PERCEIVED INFLUENCE OF CHANGES IN MUSICAL INSTRUMENT DIRECTIVITY REPRESENTATION

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ABSTRACT

The directivity representation of musical instruments in room acoustic simulations has shown to be significant in the distribution of the calculated acoustical parameters in a room. Different directivity representations of musical instruments were used to create pairs of room acoustic auralizations in order to test for perceived changes in the sound. Listening tests were designed and conducted with an emphasis on the perception of the acoustical attributes of room simulations. Results show that changes in the directivity representation of the source can influence the perceived sound in auralizations and that these perceived changes are more pronounced in terms of loudness and reverberance

1. INTRODUCTION

The radiation of musical instruments has been studied mostly considering frequency averages of the directivity over the performing pitch range of tones [1]. Recent studies have shown that the directivity of musical instruments change, in each frequency band, for different tones played [2, 3, 4] and investigations using room auralizations have shown that changes in the directivity of sound sources can be audible by a listener in a room [5]. The aim of this study has been to investigate the perceptual importance of the changes in the directivity of musical instruments in a room using room acoustic simulations as the reference.

2. DIRECTIVITY MEASUREMENTS

2.1. Method

The instruments used for the directivity measurements were a trumpet, a Bb clarinet and a French horn. The instruments were measured at a similar musical intensity using a simultaneous 13 channel setup in an anechoic chamber, at steps of 45° in the horizontal and vertical axes, 24-bit quantisation, 44.1 kHz sampling rate, in octave bands from 125 to 8000 Hz, and at a distance of 1.5 meters from the physical centre of the source. Short samples of isolated tones over the whole pitch register were used to build the averaged directivity at different octave bands and also to obtain specific directivities for particular tones in the same octave bands.

2.2 Results

Measurements showed variations between the directivities of individual tones in a given octave band. These variations were greater for the clarinet and the French horn than for the trumpet. Figure 1 and 2 show the measured directivities for three specific tones and the calculated averaged directivity over the whole pitch range at the 1000 Hz octave band. Results are shown for both, the horizontal and vertical axes.

3. DIRECTIVITY IN A ROOM

3.1. Room acoustic simulations

As a way to investigate how the changes of the directivity for the studied musical instruments affect the sound in a room and relate these changes to the perceived changes in auralizations, room simulations were carried out with one specific measured directivity and the calculated averaged for each instrument. The simulations were done using the software ODEON [6], assuming the same sound power for the sources, in a model of the Elmia concert hall in Jönköping, Sweden. The acoustical parameters considered for the simulations were the sound pressure level (SPL), the clarity factor (C80), the lateral energy fraction (LF80), and the early decay time (EDT). Two different directivity representations were used for each instrument as a basis of comparison for the simulations: a particular directivity of the instrument when playing a specific tone and the octave band averaged directivity over the whole pitch performing range. The specific tones selected for each instrument were: C4 for the trumpet, B3 for the French horn and C#4 for the Bb clarinet.

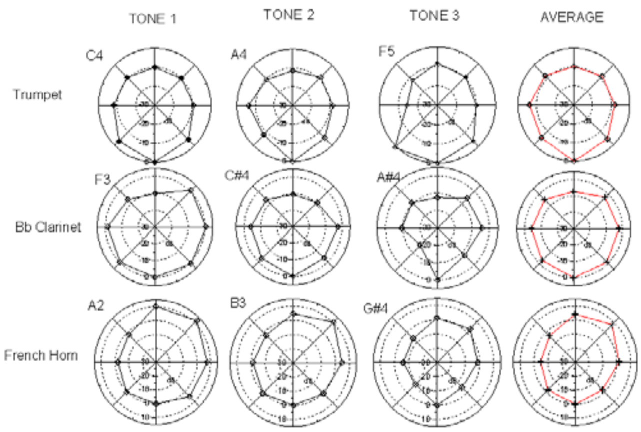

Figure 1: *Specific and averaged directivities for the trumpet, the clarinet and the French horn at the 1 kHz octave band in the horizontal axis. The fronts of the instruments are facing downwards, and in the case of the French horn, the bell is facing right. The averaged directivities correspond to the average over the whole pitch performing range of the instrument.*

