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4aNSa8. Sound quality in small music classrooms
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Good conditions for teaching, learning and practicing a musical instrument are crucial for a musician's progress. Small rooms for teaching and practicing musical instruments have specific requirements about acoustic performance and strong influence on the perception of the users. Acoustical problems in music classrooms may cause difficulties for teachers to identify mistakes from the young students' performance other than those originated from the room itself. For this paper, three music classrooms were evaluated according to reverberation, background noise and airborne sound insulation between rooms. Thus, reverberation time (RT), background noise level and standardized level difference (DnT), as a function of frequency and according to ISO 3382-2:2008 and ISO 140-4:1998 standards, were measured and judged. As some results have disagreed from literature recommendations, the main faults of each room were highlighted, considering the type of instrument that is taught, and suggestions for acoustic adjustment were made.

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INTRODUCTION

In order to have outstanding musical performances, good conditions for practice and learning a musical instrument are crucial for a musician’s progress. Rooms for these activities are widely used by musicians to improve their performances. A music student practices more than forty hours a week, and the quality of what is being heard is crucial for the musician’s progress. Thus the acoustics of rooms for learning and practicing music is of great importance for the development of a good musician. Regarding this subject, Koskinen et al., (2010) indicate that a good sound insulation, a short reverberation time and a good distribution of reflections are prerequisites for small music venues.

Rooms for teaching and practicing music may vary in size and usage and can accommodate only one student or an ensemble. A good acoustic treatment must allow music instructors to efficiently teach concepts as intonation and dynamics, for example. According to Osman (2010), acoustical problems in music classrooms may cause difficulties for teachers to identify mistakes from the young students performance other than those originated from the room itself. Paek et al. (2003) argue that an adequate volume, absorbent materials and strategically placed sound diffusers, arranged with the purpose of helping students and teachers to hear each other, are necessary for a satisfactory room.

In Brazil, there are no standards or recommendations, regarding acoustics, addressed specifically for music classrooms, therefore, it is necessary to consult publications that indicate values and parameters favorable to good acoustics for these environments. Because there are differences in the acoustical needs for these rooms, depending on the type of instrument to be executed, such as percussion, wind or strings, the parameters suggested may vary depending on the needs and purposes assigned to the room. The reverberation, for example, can be detrimental for some instruments, but advantageous for others. Osman (2010) indicates some recommendations about the Reverberation Time (RT) for music classrooms and shows that this parameter varies depending on the instrument. The recommendations indicate that the ideal RT can vary from 0.3 to 0.9 seconds depending on the instrument to be studied. It is also suggested a short variation in RT values between frequencies when applying absorptive materials. There should be a difference within 10% of the target Reverberation Time for the 250 Hz to 2000 Hz octave bands, with an increase in low frequency RT and a decrease in high frequency RT.

Regarding insulation between rooms, Lamberty (1980) shows that, for students, the most annoying noises are traffic and other people practicing their instruments. Among them, the noise of people playing the same instrument is the most disturbing. The author suggests the use of ventilation noise, which is continuous and therefore less discomfort to mask noise from other people practicing music. He also alerts to the spatial organization so that practicing rooms of similar instruments are apart from each other.

It is clear the importance of good acoustics and insulation in rooms for teaching and practicing of music. However, Brazilian reality shows that a great number of music classrooms are not suitable for this purpose. One can associate this to financial constraints of small schools, which prevent them from investing in good acoustical design and insulation for these environments.

The objective of this research is to evaluate the acoustic performance of rooms intended for teaching and practicing of musical instruments. It was analyzed three music classrooms from a music school located in Campinas/SP, Brazil. The rooms are small, with an area of approximately 10 m² to 17 m², and different acoustic conditions. They were evaluated according to reverberation, background noise and airborne sound insulation between rooms. Parameters analyzed were: Reverberation Time, Background Noise Level and Standardized Level Difference.

