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Consistency in music room acoustics

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Summary

Consider the musician practicing in a 30 cubic meter rehearsal room, preparing for group rehearsal in the 500 cbm group rehearsal room due in one hour, before the whole orchestra assembles for full rehearsal in the 5000 cbm orchestra rehearsal studio, in preparation for tonight's concert in the 20000 cbm concert hall. In all these rooms, our musician plays exactly the same. The acoustics in each of these rooms are considered to be optimal for their use, in contrast to the poor acoustics found elsewhere. Nevertheless, even if the rooms all sound nice, the perceived sound and the acoustical properties of all these perfect music rooms are completely different from each other. From this paradox, the question naturally arises: Is there any common critical feature in all these rooms, and if so - which one is it? The answer is obviously not RT or G. Consistent loudness and consistent level balance between simultaneous streams of information and maskers in the performers' listening appear to play a role.

As a part of the investigation of acoustical conditions for the orchestra musician throughout 4 typical, but very different situations, measurements at the ears and other relevant positions around the musician are to be carried out. A pilot study limited to one violin player has been completed with results close to those simulated in Odeon models. Like in the simulations, the Dry-Reverb-Balance (DRB) appears to be a possible indicator of proper acoustics in different situations. Relating to the title of this paper – consistency in music room acoustics; from simulations and measurement results the candidacy of DRB as a consistency measure cannot be rejected. Like in simulation results the Foreground-Background-Balance (FBB) seems to be a highly relevant parameter whenever other musicians are present, i.e. in all situations except individual rehearsal. Ideas about the relationship between information sources and maskers, and the alternating roles of one and the same source, are presented for discussion. In further work, other instruments will be included, significance of the two balance parameters, DRB and FBB, will be tested, and subjective differences associated with differences in balance parameters will be investigated. The relationship between critical radius r_c, and critical listening distances will be studied further.

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1. Introduction

Consider the musician practicing in a 30 cubic meter rehearsal room, preparing for group rehearsal in the 500 cbm group rehearsal room due in one hour, before the whole orchestra assembles for full rehearsal in the 5000 cbm orchestra rehearsal studio, in preparation for tonight's concert in the 20000 cbm concert hall. In all these rooms, our musician plays exactly the same. The acoustics in each of these rooms are considered to be optimal for their use, in contrast to the poor acoustics found elsewhere. Nevertheless, even if the rooms all sound nice, the perceived sound and the acoustical properties of all these perfect music rooms are completely different from each other. From this paradox, the question naturally arises: Is there any common critical feature in all these rooms, and if so - which one is it? The answer is obviously not RT or G. In the small rehearsal room, the optimum EDT for a concert hall would not be achievable without excruciating loudness, and even with ear protection it would not sound nice. Conversely, the optimum EDT of the rehearsal room would mean dry weakness in the concert hall.

One approach toward acoustical requirements for rehearsal rooms has been to consider these rooms as smaller substitutes for the bigger ones. Indeed, rehearsal rooms are often made smaller for economic reasons rather than for acoustical preference. And a larger rehearsal room is often wanted by the soloist in the final preparation, as an adaption step, for the big performance room. On the other hand, the fact that bigger groups in many cases need bigger rooms cannot be ignored. And conversely, smaller groups can be better off with a smaller room. In general, the parameters of a preferred performance space cannot be directly applied to a rehearsal space.

The significance of size must be investigated, including a list of variables with possible corresponding criteria:

- Level of sound form own group, from other groups, and from the whole orchestra
- Maskers and masker thresholds
- Level balance between information and maskers, including
  - Self-to-Others level balance
  - Foreground-Background Balance
  - Dry-Reverb Balance DRB
- density of direct and indirect sound paths
- inter-orchestral source-receiver distances
- diffraction through the orchestra
- surface source properties, and attenuation with distance
- power, room gain and loudness
- free height above the group
- floor space requirements
- other

DRB is closely related to the direct-to-reverb ratio D-R (in dB) in inter-orchestral sound paths and its average over the ensemble. Results from work by this author have indicated that orchestra musicians' preference is sensitive to this measure.

DRB is the balance between the an-echoic (dry) component and the reverberant component from all sources in the particular situation.

In Odeon simulations where D-R was consistent through different situations with varying ensemble footprint, the critical radius r_c, where D-R=0dB, tended to scale with the diameter or other linear dimension of the ensemble.

