Psst!
Listening Conditions in Museums for Musical Instruments

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Background: Museums for Musical Instruments

The 2022 definition by the International Committee of Museums (ICOM) describes museums as institutions offering "education, enjoyment, reflection and knowledge sharing" [1]. These four components depend on good communication between the museum, the exhibition and the visitors, so that knowledge can be shared properly. Additionally, to those aspects of museums, the ICOMs International Committee of Museums and Collections of Instruments and Music (CIMCIM) published a guide for museums focusing on musical instruments on how to make the knowledge they provide more accessible and enjoyable. The guide encourages he museums to focus not only on texts and displays but to use interactive and musical components in their exhibitions. These include acoustic display items and handling collections with a variety of musical instruments for the visitors to interact with and learn about music instruments in hands-on-situations. But also showing of musical performances through tour guides or even professional musicians playing the musical instruments on display, showcasing their sound in a way untrained staff are not able to [2].

Research Question

Due to the multiple aspects of a successful museum education in the context of museums for music and musical instruments a variety of acoustical conditions are required. This leads to the question: What are the current listening conditions in music museums and how do they compare with music and speech standards?

Methods

Due to the large number of museums dedicated to music and musical instruments, a selection had to be made. One aspect of the selection was to ensure standards in museum educational methods and practices. For this reason, only museums belonging to the German or Austrian council of museums were selected. An additional condition was accessibility from Vienna. A total of six museums are to be included in this project, three of which have already been measured and analysed.

The acoustical measurements were carried out in accordance with ISO 3382-2, using the description for precise measurements. For normal rooms, at least two source positions and at least three measurement points should be planned. A total of twelve source-measurement combinations should be achieved. For larger and more complex rooms, more source positions and measurement points should be considered [3]. Source positions were planned at positions of interactive or playable displays and measurement points at possible visitor positions in the rooms. For portability, regular balloons were used as impulse source by popping them. For larger rooms the balloons were inflated to a bigger size to achieve clearer results in the low frequencies. Behringer ECM-8000 microphones were used for the Berlin Museum of Musical Instruments and the Deutsches Museum in Munich, while Esper K4 microphones were used for the Vienna Museum of Science and Technology.

The room impulse responses were analysed using the "Aurora" plugin for "Audacity" by Farina and Campanini [4]. The room volumes were calculated from measurements and room plans provided by the museums. The sound strength G was calculated from the formula for the theoretical sound strength G_{Theo} using the mean reverberation time and the room volume. In addition, the maximum distance for an AL_{CONS} of 8.5 % was calculated as an indication of speech intelligibility during guided tours.

Results

The museums whose acoustics are presented here are the aforementioned Deutsches Museum in Munich, the Museum of Musical Instruments in Berlin and the Vienna Museum of Science and Technology.

Deutsches Museum, Munich

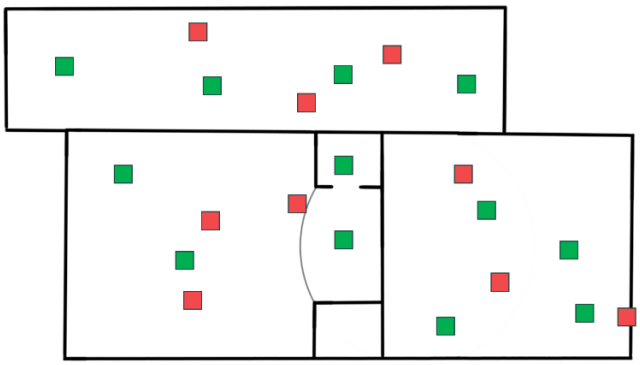

Figure 1: Room plan with source (red squares) and microphone positions (green squares) for the musical instrument exhibition in the Deutsches Museum, Munich. Bottom left to right: room 1 (music hall), room 2; top: room 3.

The musical instrument exhibition in the Deutsches Museum in Munich is housed in three separate rooms. While rooms 2 and 3 are rectangular, room 1 – also called the music hall – has a curved ceiling and a balcony with cut-out corners. In these cut-out corners, under the balcony is an office with a usually closed glass door and more space for exhibition (Fig. 1).

In each room three source positions near interactive display items were chosen. With four microphone positions, this gave the required twelve source-microphone combinations in each of the three rooms (Fig. 1).