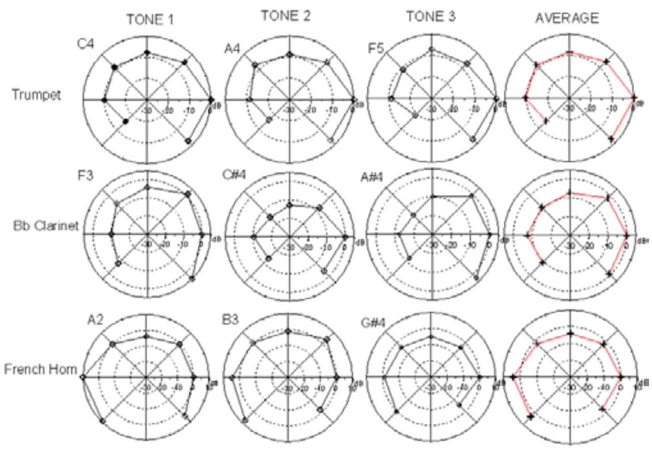

Figure 2: *Specific and averaged directivities of the trumpet, the Bb clarinet, and the French horn at the 1 kHz octave band in the vertical axis. The right sides of the figures correspond to the fronts of the instruments. The averaged directivities correspond to the average over the whole pitch performing range of the instrument.*

3.2. Results

The results of the room simulations indicate distinctive sound distributions in the room that can be linked to the original directivities of the instruments. Figure 3 shows grid-responses of the SPL in the 1000 Hz octave band simulated in the hall for the three instruments using the directivity of a specific tone and the averaged directivity over the whole pitch performing range. The difference in the spatial distribution of the acoustical parameters in the room showed to be greatest for the SPL and C80, less pronounced for LF80, and negligible for the EDT.

In order to compare the magnitude of the acoustical parameters at a certain position, for each instrument, with the two directivity representations, a location in the audience was chosen at 9 m from the source, 3 m to the right of the central axis of the hall. This position was also considered for the listening tests with auralizations in the final stage of the study.

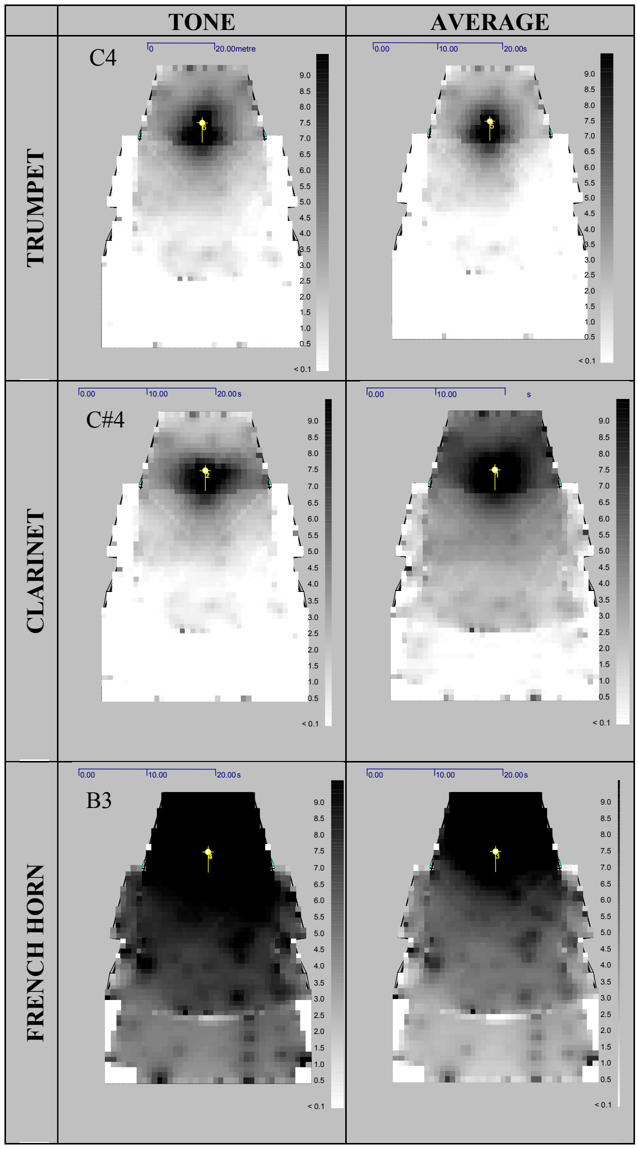

Figure 3*: Grid-responses of the sound pressure level produced by the three musical instruments in the 1 kHz octave band, simulated in the Elmia concert hall with the directivity of a tone and the averaged directivity. The scale is relative and shown from 0 to 10 dB with white and black as the minimum and maximum values, respectively.*

Table 1 shows the results in three octave bands of the simulation of the acoustical parameters at the selected position in the room for each directivity of the three instruments. In most of the cases the results of the comparisons proved that there existed a considerable difference in the acoustical parameters for the different directivity representations. As in the spatial distribution of the acoustical parameters, the difference are greater for the SPL and the C80, less noticeable for the LF80, and minor for the EDT.

