Technische Universität Berlin

The Perception of Stage Acoustics by Solo Musicians (Proposal)

Name: Nagisa Ghaffari (338495)
E-Mail: nagisa.ghaffari@campus.tu-berlin.de

Master's program: Audio Communication and Technology

Jan. 2017

Advisors:
Prof. Dr. Stefan Weinzierl
Dr. Zora Schärer-Kalkandjiev

1 Abstract

This project is a study of acoustics from perspective of solo musicians on stage. The goal is to specify understandable acoustical parameters for the musicians to optimize the acoustical environment for them on stage and to improve acoustical planning of a stage. Within two other theses (Schärer-Kalkandjiev, 2015) & (Stahnke, 2013) solo musicians have been interviewed and their performance has been recorded in virtual rooms (via dynamic binaural synthesis). The acoustical parameters have been extracted from the models and the musicians have rated the rooms via surveys. The ratings of the rooms (items) and the acoustical parameters will be analyzed by a Multilevel Analysis Method to find the relation between the two. A qualitative evaluation of the interviews will support the results to understand the interindividual differences between the levels of the multilevel analysis.

2 Introduction and Motivation

The room acoustical parameters such as Strength and Reverberation or the Timbre has been studied and predicted through technical parameters in many studies especially from the perspective of the audience in a room but the acoustical impact of a room on the performance of musicians and their subjective perception of a room especially on the stage hasn't been studied as much. Within a PhD thesis (Schärer-Kalkandjiev, 2015) in the anechoic room of Technical University of Berlin in 2015 solo musicians have played actively in different virtual rooms through a dynamic binaural synthesis. Firstly the aim of the study was to find a proper vocabulary to describe their acoustical environment via a combined qualitative-quantitative method (Repertory Grid Technique, RGT) by musicians (Study by Eric Sathnke) (Stahnke, 2013). Subsequently the solo musicians have evaluated the rooms via defined bipolar terms via a survey handed to them. In the third part of the study the musician performances have been recorded to distinguish their adjustment to the different room acoustics. The results of the second and third part of the study have showed that the perception and performance adjustment of each musician to every room is highly individual. This has complicated the data analysis with classical multivariate methods such as Cluster, factor or regression analysis. Hence in this thesis the data should be evaluated by a multilevel analysis method to investigate the results of the second and the third part of the study. The questioning of this thesis is to find the relation between the ratings (items) of the rooms by solo musicians and the actual room acoustical parameters, which were suggested in the past studies and norms. The goal is to optimize the condition for solo musicians on stage; and also to find the most important parameters by planning acoustics for a stage from the perspective of the solo musicians in contrast to the last studies, which were mostly focused on the audience perception of room acoustics. Furthermore suggested acoustical parameters by past literature should be proved to achieve better subjective stage acoustical conditions and better possible predictors. Ultimately, a qualitative content analysis of interviews (from the third part of the study) can be used as a secondary source of information to reach a better understanding of the interindividual differences.

3 State of Art

In 1970 studies started some investigation apropos acoustics on stage for the musicians with the aim of optimizing the latter for them. Some of the recent ones are as followed:

3.1 Gade (2010)

Firstly to define the acoustical attributes on the stage subjectively by musicians, 32 classical music musicians in Scandinavia have been interviewed to gather a proper vocabulary to describe the acoustic conditions on the stage. Through the interviews, different aspects have been extracted, which have been called subjective parameters: Reverberance, Support (including hearing one self), Timbre, Dynamics, Hearing each other and Time delay. The results of the study have shown that different musicians have different threshold of perception (for the early support parameter). Among the objective measures suggested, only Support early/late/total has been used by several acousticians. There are some results from previous studies which prove that the level of reverberation is important but there is no specific measurement parameter for it or a suggested way to optimize it. The other problem was that most of the results from laboratory studies were not very realistic comparing to the sound of a full orchestra. This made it hard to judge the rooms also using a unified vocabulary. At the end there have been improved suggestions to optimize the stage design.

3.2 Gade (2013)

This study offers more clarification on objective and subjective parameters especially in terms of the measurements suggested by ISO 3382-1 (ISO3382-1, 2009) and geometrical parameters relevant to the room architecture. Gade demands for further studies in more realistic situations for full orchestras especially a unified approach to data collection from acoustic experiments by experts. The other issue regarding the objective parameters is the distance between the source and the receiver, which is not estimated exactly in the last studies. Another aspect of interest was the suggested measurement positions on the stage (lay out) according to Dammerud (Dammerud, 2009) and ISO 3382-I (ISO3382-1, 2009), which were different. Ultimately, a form of questionnaire has been introduced to estimate subjective parameters by musicians.