	V [m³]	T_{20} [s]	G_{Theo} [dB]	C_{50}	C_{80}	$D_{ALcons=8,5\%}$
Room 1	1350	1,93	+16.34	-3,37	-0,55	2,5 m
Room 2	1000	0,92	+14.42	1,95	5,09	4,5 m
Room 3	1010	1,13	+15.27	-0,23	2,93	3,7 m

Table 1: Volume V, reverberation time T_{20}, theoretical sound strength G_{Theo}, clarity C_{50} and C_{80} and distance for AL_{CONS}=8.5% $D_{ALcons=8.5\%}$ for the three rooms of the musical instrument exhibition at the Deutsches Museum, Munich.

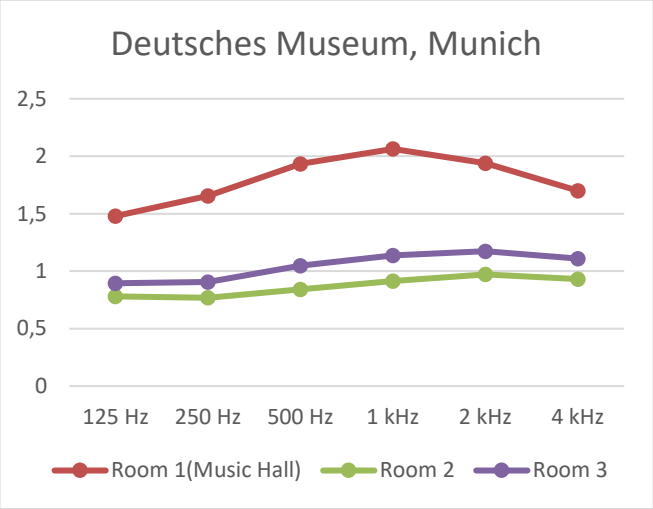

Figure 2: Reverberation times T_{20} over the octave bands for the three rooms of the musical instrument exhibition at the Deutsches Museum, Munich.

Room 1 (or the "music hall") is the only room designed for musical performances with a reverberation time of 1.93 s and a clarity C_{80} of -0.55, although the room "booms" due to a sound strength of +16.34 dB (Table 1). Rooms 2 and 3 on the other hand, have been designed with the museums loudspeaker system in mind, with a reverberation time of around 1 s over all frequency bands (Fig. 2) and a clarity C_{50} between -1 and +3, being well suited for lectures and teaching. They also show a greater distance for usable speech intelligibility than the music hall (Table 1). However, it can be argued that a distance of 2.5 m between the museum guide and visitors is sufficient for guided tours with a smaller number of people. Rooms 2 and 3 nevertheless have sound strengths nearly at the same level as the music hall (Table 1).

Vienna Museum of Science and Technology

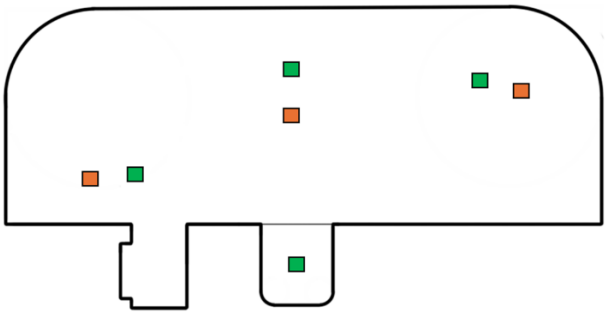

Figure 3: Room plan with source (red squares) and microphone positions (green squares) for the musical instrument exhibition at the Vienna Museum of Science and Technology.

The exhibition on musical instruments and music at the Vienna Museum of Science and Technology is partly in the open main room of the museum and partly in a room separated from the main room for older musical instruments, which are sensitive for changes in temperature and humidity. Only the separate room is measured. It has a rectangular main part with two rounded corners and two small alcoves, one of which is used as a media room with seating, a projector and acoustic panels on the walls and ceiling. Again, microphones were placed at possible visitor positions (one in the media room) and sources at interactive displays (Fig. 3).

V [m³]	T_{20} [s]	G_{Theo} [dB]	C_{50}	C_{80}	$D_{ALcons=8,5\%}$
2070	2,41	+15.44	-3,69	-1,35	2,5 m

Table 2: Volume V, reverberation time T_{20}, theoretical sound strength G_{Theo}, clarity C_{50} and C_{80} and distance for AL_{CONS}=8.5% $D_{ALcons=8.5\%}$ for the musical instrument exhibition at the Vienna Museum of Science and Technology.

