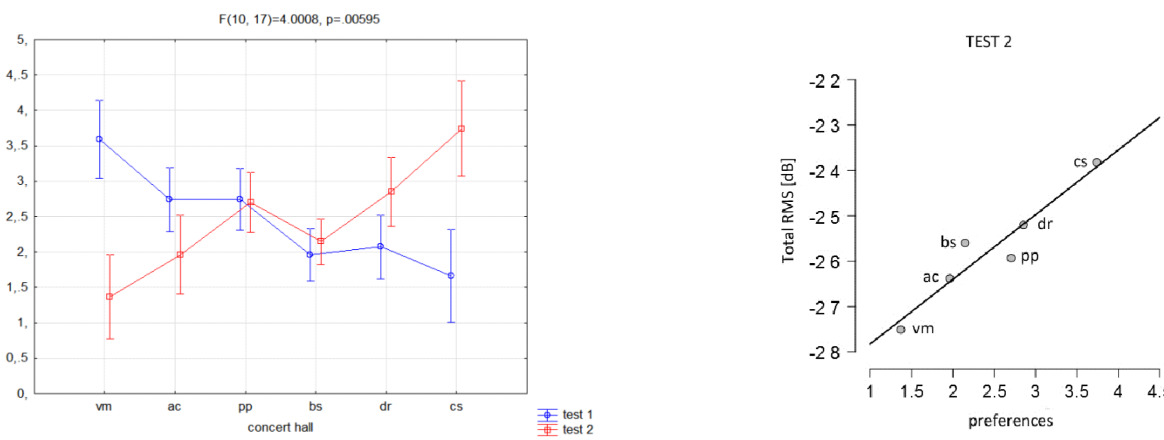


Figure 7: Comparision of average (Total RMS) loudness of auralized music in Test 1 and Test 2



a) b)

Figure 8: Preferences (mean of number of choices) of concert halls. Comparison of results between Test 1 and Test 2. (a);Dispersion of preferences depending on the music loudness (estimated linear relationship) (b)

4. Summary

Results show, that Shoebox typology is preferred over arena one. This confirms findings by Lokki [3]. In direct comparison of auralized music, loudness, seems to be the decisive factor for preference judgments. This was reported earlier [9, 10], but not shown in such a clear way, as it was observed in this study. As classical shoeboxes are generally louder, so shoe-box shape is preferred over the arena/terraces.

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