METHODS

The chosen music school is located on a busy avenue in the city of Campinas/SP (Brazil), and is in activity since 2005. The building was not designed to be a school; it is a commercial building that was adapted to become a music school. Figure 1 shows a drawing of the school spatial configuration. The areas marked in color indicate the evaluated classrooms. The selected rooms have different physical characteristics and are located one next to each other. Figure 2 shows pictures from the evaluated music classrooms.
FIGURE 1. Music school spatial configuration with highlight to evaluated classrooms.

FIGURE 2. Pictures of evaluated rooms.

Room 1 (Figure 2a) and room 2 (Figure 2b) are used for acoustical and electrical guitar classes and room 3 (Figure 2c) is for drums classes. Most activities are individual lessons and take place during weekdays and evenings. Table 1 shows area and volume for each room. All three are 3,0 m high.

<table>
<thead>
<tr>
<th>Rooms</th>
<th>Area (m²)</th>
<th>Volume (m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Room 1</td>
<td>15,1</td>
<td>45,4</td>
</tr>
<tr>
<td>Room 2</td>
<td>9,3</td>
<td>27,8</td>
</tr>
<tr>
<td>Room 3</td>
<td>17,3</td>
<td>51,8</td>
</tr>
</tbody>
</table>

For an objective acoustical evaluation of the classrooms, the parameters Reverberation Time (RT), Background Noise Level (Lp) and Standardized Level Difference (DnT) were measured. Reverberation Time was measured with the impulse response method, according to ISO 3382-2:2008, using Dirac Room Acoustics software from Bruel&Kjaer (B&K) with exponential sine sweep. The system includes an omnidirectional sound source B&K model 4296, a power amplifier B&K model 2716, a sound level meter B&K model 2238, which was used only as a microphone to capture sound signal, and a sound interface Digigram model VX Pocket V2.

The Background Noise Level was measured using a sound level meter B&K model 2238². Parameter Standardized Level Difference (DnT) was calculated according to ISO 140-4:1998, from the measurements of Sound Pressure Levels L₁ (source room) and L₂ (receiver room) using white noise with the 2260 Investigator from B&K and the omnidirectional sound source.

In measurement of room 1, two points of sound source and four measurement points were chosen. In room 2, due to its size, two points of sound source and three measurement points were chosen. For room 3, two sound sources and four measurement points were chosen. Figure 3 shows the spatial configuration of the rooms and the location of the measuring points. In all measurements, the rooms were unoccupied, keeping only the usual furniture.

1 DIRAC 3.1® - Room Acoustics Software – Type 7841
2 Integrating Sound Level Meter – type 2238 Mediator
RESULTS AND DISCUSSIONS

Reverberation Time

Results of Reverberation Time are shown in Figure 4. The graph shows the spatial average of the measurements as a function of frequency, in 1/1 octave bands between 63 Hz and 8000 Hz.

As expected, due to little acoustic treatment of room 1, it presents values of RT above those recommended by the specialized literature (Lamberty, 1980; Osman, 2010; Koskinen et al., 2010). The majority of the guidelines presented by the authors indicates a Reverberation Time around 0.7 seconds, and can vary between 0.5 and 0.8 seconds depending on the size of the room. Room 1 is a small room with 15.12 m², which fits Lamberty's (1980) recommendation of rooms between 15 m² to 20 m² for music classes purpose. However, the lack of acoustic treatment makes the Reverberation Time reaches 1.3 s in 125 Hz, which is quite high for a frequency present in most musical instruments.

In room 2, conditions for measurement were a little less favorably due to its small dimensions. In addition to the carpet on the floor, the walls are covered with styrofoam and egg crates, which were fixed with the intention to provide some acoustic treatment in the room. The absorption coefficient of these last two materials has a very narrow bandwidth, causing little influence in the total acoustic absorption of the room. Room 2 presented a quite satisfactory result for the parameter Reverberation Time. The total area is only 9.25 m², which makes the early reflections very close in the time domain. It can also be noted in Figure 4 a small variation in RT between frequencies in this classroom. At 8000 Hz the value is around 0.3s and the maximum value, at 125Hz, is 0.7 s. In comparison, the variation in room 3 between the RT maximum and minimum reached 2.3 s.