2. Music room research project

This paper is part in a series of reports from an ongoing search for consistent criteria in music room acoustics throughout the span from 20 to 25000 cbm. Previous reports are:

- Rehearsal room acoustics for the orchestra musician (2014) [1], Odeon models of typical situations in an orchestra musician's day at work
- Music Room Acoustics – Critical Parameters (2012) [10], a review of relevant aspects, their corresponding physical measures and possible criteria

It is assumed that in addition to any consistent criteria, i.e. criteria relevant for the full size performance space that are found to be relevant for smaller rooms too, there may be criteria that depend on the specific rehearsal activity and situation. E.g. there may be other criteria in the early phase of rehearsing a music piece than in the later phase, such as the need to hear specific details and individual instruments in the orchestra rehearsal studio, versus the need for these to blend together in the performance space.

3. Orchestra musician study

As a pilot study, in order to gain more insight in possible acoustical factors that could affect an orchestra musician, this author has investigated the varying situations through days at work for a violin player in an orchestra. By measurements and interviews, objective and subjective observations have been collected. Four different situations were predefined for the study, based on the fact that they not only represent different acoustical environments (rooms), but also well-defined corresponding activities and duties:

1. Individual rehearsal
2. Group (voice) rehearsal
3. Orchestra rehearsal in studio
4. Orchestra performance

3.1. Odeon model study

As a part of the project, all four situations above were modeled in Odeon and simulations were made [1]. A total of 18 models with varying degree of sound absorption were tested.

In order to analyze the results, sound on a musician's ear was divided into a foreground FG (direct sound from own instrument) and a background BG (direct and reverberant sound from others, and reverberant sound from own instrument). It was concluded that the foreground-to-background balance (FBB=FG-BG) can be sensitive to room acoustical conditions.

BG, when too strong, seemed to be able to drive the musician to play louder.

Highlighted in the presentation of the results at BNAM2014, was the aforementioned balance between "Dry" and "Reverb" sound in all four situations, i.e the Dry-Reverb-Balance DRB.

While the overall variation of DRB throughout the 18 models was in the range of 3dB to 13dB, the values of DRB turned out to be more consistent in "good rooms": In models with value-combinations of V, T and G that are considered proper for their use, DRB showed values in the narrow range of 6-7dB.

The smaller the ensemble, the more was BG dominated by reverberant sound. In further work, the study was to be extended to include other instruments and more spectral data than just mid-frequencies.

In individual rehearsal rooms it remained to settle the proper level of the reverberant sound, since the observed variation was big among rooms that have the recommended T (according to NS8178). Also, the delicate hearing balance and masking effects discussed in the report was to be pursued, please refer to discussion in 4.6 below. In addition to more simulations, measurements and analytical methods were to be included in the research.

Since the orchestra model in the study was a plane surface with no obstacles, one should try to analyze what the effect of such obstacles would have on BG in the bigger ensembles. Observations of two rooms having equal T, but different reverberant levels, and vice versa, invited for closer investigation.

A possible difference in intensiveness of playing during different kinds of sessions – performance, orchestra rehearsal, group rehearsal and individual rehearsal - should be investigated further. While this is relevant to the noise and health concerns, it is expected to be far less relevant to issues of mutual hearing.

It must be distinguished between the direct effect and the indirect effect of room response. While the direct effect can cause a musician to play stronger when the room response is weak and vice versa, i.e. a negative feedback loop, the indirect effect is a positive feedback loop: Stronger reverberant sound from an ensemble can drive the individual musician of the ensemble to play louder, trying to improve an insufficient FBB.

From the insight and experience gained through the work described above, it seems fruitful to analyze the complex time signal at the musician's ears in three parallel information streams:

1. Dry sound from own instrument
2. Dry sound from other instruments
3. Reverberant sound

The information streams could be grouped in two different ways:

Table 1 Time signal at musician's ears analyzed into separate information streams

1 Dry Self	Foreground	Dry
2 Dry Others	Background	
3 Reverb All		Reverberant

In further work, measurements and simulated measurements should at least provide data that can be analyzed into these separate streams.

3.2. Measurements on a musician

As a part of the research program described above, measurements on musicians are to be carried out in rehearsal sessions in the four typical situations. A measurement series on a violin player has been completed, Figure 1 thru Figure 4, below. The group rehearsal had to be postponed to a later time this year due to the orchestra rehearsal program. This left the opportunity to make separate recording of the individual violin in the big rehearsal room which is intended for group rehearsal, Figure 2.

An example of sound pressure level spectra measured at each ear, in the four different situations of the series, is presented in Appendix, Figure 4.

The music played in all sessions was the first 25 minutes of Swan Lake by Tchaikovsky, from Entre thru Scene Nr 5. In individual rehearsal sessions, the tacit parts were not skipped; they were performed as silence in given tempo.