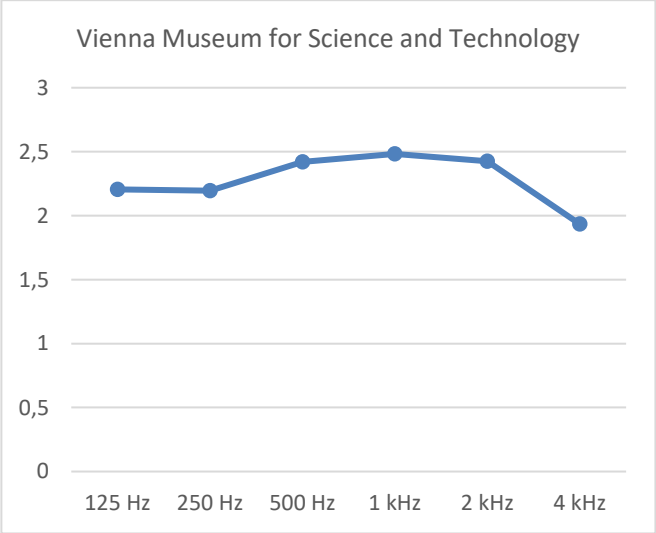

Figure 4: Reverberation times T_{20} over the octave bands for the musical instrument exhibition at the Vienna Museum of Science and Technology.

Apart from the acoustic panelling in the media room, there are no obvious acoustic measures for the exhibition room, which can explain for such a high reverberation time of 2.41 s (Table 2), which is only beneath 2 s at a frequency of 4 kHz (Fig. 4). With a clarity C_{50} of -3.69 it is definitely not suitable for speech-based education. However, with a clarity C_{80} of -1.35, it is not quite good enough acoustically for music performances, coming closer to the functionality of the music hall of the Deutsches Museum than the other rooms, even in terms of sound strength (Table 2). Again, with a maximum distance for speech intelligibility of 2.5 m (Table 2), it is adequate for small, crowded guided tours.

Museum of Musical Instruments, Berlin

The Museum of Musical Instruments in Berlin is the only stand-alone exhibition of the three museums presented here. The museum building also houses the State Institute for Music Research. The exhibition is one very large open room on two levels. The upper level acts as a balcony around the room. It is also the exhibition with the most complex room shape, resembling a fan-shaped music hall. Most of the exhibition on the ground floor is located beneath the balcony (Fig. 5).

Additionally, on the upper floor there is an auditorium used as an exhibition room with open entrances to the main exhibition room. A cinema organ “hangs” from the balcony (Fig. 6)

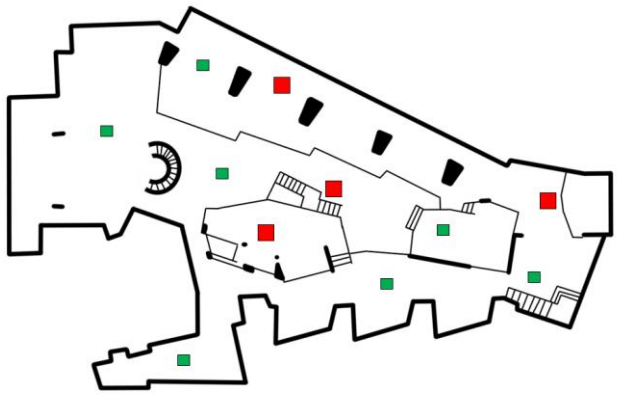

Figure 5: Room plan with source (red squares) and microphone positions (green squares) for the ground floor of the Museum of Musical Instruments, Berlin.

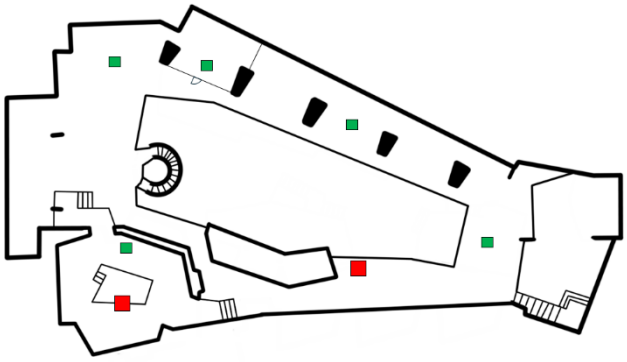

Figure 6: Room plan with source (red squares) and microphone positions (green squares) for the upper floor of the Museum of Musical Instruments, Berlin.

