Noise exposure of musicians: the own instrument's sound compared to the sound from others

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Summary

The noise exposure of symphony orchestra musicians has many different contributions. While playing in the orchestra, measurement devices cannot discriminate between different contributions of different sound sources. When playing at home, rehearsing individually, the own instrument's sound is amplified by the room differently. To investigate how much sound is received from one's own instrument compared to all others in the orchestra, a model is used that calculates the contribution of direct, early and late reflected sound on the noise exposure. Besides looking at the full orchestra rehearsal, a hypothetical case is investigated where one is individually playing the same musical score at home in a small rehearsal space with 8 m^2 of sound absorption. In the calculations for the home rehearsal case, silent parts longer than 2 seconds are removed from the input data. Then, the sound level is calculated for the same amount of rehearsal time as for playing the full piece during orchestra rehearsal, resulting in a higher exposure for the same period. The outcome of the model shows, for two examples of musical pieces of 2 to 3 minutes duration, that during orchestra rehearsal the other orchestra members contribute more to the total noise exposure than the own instrument for all instrument groups, with a difference varying from 2 dB(A) up to more than 10 dB(A), depending on the musical instrument and piece. This suggests, that the contribution of the own instrument may play a minor role during full orchestra rehearsal. The total noise exposure during individual rehearsal is 4 dB(A) lower that during orchestra rehearsal for the same amount of rehearsal time, averaged over all instruments. This suggest that, even though individual rehearsal causes more noise exposure from the own instrument than during orchestra rehearsal, the total noise exposure during orchestra rehearsal is still the highest.

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1. Introduction

The amount of noise exposure of symphony orchestra musicians has many different contributions. Some contributions are musically based, like the different musical pieces played and the amount of time rehearsed at home or playing in an orchestra. Other factors are acoustically based, like the impact of the amplification of sound by the room and the contribution of the various sound sources tot the total exposure (the own instrument and that of others). It is important to understand the contribution of each aspect to be able to point out the mayor factors in the total sound exposure that a musician endures during his professional career.

In an attempt to do so, noise exposure measurements have been performed by many researchers to find the most contributing factors (for example [1]). However, while playing in the orchestra, measurement devices cannot discriminate between different contributions of different sound sources or different acoustical factors. For instance, when playing at home, rehearsing individually, the own instrument's sound is amplified by the room differently than in a large rehearsal room or concert hall. Also, it is impossible to isolate the contribution of the various instrument groups from a single sound level measurement.

To investigate how much sound is received from one's own instrument compared to all others in the orchestra, in this paper, a model is used, based on

calculations of the direct, early and late reflected sound from each source to each receiver.

Besides looking at the full orchestra rehearsal, a hypothetical case is investigated where one is individually playing the same musical score at home in a small rehearsal space.

2. Method

A calculation model is used to estimate sound levels in the orchestra. The full model is explained in [2] and it is recommended to read this paper for details about the calculations.
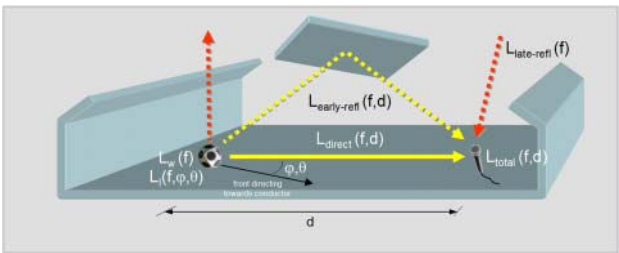

Figure 1: summary of the calculation model [2]

To summarize, see figure 1, the direct sound L_{direct} is calculated based on the sound power, source directivity, distance, absorption of objects in the sound path and the HRTFs of the listener's ears. The amount of reflected sound $L_{early-refl}$ and $L_{late-refl}$ is estimated based the sound power of the musical instrument and measured values of $ST_{early,d}$ and $ST_{late,d}$ [3]. For the direct sound of the own instrument, the distance between the estimated acoustical centre of the instrument and the ear is used together with the sound power and directivity. The model for the direct sound level of the own instrument has been validated by measurements, showing an average deviation of 1.7 dB(A). The sound power of the instruments is derived from anechoic recordings of a Mahler Symphony no. 1 sample (2:12 min) and a Bruckner Symphony no. 8 sample (1:27 min). The calculations have been performed for the left ear only and for a 2,500 m^3 rehearsal room as described in [4] using the orchestra layout as presented in figure 2.