The musician was asked to play as similar as possible in all four sessions, and did not report any difficulties with this.

Measurement setup and instrumentation was chosen in order to provide data according to demands mentioned in 3.1. In all four situations, the following data was recorded:

- P(t) (L) Outer ear canal, left ear, full wave data
- P(t) (R) Outer ear canal, right ear, full wave data
- $L_{Aeq,1s,1m}$ (t)(far) direct path from violin screened by musicians body
- $L_{Aeq,1s}$ (t) at 2-3m from violin, least 1m from any instrument

While the two first bullet points are intended to acquire information about the musician's Foreground and Dry levels, the latter two are assumed to carry information about Background- and Reverb levels. Some degree of redundancy between the two latter bullet points was expected and intended.

Levels of all recordings were calibrated with a Norsonic 140 sound level analyzer. (L) and (R) were calibrated to the same equivalent levels as a microphone in a stationary sound field with long-term uniform incidence, referred to as "free-field equivalent". See discussion of this choice below. From the recorded data, three forte parts were chosen for analysis, one from Entre, one from

Scene 1, and one from Scene 5. Durations were 42s, 60s and 117s respectively, adding up to a total of 219 seconds. The reasons for choosing these parts are discussed below.

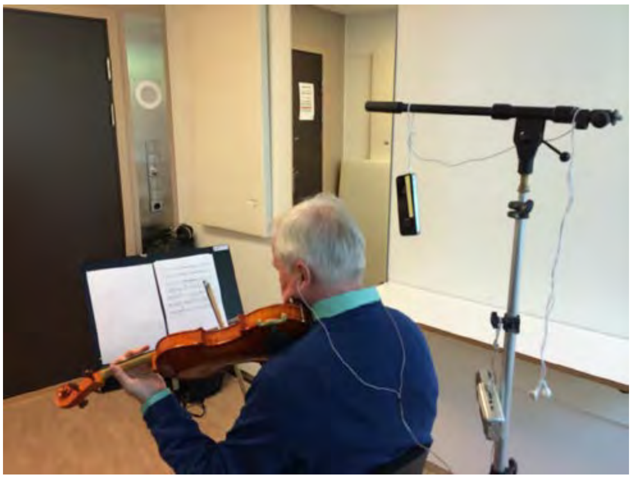

Figure 1 Individual rehearsal room,
V=30m3; T=0.4s; G_{rev} (V,T)=26dB

Figure 2 Big rehearsal room, intended for groups,
V=1000m3; T=0.8s; G_{rev} (V,T)=14dB

Figure 3 Orchestra rehearsal Studio,
V=5500m3; T=1.0s; G_{rev} (V,T)=8dB

Figure 4 Orchestra Pit,
V=14000m3; T=2.1s; G_{rev} (V,T)=6dB

3.3. Results

Measured data during 217s of forte play are presented (in bold) in the first three rows of Table 1. Equivalent levels from the whole first 25 min were 4-5dB lower. The rest of the table consists of best fit data resulting from an iteration process starting with arbitrary input data in *red italic*, aiming for least sum of square errors. Error is defined and discussed below.

Table 2 Results. Measured data (in **bold)** and best fit data from the iteration process, from 219s play at f-ff. Best fit input values are in *red italic*. Decimals in levels are hidden. Notation: All values are levels in dB unless other unit denoted in leftmost column. L_{Aeq}= free-field equivalent (see text), A-weighted, sound pressure level; L=left ear; R=right ear; "far"= not in the near or direct field of violin; "self"=own instrument; "dry"= non-reverberant part of sound; "other"= other instruments; r'=apparent source-receiver-distance.

	Reh. Room	Big Reh Room	Orch. Reh. studio	Orch. Pit
L_{Aeq} L	**91**	**90**	**93**	**93**
L_{Aeq} R	**84**	**84**	**89**	**92**
L_{Aeq} far	**81**	**75**	**89**	**91**
L_{Aeq} self dry L	90	90	90	91
L_{Aeq} self dry R	83	84	84	85
L_{Aeq} self dry far	71	71	71	72
L_{Aeq} other dry L	-∞	-∞	87	87
L_{Aeq} other dry R	-∞	-∞	85	90
L_{Aeq} other dry far	-∞	-∞	87	90
L_{Aeq} all dry L	90	90	92	93
L_{Aeq} all dry R	83	84	87	91
L_{Aeq} all dry far	71	71	87	90
L_{Aeq} background L	81	72	88	89
L_{Aeq} background R	81	72	88	91
L_{Aeq} reverb all	81	72	84	84
L_{wA} power all	87	88	107	109
G_{refl} room gain	*25*	*15*	*8*	*6*
L_{wA} power self	*88*	*88*	*88*	*89*
L_{wA} power other	*-∞*	*-∞*	*107*	*109*
self r'(L) [m]	*0,22*	0,22	0,22	0,22
self r'(R) [m]	*0,47*	0,47	0,47	0,47
self r'(far) [m]	*2,0*	2,0	2,0	2,0
other r'(L) [m]	∞	∞	*3,0*	*3,5*
other r'(R) [m]	∞	∞	*3,6*	*2,6*
other r'(far) [m]	∞	∞	*2,7*	*2,5*
FBB (avr{L+R})	6	16	0	-1
DRB (avr{L+R})	6	16	6	8