Trumpet						
Frequency (Hz)	**500**		**1000**		**2000**	
Directivity Representation	C4	Average	C4	Average	C4	Average
SPL (dB)	13.7	6.7	8.6	6.8	7.2	6.6
C80 (dB)	0.1	0	1	2.1	2.8	2.0
LF80	0.28	0.20	0.14	0.2	0.16	0.18
EDT (s)	1.78	1.79	1.60	1.52	1.36	1.41
Bb Clarinet						
Frequency (Hz)	**500**		**1000**		**2000**	
Directivity Representation	C#4	Average	C#4	Average	C#4	Average
SPL (dB)	1.3	7.1	2.8	5	7.4	7.4
C80 (dB)	3.6	0.3	1.9	1.6	0.2	2.1
LF80	0.10	0.21	0.10	0.19	0.16	0.17
EDT (s)	1.29	1.82	1.49	1.58	1.54	1.4
French Horn						
Frequency (Hz)	**500**		**1000**		**2000**	
Directivity Representation	B3	Average	B3	Average	B3	Average
SPL (dB)	4.2	4.4	9.7	7.3	15	4.3
C80 (dB)	0.8	0.8	-0.3	-0.1	-0.5	1.2
LF80	0.16	0.17	0.22	0.21	0.32	0.17
EDT (s)	1.79	1.79	1.97	1.92	1.77	1.61

Table 1: *Room Acoustic parameters simulated for the three musical instruments in the position of the listener.*

4. LISTENING EXPERIMENTS

4.1. Method

Listening experiments were designed with the goal of testing the audibility of differences between the two directivity representations of each instrument. Using the software ODEON [6] pairs of room acoustic auralizations were created using these directivity representations in the previously described position in the Elmia concert hall. Short melodies of approximately 10 s played on the three musical instruments were recorded anechoically and used for the comparisons in the listening tests.

A forced choice paired comparison method was used for the listening tests, which consisted of eleven test subjects. The subjects were presented with pairs of auralizations, created for each of the instruments, through Sennheiser HD 250 headphones. After a training session the listeners were asked to make a qualitative comparison between the two auralizations and select one according to five perceived acoustical features: loudness, perceived reverberance in the hall, clarity, ease of source localisation and naturalness of instrument timbre. Each of the comparisons was tested twice as a part of a balanced random test sequence.

4.2. Results

The results of the experiments were first analysed using the McNemar test in order to determine the level of randomness of the data [7]. This method was used to separate the data provided by test subjects who were inconsistent from those who were consistent in their answers. A test was also used to determine which results were statistically significant compared to a threshold of 0.95 [8].

The results of the three instruments were analysed separately for each of the five parameters. Table 2 shows the significant results according to the McNemar test.

Instrument / Parameter	**Trumpet**	**Bb clarinet**	**French Horn**
Loudness	C4	Average	B3
Reverberance	C4	Average	No preference
Clarity	No preference	No preference	B3
Localization	No preference	No preference	No preference
Timbre	No preference	No preference	No preference

Table 2: *Statistically significant results of the listening tests, according to the McNemar test. The directivity pattern that was found to be "favoured" for each parameter is shown as the average directivity or the directivity of a tone. In the cases where no conclusions could be made from the analysis, "No preference" is stated.*

As shown in Table 2, the results show that all test subjects could hear a difference in loudness between the two compared auralizations. The audibility of the changes of in reverberance proved to be significant for two of the three instruments and the audibility of the clarity was significant only for the French horn. The audibility of differences in timbre and the localisation of the source did not prove to be significant.

4.3. Discussion

The results of the listening tests have shown that there are changes in the directivity representation that were perceived by the listeners. Comparing the results of the simulation of the acoustical parameters of Table 1 with the results of the listening tests of Table 2, one can see that the only parameters that proved to have the same general tendencies in both cases were the sound pressure level and the loudness. The comparison between the results for the perceived reverberance and the simulated EDT showed some correspondence that could also be linked with the SPL. However these comparisons between the subjective reverberance parameter and the calculated EDT parameter are unclear due to the EDT fluctuating across frequency bands. The level of the sound could have helped the subjects to hear better the sound decays in the room. The discrimination of the clarity of the listening tests for the French horn did not prove to be strongly correlated with the simulations of the C80 in the room. Not much information can be obtained from the other simulated acoustical parameters that could be related to the results of the listening tests.

5. CONCLUSIONS

Room acoustic simulations using averaged and specific directivities of tones of musical instruments have shown that the directivity has a direct influence on the distribution of acoustical parameters in a room. Listening tests with auralizations using different directivity representations showed that the directivity changes were mostly audible in the perceived loudness and that some of these results could be correlated to the simulated acoustical parameters in the room. Further investigations could consider alternative types of directivity representation where the changes of the directivity of the source could be considered as in a performance situation.

6. AKNOWLEDGMENTS

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