In the calculations for the home rehearsal case, it is assumed that musicians skip long silent parts. Silent parts longer than 2 seconds are removed from the anechoic recordings, corresponding to one 4/4 measure at 120 bpm. Then, the sound exposure level is calculated for the same amount of rehearsal time as for playing the full piece during orchestra rehearsal, resulting in a higher

exposure for the same period. Besides, the sound exposure is also increased by the amplification of the room. For a diffuse sound field, the amplification of the room can be estimated by the sound power L_w and the amount of absorption A by $L_{p,diffuse} = L_w + 10$ log (4/A). In this paper, a room with 8 m^2 sound absorption was assumed for most musicians. Except for the percussion players an amount of 16 m^2 of sound absorption was assumed. The total sound level in the home rehearsal case is estimate from the summation of direct and diffuse sound.
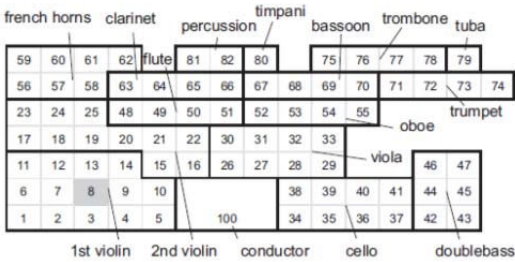

Figure 2. Orchestra layout for the calculation model

3. Results

3.1 Self relative to others

It has been suggested that the sound exposure level by the own instrument can be extracted from recordings made close to the player's ears [1]. Schmidt observed a clear increase in sound level when the player was active. However, it is uncertain whether the increase in sound level was caused by the own instrument or the sound produced by the whole section playing simultaneously. To investigate this uncertainty, the sound exposure by the own instrument is compared to the sound exposure by the own section members (averaged over all positions in the orchestra) using the calculation model.

As shown in figure 3, calculated differences between the section and the own instrument (self) are up to 7 dB, making separate own instrument level measurements difficult. Except for the high strings players, the section is 3 to 4 dB softer than single own instrument. Even under these conditions, it might not be possible to determine the own instrument's sound exposure independently during full orchestra playing.

Figure 3 and 4 also show the level difference between all other players and one's self for both musical excerpts respectively. Calculated results indicate that the average sound exposure per

section, caused by the other players including the own section members, is always higher than the sound exposure caused by the own instrument. For the high strings, the difference is 2 to 3 dB for the Mahler excerpt and up to 8 dB for the Bruckner excerpt. For the low strings, the difference may reach up to 19 dB. For the brass, woodwinds and percussion, the total of the neighboring instruments are 3 to 10 dB louder than the own.

In terms of noise exposure measurements, these calculated results do not necessarily mean that the measurement of the own sound level would not be possible due to the contribution of the other players, because playing will not always overlap.
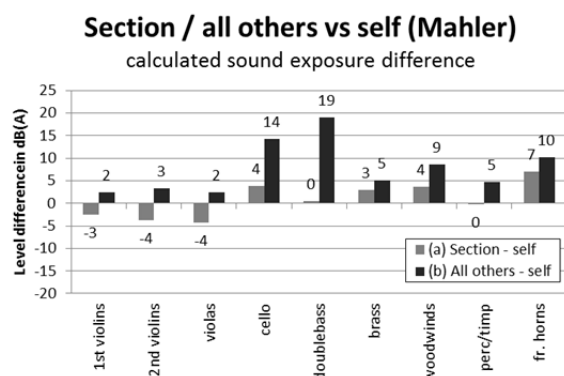

Figure 3. For every orchestra section, the level difference in dB(A) between (a) the section and self (=own instrument) and (b) all other players and self for the Mahler excerpt.
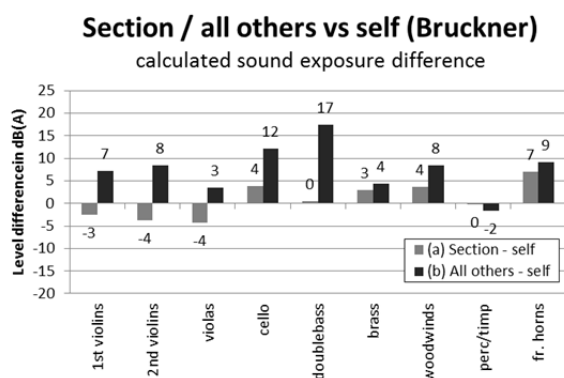

Figure 4. For every orchestra section, the level difference in dB(A) between (a) the section and self (=own instrument) and (b) all other players and self for the Bruckner excerpt.

3.2 Own instrument: home versus orchestra

The results from the calculation model suggest that, for these musical excerpts, most of the sound exposure is caused by the other players in the orchestra, both in the own section and other

sections. However, this does not necessarily mean that during orchestra rehearsal, noise exposure levels are higher than during home rehearsal. Figure 5 shows the increase in equivalent sound pressure level by playing the same score, but without silent parts (while assuming that the player does not adept his playing style to the room). Difference may reach up to 8.5 dB.
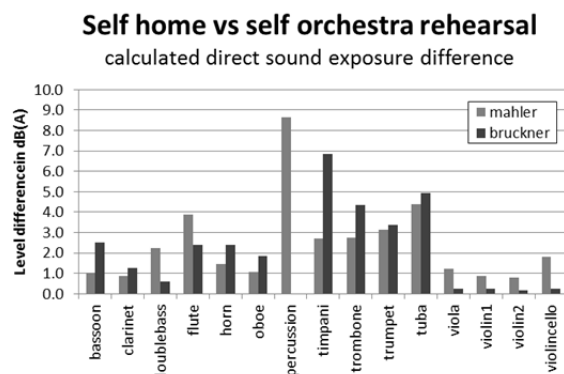