3.4. Comments to the results

During individual rehearsal of the forte parts, the musician's left ear is exposed to levels 2dB below those when playing in the full orchestra. At the right ear the rehearsal level is 8-10dB lower than when playing in the orchestra.
At the left ear, with orchestra present, the musician can hear his own violin 3-4dB above Others, i.e. the sum of dry sound from the rest of the orchestra. When including reverberant sound in the rehearsal studio, he can hear his own instrument equally loud as the sum of dry and reverberant sound from the orchestra, i.e. the Background, FBB=0dB. In the pit, he hears his own instrument slightly weaker than the Background, FBB=-1dB.
As mentioned above, attention has been drawn toward the balance parameters FBB (Foreground-Background-Balance) and DRB (Dry-Reverb-Balance). In Table 3, balance parameter results in Table 2 can be compared with results (in parenthesis) from the aforementioned simulations in Odeon. First of all, note that like in the simulations, DRB exhibits consistent levels within a narrow range (6-8dB) in rooms considered to have proper acoustics. In contrast, in Big Rehearsal Room, which is considered not proper for individual rehearsal for a single member of a big group, DRB=16dB is a considerable deviation from the 6-8dB range. Subjectively, the situation with the deviating (too high) DRB was described to lack the aspect of source enlargement. Moreover, it lacked the full tone that can be heard in the in the regular individual rehearsal room and when the rest of the group is playing in unison in the big rehearsal room.
More detailed, we see that in Rehearsal Room and in Big Rehearsal Room, measurement values from Table 2 are equal to simulated values. In Orchestra Rehearsal Studio, measured FBB is 2dB lower than simulated, while measured DRB is 1dB lower than simulated. In the Orchestra Pit balance parameters has not been simulated, so there is no simulated value to compare with. However, it is interesting to note that measured FBB in Orchestra Pit is 1dB lower than in Rehearsal Studio, and DRB is 2dB higher in Orchestra Pit than in Rehearsal Studio. These differences are partly due to louder presence of instruments exposed to the right ear in the pit. However, with FBB and DRB measured at lower levels than simulated, it would be natural to consider a lower receiver position, i.e. ear position, relative to the surface source representing the orchestra in the model. In this

way the foreground and dry components would become stronger, and even closer to the measured results. Refer to further discussion below.

Table 3 Balance parameters from Table 1, based on energy average at left and right ears. Comparable results from simulations in Odeon in paranthesis.

Balance parameter	Reh. Room	Big Reh. Room	Orch. Reh. studio	Orch. Pit
FBB (avr{L+R}) (Odeon simulation)	6 (6)	16 (16)	0 (2)	-1 (-)
DRB (avr{L+R}) (Odeon simulation)	6 (6)	16 (16)	6 (7)	8 (-)

As to daily exposure dose (re L_{Aeq},8h=85dB), 93dB during 217s means 4.8% of daily dose, while 88-89dB during 25min means 10-12% of daily dose. With equivalent music content, 2 hours in the pit would result in 50-60% of daily dose. Due to 2dB lower exposure level in Rehearsal Room than in Pit, a full individual rehearsal of the same music would result in 32-38% of daily dose. This means that 2 hours individual rehearsal and 2 hours orchestra rehearsal in the pit would add up to 82-98% of daily dose, which is within recommendations. In contrast, a full rehearsal and a performance night on the same day would add up to 100-120%, which would require protection of the left ear. Since exposure levels at right ear are lower, protection at both ears would not be required in this case. The exposure levels seen in these measurements are not unusual, statistically[14], but they indicate that the actual music case is in the loud category.