Room 3 is the largest of the three rooms evaluated and also has an adjacent space, used as a deposit that has a considerable influence in the results according to the positions of the student and the teacher. This room is used for drums classes, which generates a high sound pressure level and wide frequency response. With the purpose of
controlling the Reverberation Time in the room, there are foam boards on almost every wall, but nothing was made

to control or minimize the lower frequencies reflections.

Room 3 presented the higher variation in RT between frequencies. Reverberation Time for frequencies above

500 Hz, is below the recommended by Lamberty (1980). At frequencies below 125 Hz we can see an elevation in

reverberation time much higher than the guidelines proposed by literature (Lamberty, 1980; Osman, 2010; Koskinen

et al., 2010). As the room is designed for drums rehearsals, which has a wide frequency bandwidth, it can be

concluded that the auditory sensation caused by the absorption in high frequencies shows an unbalance between high

and low frequencies. The adjacent area (small deposit) sums its volume to the room, generating the elevation of the

RT in low frequencies. Room 3 is almost entirely coated with foam, which reflects in the low value of RT in the

frequencies above 500 Hz.

By comparing the values of RT in the middle frequencies with some values recommended by foreign standards,

indicated by Osman (2010) and shown in Table 2, it can be noticed that only room 2 reaches the recommended

values. The average results of Reverberation Time (RT_{mid}^3) presented in Table 2 can cause a false impression of

adequacy, especially in room 3. However, it is important to note that lower frequencies, strongly present in drums,

are not included in this calculation.

It is strictly recommended for rooms 2 and 3 an absorptive treatment intended to reduce and Reverberation Time,

especially for low frequencies.

<table>
<thead>
<tr>
<th>RT_{mid} recommended</th>
<th>RT_{mid} measured</th>
</tr>
</thead>
<tbody>
<tr>
<td>DfES, 2002</td>
<td>Room 1 0.9</td>
</tr>
<tr>
<td>BB93, 2003</td>
<td>Room 2 0.4</td>
</tr>
<tr>
<td>ANSI S12.60</td>
<td>Room 3 0.4</td>
</tr>
</tbody>
</table>

### Background Noise

During the measurements of background noise there was no lessons in other classrooms, but it still remained the
usual movement in the reception, administration and external area of the school (such as transit or trade). Table 3
shows the mean values of background noise level measured in the rooms, in function of frequency by 1/1 octave
bands, between 63Hz and 8000Hz.

<table>
<thead>
<tr>
<th>Frequency (Hz)</th>
<th>Room 1</th>
<th>Room 2</th>
<th>Room 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>63</td>
<td>55</td>
<td>61</td>
<td>51</td>
</tr>
<tr>
<td>125</td>
<td>47</td>
<td>48</td>
<td>36</td>
</tr>
<tr>
<td>250</td>
<td>45</td>
<td>47</td>
<td>30</td>
</tr>
<tr>
<td>500</td>
<td>37</td>
<td>35</td>
<td>21</td>
</tr>
<tr>
<td>1000</td>
<td>39</td>
<td>25</td>
<td>15</td>
</tr>
<tr>
<td>2000</td>
<td>37</td>
<td>19</td>
<td>11</td>
</tr>
<tr>
<td>4000</td>
<td>26</td>
<td>14</td>
<td>16</td>
</tr>
<tr>
<td>8000</td>
<td>18</td>
<td>14</td>
<td>19</td>
</tr>
</tbody>
</table>

By comparing the results with the NC curves, available in Annex A of the Brazilian standard NBR 10152:1987,
the rooms can be classified as shown in Table 4, and then compared to the recommended values. Global Sound
Pressure Level (Lp) of background noise is also presented in the same table. The last line of table 4 shows the
recommendations that the NBR 10152 indicates to music rooms.