Figure 5. For the Mahler Symphony no. 1 sample and the Bruckner Symphony no. 8 sample, the increase in A-weighted sound level is shown when excluding all silent parts longer than 2 seconds (corresponding to one 4/4 measure at 120 bpm).
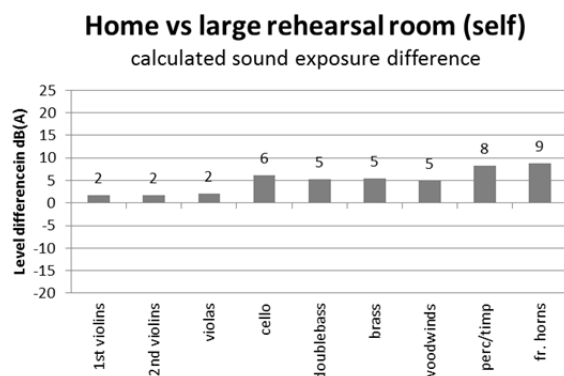

Figure 6. The increase in A-weighted sound level is shown for the own instrument sound (=self), when rehearsing the same musical piece at home without breaks instead of rehearsing in a large rehearsal room (in the hypothetical case without the rest of the orchestra playing).

Besides the increase in sound exposure of the own instrument due to the skipping of silent parts, the sound exposure is also increased by the amplification of the room. Figure 6 shows the combined effect of increased sound exposure by excluding silent parts and by amplification of a room with 8 m^2 sound absorption (except for the

percussion players an amount of 16 m^2 of sound absorption was assumed). Results show that, for the sound exposure of the own instrument, the sound exposure level can increase by 2 dB for the high strings, and up to 9 dB for the French horns.

3.3   Total exposure: home versus orchestra

Now we have estimated the noise exposure level while playing at home, it is possible to compare the noise exposure for the same musical piece played at home and played in a full orchestra inside a large rehearsal room. Figure 7 shows the difference between orchestra rehearsal and home rehearsal. Results are presented for the left ear only, and calculated results for the right ear did not differ more than 1 dB for all sections.
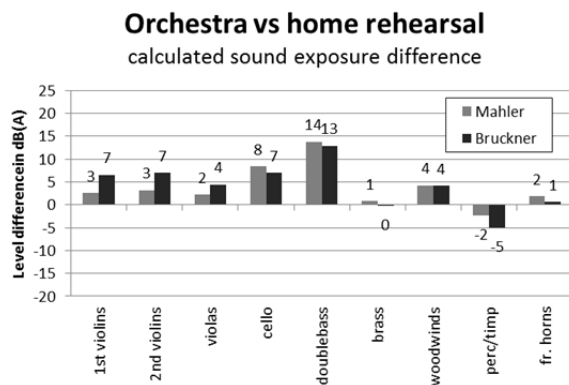

Figure 7. The difference in A-weighted sound level between home rehearsal and orchestra rehearsal for the Mahler Symphony no. 1 sample and the Bruckner Symphony no. 8 sample.

Calculated results based on two musical pieces, for playing in an orchestra instead of playing at home, for the same amount of time, show that:

- the high strings have sound exposure levels 2 to 7 dB(A) higher, mainly caused by the loud instruments in the orchestra (not strings);
- the double basses have sound exposure levels up to 14 dB(A) higher. Such large differences are partly caused by the fact that the A-weighting filters out their low frequencies. However, additional C-weighted calculations still showed a level difference up to 9 dB;
- the brass and French horns sections appear to be equally exposed (brass represents the average value for trumpet, trombone and tuba);
- the woodwinds have a 4 dB higher noise exposure (average value for the flute, clarinet, bassoon and oboe);

- the timpani and percussion players are 2 to 5 dB less exposed.

4.   Conclusions

In this study, the noise exposure of the own instrument has been compared to the noise exposure due to other instruments in a symphony orchestra for two musical excerpts. Results from calculations using a prediction model suggest that:

- the difference in noise exposure level of the other instruments in the same section and the own instrument is -4 to 7 dB. This suggest that it might not be possible to measure the own instrument's noise exposure when the full orchestra is playing.
- the noise exposure level of the own instrument is 2 to 9 dB higher when playing at home without pausing instead of playing in a large rehearsal room (with individual pauses).
- even though the noise exposure of the own instrument is less when playing in the orchestra, the total sound exposure can be considerably higher for string and woodwind players. For brass players, the noise exposure can be similar in both conditions, while for the timpani and percussion players the noise exposure can be less when playing in the orchestra.

References

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