3.3 Stahnke (2013)

14 musicians have been asked to play their classical solo instruments (violin, cello, trombone, oboe, trumpet, bassoon, clarinet) in 10 different virtual rooms via a BRIR simulation on headphone in the anechoic room of TU Berlin. They valued the rooms via a rating interface with 20 items, which were developed through a Repertory Grid Technique and a cluster analysis. 15 room acoustical parameters defined by DIN EN ISO 3382-1 (ISO3382-1, 2009) have been calculated and their relation to the valued items by musicians has been studied.

The results show that the Reverberation time T_{30} (objective parameter) correlates as much with the items (subjective parameters). Also the items correlate highly among each other. One item (subjective room acoustical parameter) which correlates with another item (full-empty sound of the room) is the Strength by 1m (G_{1m}) and Clarity (C_{30}, 1 m). Also the Clarity (C_{50}, 1 m) correlates with some items. It is worth to mention that the acousical parameters: Eary decay time (EDT, 1 m), Support early (ST_{Early}, 1 m), LQ_{7-40}, (BR_{EDT}), EDTF, (BR_T), (BR_G) and (TR_G) have no significant correlation with the items at all. Those items, which have an impact on the general perceptive reverberance of the room correlate much with the reverberation time (T_{30}).

3.4 Schärer, Weinzierl (2015)

This study investigates the effects of room acoustical conditions on different aspects of music performance. 14 room models have been simulated in the computer corresponding to real halls and concert venues. The room acoustical parameters have been measured according to the ISO 3382-1 (ISO3382-1, 2009). The solo musicians have been recorded via a single microphone and the rooms have been simulated via a dynamic binaural synthesis.

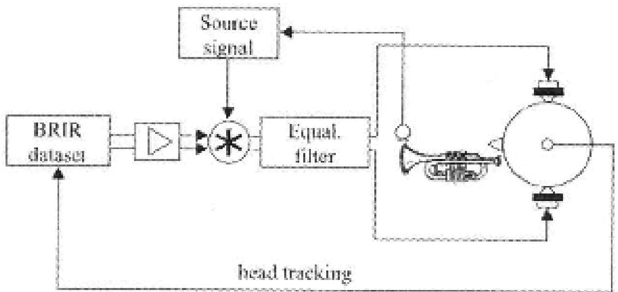

Figure 1: Technical setup of the experiment. It denotes the convolution of the source signal and sound level-calibrated BRIR (Schärer-Kalkandjiev, 2015)

From the audio recordings the performance attributes have been extracted. A hierarchical linear model has been used to investigate the effect of the played instruments (violin, cello, clarinet, bassoon, trumpet, trombone), the rooms and the musical content (3 Levels). The variance for each level has been calculated separately. The results have shown that the reverberation has a significant effect on the tempo chosen by musicians. None of the room parameters had a significant influence on the performance attributes: "Agogic" and "Dynamic strength" and only the cellists increased their strength of playing for very dry and reverberant rooms. The musicians on average played softer (timbral parameter) in rooms with high Early sound strength (G_e) and harder in rooms with high Bass strength (G_{125}). Furthermore the Bass strength (G_{125}) had greater effect on the musician's performance than the bass ratio (BR) in most cases and hence Bass strength (G_{125}) can be used as a better predictor to describe the timbral properties of a room for musicians on the stage.

4 Groundwork

Within the second and third part of the study by Eric Stahnke (2013) and Schärer and Weinzierl (2015), solo musicians have been interviewed and their performance have been recorded in virtual rooms (via dynamic binaural synthesis). The acoustical parameters (independent variables) have been extracted from the room models. From the surveys evaluated by 12 musicians the subjective room parameters (items, dependent variables) have been extracted.