<table>
<thead>
<tr>
<th>Rooms</th>
<th>NC rating</th>
<th>Global Lp (dBA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Room 1</td>
<td>NC 40</td>
<td>44</td>
</tr>
<tr>
<td>Room 2</td>
<td>NC 40</td>
<td>41</td>
</tr>
<tr>
<td>Room 3</td>
<td>NC 25</td>
<td>29</td>
</tr>
<tr>
<td>NBR 10152:1987</td>
<td>NC 30 – NC 40</td>
<td>35 – 45</td>
</tr>
</tbody>
</table>

3 RT_{mid} is the mid-frequency value of Reverberation Time of the mean of the values in the octaves centred on 500 Hz, 1000 Hz and 2000 Hz.
Background noise of rooms 1 and 2 is relatively high for its activities. Regarding background noise, Lamberty (1980) indicates that the second biggest complaint of the students, after the interference of the sounds of other instruments, is about the traffic noise. The relatively high sound pressure level (Lp) can be quite uncomfortable for the activities developed in a classroom. Osman (2010) shows some recommendations for maximum levels of background noise indicated by some references, transcribed to the Table 5.

<table>
<thead>
<tr>
<th>TABLE 5. Recommended background noise levels, shown by Osman (2010)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Music activity</strong></td>
</tr>
<tr>
<td>Music classroom</td>
</tr>
<tr>
<td>Individual practice</td>
</tr>
</tbody>
</table>

Room 1 and room 2, with Lp of 44 dBA and 41 dBA respectively, exceed almost all of the proposed recommendations. The high level of noise in these environments is due to the fact that both rooms are close to the street and the administrative area of the school. These levels of noise can be very uncomfortable during music classes, disturbing the student’s concentration and performance. Room 3, showed a background noise level quite low and acceptable in all recommendations proposed by the mentioned author. By being away from noise sources (the street and the administrative area of the school), this room is more suitable for teaching and practicing of music regarding to low background levels.

The Brazilian standard NBR 10152:1987 recommends, as shown in Table 4, Lp values for music rooms between 35 to 45 dB, where the lower value represents the comfortable sound level and the higher value represents the maximum acceptable noise level. The comparison with these values indicates that room 1 and room 2 are close to the acceptable limit, both in Lp and NC classification indicated by the same standard (NC 40 for music rooms). One also can note that the minimum limit indicated by Brazilian standard is the maximum value of noise recommended by some international standards.

Room 1 shows high sound pressure levels, as seen in Table 3, especially at frequencies between 500 and 2000 Hz. These frequency bands are important for the understanding of what is being played, sung or spoken. In such kind of situation it is difficult to play or sing in tune or understand errors, since the noise in the room does not allow the proper perception of the instrument details in these frequencies. This is the room nearest the street and, therefore, suffers greater interference from external sounds.

In room 2 the background noise is more concentrated on bass frequencies, which can cause a constant annoyance in the student and the professor. One of the causes of this noise in low frequency can be associated with the busy avenue located in front of the school. This situation is hard and expansive to solve. To reduce the sound pressure level in low frequencies it is recommended double walls built through the system box-in-box. In this type of construction a second floor, ceiling and wall are constructed and mechanically disconnected from the first one through resilient material with high flexibility, such as rubbers of neoprene (due to high durability) or coil systems.

It can be said that the background noise in room 3 is almost insignificant, especially if it is considered the instrument used in this classroom. The drums reaches levels over 100 dB and the sound generated by it mask the background noise, making it inaudible. In the case of room 1 and 2 the background noise in those rooms can be very uncomfortable for music classes.

**Insulation**

Regarding insulation, it was measured the sound transmission between room 2 and the adjacent rooms. Measurements were performed to characterize the insulation of the system that separates room 1 and room 2 as well as the system that separates the room 3 and room 2. A single wall of masonry divides the first two rooms, with no significant acoustic coating apart from the plaster. A section of the division between room 2 and room 3 is composed of a single masonry wall. The side of the wall that faces room 3 has acoustic treatment with porous material and the face to room 2 is covered with styrofoam and egg crates. The application of these materials is a very common myth in Brazil as a non-professional solution intended to acoustically correct some rooms. The other section of the division between these two rooms there is a bathroom. Part of the division between room 2 and room 3 is composed of the entire constructive system of this environment. Measurements of insulation were made with the bathroom door closed, as it is normally used for music lessons.
To characterize the airborne sound insulation between the rooms, the standardized level difference ($D_{nT}$) between the rooms was calculated, as well their weighted differences ($D_{nTw}$) according to ISO 140-4:1998 and ISO 717-1:1997. Figure 5 shows the curves for $D_{nT}$ by frequency bands in 1/3 octave, with the $D_{nTw}$ value indicated on the legend.