Source positions were placed at interactive displays, playable handling collections and musical instruments used as stops on guided tours. One source was placed next to the cinema organ, and one of each source and microphone positions was planned for the auditorium (Fig. 6). One microphone was placed at the entrance (Fig. 5).

V [m³]	T_{20} [s]	G_{Theo} [dB]	C_{50}	C_{80}	$D_{ALcons=8,5\%}$
15030	0,87	-11,37	-0,64	2,34	18 m

Table 3: Volume V, reverberation time T_{20}, theoretical sound strength G_{Theo}, clarity C_{50} and C_{80} and distance for AL_{CONS}=8.5% $D_{ALcons=8.5\%}$ for the Museum of Musical Instruments in Berlin.

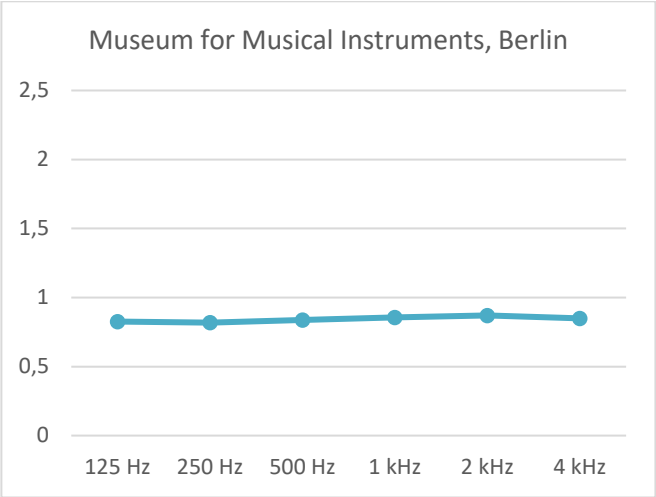

Figure 7: Reverberation times T_{20} over the octave bands for the Museum of Musical Instruments, Berlin.

With a volume of over 15,000 m³ the exhibition room is quite large, but has a reverberation time of only 0.87 s (Table 3), which appears to be consistent across all relevant octave bands (Fig. 7). This is a much shorter reverberation time than the recommended 1.4 seconds for speech in this room size [5]. Nevertheless, both clarity measures are at levels suitable for both musical and speech performances (Table 3). Due to the unusual relationship between volume and reverberation time, the sound strength for the Museum of Musical Instruments is very low at -11.37 dB (Table 3). This results in an apparent (uncomfortable) quietness.

Unfortunately, it was not possible to record the room impulse responses of every source-microphone combination. Very little sound reached the microphone in the auditorium on the upper floor, and very little sound from the auditorium source reached microphones in the main exhibition room.

Summery

There are many educational recommendations for museums and exhibitions, including interactive displays, guided tours and musical performances by professional musicians. This places different demands on the acoustics of exhibition rooms. Museums differ greatly in their acoustics, and some museums have acoustics that can be used for different purposes.

The music hall of the Deutsches Museum in Munich was designed to be good for musical performances, with appropriate reverberation time and clarity C_{80}. The exhibition room of the Vienna Museum of Science and Technology is acoustically closest to the music hall but has a reverberation time too long and a clarity C_{80} too low. The other two rooms of the Deutsches Museum on the other hand are designed for the museum’s loudspeaker system and are suitable for teaching and lectures, as indicated by the reverberation time and clarity C_{50}. All four of these rooms boom due to a high sound strength of ca. +15 dB. The Museum of Musical Instruments in Berlin does not show a clearly suitable purpose, as it is shaped like a fan-shaped music hall, but having a reverberation time that is even too short for speech performances. Both clarities C_{50} and C_{80} indicate a possible usage for music as well as for speech performance.

Sources

[1] ICOM: “Museum Definition”: https://icom.museum/en/resources/standards-guidelines/museum-definition

[2] Birley, M; Eichler, H.; Myers, A.: “Voices for the Silenced: Guidelines for Interpreting Musical Instruments in Museum Collections”, CIMCIM 1998.

[3] “Acoustics – Measurement of room acoustic parameters – Part 2: Reverberation time in ordinary rooms” (ISO Standard No. 3382-2:2008).

[4] Farina, A.; Campanini, S.: „A new Audacity feature: room acoustical parameters calculation module”: http://www.angelofarina.it/Public/Aurora-for-Audacity/2.0.0/

[5] “Hörsamkeit in Räumen – Anforderungen, Empfehlungen und Hinweise für die Planung” (DIN Standard No. 18041:2016-03).