4.1 Second experiment

In this experiment by Eric Stahnke (Stahnke, 2013) the 8 acoustical parameters: Reverberation time (RT), Early decay time (EDT), Early support (ST_{Early}), Late sound strength (G_l), Clarity (C_{80}), Late support (ST_{Late}), Early sound strength (G_e) and Bass ratio (BR) have been extracted from the room impulse responses for the 10 rooms as demonstrated in the following table:

Room	**Modeled from**	**Comment**	**V** $[m^3]$
Chamber 1	Concert house (small hall) Berlin		2380
Chamber 2a	Brahmssaal, Vienna		3233
Opera house	Opera Garnier, Paris		14862
Concert hall 1a	De Doelen Concertge- bouw, Rotterdam		21661
Concert hall 2	Stadtcasino, Basel		10262
Church a	Dom St. Stephan, Passau		12530
Church b	see Church a	Church a with a shorter T_{20} and a varied frequency response	12530
Chamber 2b	see Chamber 2a	Chamber 2a with a shorter T_{20} and a varied frequency response	3233
Concert hall 1b	see Concert hall 1a	Concert hall 1a with a shorter T_{20} and a varied frequency response	21661
Theater hall(TJV)	Theatre Jean Vilar, Vitry-sur-Seine		11176

Table 1: Modeled rooms via *EASE* in the second experiment

and from the surveys evaluated by musicians, a three dimensional Matlab matrix has been made which included lines with 20 rated items, which are shown in Table 2.

These items varied between -5 and 5 from right to left. For instance a room with reverberation which sounded soft, would have the rate of +5 and a hard one would be -5. The columns of the matrix specified the musicians which were shown in Table 2 and the third dimension specified the rooms in Table 1. Table 3 shows the instruments played by musicians.

Description (the question in surveys in German)	**Item (subjective acoustical parameter in english (+5 —0— -5)**
Trägt der Raum das Spiel oder nicht?	Play stability (more-less)
Können Sie Ihr Instrument gut hören?	Self listening (good-bad)
Hat der Raum einen langen oder kurzen Nachhall?	Reverberance (long-short)
Kommt der Raumklang gleich oder verzögert?	Room delay (early-late)
Handelt es sich um einen groen oder kleinen Raum?	Room size (big-small)
Gefällt die Akustik oder nicht?	Room acoustics (good-bad)
Wirkt der Raum niedrig oder hoch?	Room height (high-low)
Wirkt der Raum breit oder schmal?	Room width (wide-narrow)
Wie ist die Klangfarbe des Raums, des Nachhalls?	Timbre (dark-bright)
Wie ist die Balance zwischen Instrumen und Raumklang?	Instrument and room balance (much room-less room)
Hilft der Raum beim Spielen?	Play support (supportive-not supportive)
Nehmen Sie Ihr Instrument laut oder leise wahr?	Instrument loudness (loud-quiet)
Ist der Raumklang durchmischt oder klar?	Room sound (diffuse-clear)
Hat der Raum einen dünnen oder vollen Klang?	Timbre (lean-full)
Wirkt der Raum weich oder hart?	Timbre (soft-hard)
Hat der Raum einen dumpfen oder eher einen metallischen Klang?	Timbre (round-metallic)
Wie klingt der Nachhall aus?	Reverberation (soft-hard)
Bietet der Raum ein in sich stimmiges Gesamtbild?	General sound of the room (balanced-not balanced)
Bleibt die Klangfarbe im Nachklang gleichmäig oder schwankt sie?	Timbral stability (even-fluctuated)
Wie ändert der Nachklang im Verlauf seine Klangfarbe?	Reverberation of timbre (sharp-dull)

Table 2: Items explained

Musician	Played instrument
VP 1	Violin
VP 2	Violin
VP 3	Clarinet
VP 4	Violin
VP 5	Cello
VP 6	Trumpet
VP 7	Bassoon
VP 8	Trumpet
VP 9	Trombone
VP 10	Cello
VP 11	Violin
VP 12	Cello
VP 13	Oboe
VP 14	Oboe

Table 3: Instruments played by musicians in the second experiment

4.2 Third experiment

In this experiment by Zora Schärer-Kalkandjiev (Schärer-Kalkandjiev, 2015) the 10 acoustical parameters: Early decay time (EDT), Reverberation time (RT), Clarity (C_{80}), Strength (G), Early support (ST_{Early}), Late support (ST_{Late}), Early sound strength (G_e), Late sound strength (G_l) , Bass ratio (BR), Strength by 125 Hz (G_{125}) have been extracted from the room impulse responses for the 14 rooms as demonstrated in the following table.