Figure 5. $D_{nT}$ values for the evaluated rooms.

It is observed that value obtained at low frequencies is always lower than high frequencies. Although the insulation between the room 2 and room 3 is not that low, if only taken the weighted value, it is important to notice that the $D_{nT}$ between these environments for low frequencies are less than 40 dB. This indicates that much of the bass sound from the drums lessons is transmitted to room 2.

The level difference between rooms 1 and 2, in general, was smaller than the level difference between rooms 2 and 3. It is worth to point that the sound pressure level ($L_p$) generated by the instruments taught in rooms 1 and 2 is smaller than the sound pressure level generated by the drums in room 3. In the region between 125 Hz and 315 Hz, the $D_{nT}$ values are below 35 dB, which provides strong sound leakage between rooms. Whereas in room 1, if the sound pressure level produced by the electric guitar reaches 80 to 85 dB, the student who is in room 2 will hear a leak of approximately 50 dB at those frequencies. One possible solution to improve isolation between rooms is to build a second wall with drywall in each room, with the addition of mineral wool between the plates and the wall existing on both sides. This kind of construction can increase the insulation up to 15 dB.

Probably the most delicate issue regarding insulation is between room 2 and room 3. The first one seems to be very interesting regarding its reverberation time, but sound insulation between room 2 and room 3 is insufficient. Drums is an instrument of wide frequency response and can emit sound pressure levels quite high. “The percussion instruments produce average sound pressure level in excess of 100 -110 dB in the low frequencies and decreases as the frequency increases and decreases to 75-100 dB in the middle and high frequencies” (Paek et al., 2003). In that case, there is a sound leak between rooms of up to 50 dB in 1000 Hz, which can be a cumbersome in the case of simultaneous classes. This occurs because a single wall divides the rooms. If the improvement of the walls’ insulation is not possible, another solution widely used in music schools is to allocate a different room for drum lessons, away from other rooms.

It is interesting to note that, when evaluating only the value of $D_{nTw}$, the insulation between the room 2 and room 3 would be in an acceptable range of insulation. But the low performance of the insulation at frequencies below 1000 Hz is considerable, taking into account the instruments that are used in these rooms. It can be concluded that for a music practice room, it is essential to evaluate the acoustic criteria regarding the frequency bands emitted by the instrument or sound source, in opposite to the global or weighted values. This is because different frequency bands are of great importance according to different musical instruments.

**CONCLUSIONS**

This study evaluated the acoustical performance of three music classrooms regarding its Reverberation Time, Background Noise Level and Airborne Sound Insulation between rooms. It was found that for Reverberation Time only one room was adequate to its activities by presenting lower values of RT and short variation over frequency. As for the background noise, classrooms closer to the street and to the school's administrative area proved to be less adequate. Regarding insulation, all classes showed unsatisfactory values considering the levels of sound pressure
generated by musical instruments. The sound leakage between room 1 and room 2 can be uncomfortable for users since the same instruments are taught. The sound transmission from room 3 to room 2 is also a problem due to the high sound pressure level generated by the drums in room 3.

In general one can highlight the difficulties perceived by the reuse of a building. When the current activities of this building are very different from those provided by the original design is harder to fit the space, especially for a use as delicate as that of a music school. Care should be taken to the distribution of the rooms throughout the building, regarding its use. It’s also important to consider: (i) that similar instruments should not be taught in very close classrooms, (ii) instruments that generate high sound pressure level should be distant from the others; (iii) study rooms should be away from external noise sources, eg streets with heavy traffic.

It is also clear that, for all parameters considered, it is not recommended to evaluate only the global or weighted values. Since different frequency bands are critical to different musical instruments, it is important to observe the variations of these parameters as a function of frequency.

ACKNOWLEDGMENTS

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REFERENCES