Abbr.	Purpose	V [m^3]	A_{stage} [m^2]
CHA1	Chamber hall	2300	56
CHA2 a/b	Chamber hall	3200	85
CHU a/b	Baroque church	12500	55
CON1 a/b	Concert hall	21700	109
CON2	Concert hall	10300	186
OPR	Opera	14900	97
ANC	Chamber hall	5700	83
GGA	Concert hall	12600	108
PLE	Historical concert hall	900	29
TJV	Theatre	11200	67
WMH	Chamber hall	2800	32

Figure 2: Abbreviation, purpose, volume and stage area of the simulated concert spaces (from the laboratory study). The affix a/b denotes the halls generated with two different versions of absorption properties. (Schärer-Kalkandjiev, 2015)

The acoustical parameters were calculated for 6 octave bands (from 125 Hz to 4000 Hz). Afterwards, from the surveys evaluated by musicians, a three dimensional Matlab matrix has been made with lines with 20 rated items (as in the second experiment) by 12 musicians as shown in table 4.

Furthermore, the interviews (12 musicians x 14 rooms) have been summoned in the form of a text file for this experiment and will be analyzed via a qualitative method.

Musician	**Played instrument**
VP 1	Cello
VP 2	Bassoon
VP 3	Cello
VP 4	Bassoon
VP 5	Trumpet
VP 6	Trumpet
VP 7	Trombone
VP 8	Clarinet
VP 9	Violin
VP 10	Trombone
VP 11	Clarinet
VP 12	Violin

Table 4: Instruments played by musicians in the third experiment

5 Methods

There is a tendency for the musicians who play the same instrument to judge a room in a more similar way. Also each musician has a preference in terms of room acoustics depending on which classical school of playing they come from. The musicians mostly develop performance habits in similar environments such as an orchestra hall or a chamber etc. Furthermore, each room seems to have a semi-similar influence on the ratings of the musicians therefore, to investigate these similarities, a 3 level analysis has been chosen to process the data. First level will be the musicians, second the rooms and third will be the instrument which was played. So via a HLM method, the effect of room acoustic parameters (independent variables) on each item (subjective room parameters rated by musicians, dependent variables) will be analyzed.

The data from the third experiment will be also proved with a MANOVA as Eric Stahnke did with the data from the second experiment. The reliability of the two experiments will be judged by calculation of intraclass correlations of the statistical model. To find the relations between the items and the acoustical parameters the correlation coefficients will be calculated via IBM SPSS and the results will be interpreted significantly. A power analysis could complete the analysis to judge the results and support the further studies. Another approach would be to switch the level 2 (room) with Level 3 (instrument) and for each model, the explanatory power (pseudo-R2) could be calculated and the model with the higher one will be considered as a better model to chose for the results. Ultimately, A qualitative content analysis of the interviews from the third experiment will support the results.

6 Timetable

Table 5: 1. November 2016 till 1. May 2017

Step	**Time**
Preparation	3 Weeks
Statistical data processing	4 Weeks
Results analysis	5 Weeks
Qualitative evaluation of interviews	3 Weeks
Improvement of acoustical parameters	3 Weeks
Writing	6 weeks

References

Baumann, Dorothea (2011): *Music and Space*. Bern: Peter Lang AG.

Dammerud, J. J. (2009): *Stage acoustics for symphony orchestras in concert halls*. Ph.D. thesis, University of Bath, Bath.

Gade, A.C. (2010): "Acoustics for symphony orchestras: Status after three decades of experimental research." In: *Proc. of the ISRA*.

Gade, A.C (2013): "Subjective and objective measures of relevance for the description of acoustics conditions on orchestra stages." In: *Proc. of the ISRA*.

ISO3382-1 (2009): *ISO 3382-1 Acoustics- Measurement of room acoustic parameters. Part 1: Performance spaces*. Tech. rep., Geneva: International organization for standardization, Geneva.

J.Hox (2010): *Multilevel Analysis*. 2nd. New York: Routledge.

Schärer-Kalkandjiev, Zora (2015): *The Infuence of Room Acoustics on Solo Music Performances. An Empirical Investigation*. Phd, TU Berlin, Berlin.

Stahnke, Eric (2013): *Über die raumakustische Wahrnehmung durch Musiker*. Master thesis, TU Berlin.

Tabata, Ronald. H Heck Scott L Thomas Lynn. (2010): *Multilevel and Longitudal Modeling with IBM SPSS*. New York: Taylor & Francis Group, Routledge.

Weinzierl, Zora Schärer-Kalkandjiev & S. (2013): "The influence of room acoustics on solo music performance: An emperical investigation." In: *Acta/Acoustica*, pp. 433–441.

Zwicker, Eberhard and Fastl, Hugo (2007): *Psychoacoustics: Facts and Models*. 3th edition. Berlin, Heidelberg: Springer-Verlag.