4. Discussion

4.1. When an instrument, like the violin, sounds louder at one ear than the other

In the case of a violinist, it is not obvious that the musician's foreground is made up by the energy average over both ears. One should also consider the balance relative to the loudest foreground and dry component. For the violinist, due to the instrument's position at the left shoulder, these components are found at the left ear. For the assumption that the components Foreground and Dry are found at the left ear, resulting balance parameters are given in Table 4. From this table we see that 6 out of 8 balance parameters are 2dB higher than in Table 3, while the two remaining (Orchestra Pit) are 1-3dB higher. Further discussion over which assumption to use would be relevant to cases of violin and viola, and maybe French horn. For most other instruments, sound from the instrument would be emitted symmetrically without bias to left or right, and thus the balance parameters would not depend on choice of assumptions. As long as such asymmetry is not built in to the model, one should use the average of left and right measurements whenever comparing with simulations. One way to build asymmetric listening into the model could be to use one point receiver for each of the violinist's ears, positioning the left ear closer to the orchestra surface source than the other.

Table 4 Balance parameters based on results in Table 1, assuming that the significant Foreground and Dry components are found at the ear with the highest levels, namly the left ear. Comparable results from simulations in Odeon in paranthesis.

Balance parameter	Reh. Room	Big Reh. Room	Orch. Reh. studio	Orch. Pit
FBB (max{L,R}) (Odeon simulation)	8 (6)	18 (16)	2 (2)	2 (-)
DRB= Dry – Reverb (Odeon simulation)	8 (6)	18 (16)	8 (7)	9 (-)

4.2. Errors

In the best-fit iteration process used to data in Table 1 above, errors are defined as the difference between a measured value, e.g. $\mathbf{L_{Aeq}\_L}$, and the computed sum of best fit energy components, namely

- L_{Aeq} self dry L
- L_{Aeq} other dry R
- L_{Aeq} reverb all

For 10 out of 12 of measured values, errors are less than 0.1dB. In Rehearsal Room, $\mathbf{L_{Aeq}\_R}$ is computed 1.2dB higher than measured, and $\mathbf{L_{Aeq}\_far}$ is computed 0.6dB higher than measured. Explanations for these errors have not been found in instruments, calibration, data-processing or in the possible overestimation of reverberant levels. Despite these two errors, the data fitting process is considered very successful, given the fact that error is less than 0.1dB in 10 out of 12 output values.

4.3. Choice of music parts for analysis

At least two advantages are related to the choice of forte parts as a basis for the analysis above: The high intensity of forte parts provides condensed information from the whole orchestra in a rather short period of time. Besides, it is believed to be easier for the musician to control repeatability in forte-fortissimo play than in softer or more varied parts. E.g., there is a physical limit as to how strong one can play, while softer play is only limited by memory and training. Moreover, softer play requires more fine motor effort. Stronger play has a lower ratio of measureable difference in dB output per noticeable difference in muscle movement, than has softer play. Results reveal that the level on the left ear measured in the individual rehearsal room is less than 0.6dB different from the level at the same ear when the same part was played in the big rehearsal room. This is indeed confirming that the power repeatability of a musician can be very high. On the other hand, one should not apply results directly to matters of softer play.

4.4. Sound pressure in ear and in free field

While the actual sound pressure level distribution around the head and in the ear canal could be an interesting research topic, it is outside the scope of this project. We need all quantities to be comparable with each other and with quantities that can be predicted in simulation software or classical calculations, and that also can be measured in free field without the head and ear of the music being present. Therefore, we have chosen to calibrate the in-ear levels (L) and (R) to be equal to the equivalent levels of a microphone in a stationary sound field with long-term uniform incidence, referred to as “free-field equivalent”. Based on measurements we found that the A-weighted level in the opening of the outer ear canal is approximately 5dB higher than its “free-field equivalent”. Thus, the measured in-ear levels are corrected with -5dB to yield the reported $\mathbf{L_{Aeq\_}L}$ and $\mathbf{L_{Aeq\_}R}$ in this paper. Theoretically, compared to the free field case, a +6dB rise in SPL is to be expected on a perfectly rigid sphere with radius a, when $ka>>1$. However, the human head is less rigid than this, and thus a smaller pressure rise is seen.

4.5. Driving factors

The factor that an orchestra musician needs to hear one's own instrument more or less above the other's [14], may be one of the keys to understanding the mechanisms that has long-term effects on development of sound levels, playing style and noise exposure in an orchestra. From the simulations with models of rooms, single musician, group of musicians and full orchestra ensembles referred to above, it was concluded that even where reverberant sound has little direct effect on the sound pressure levels at the musician’s ear, they could indeed have an important indirect effect by driving the musician to play louder [1]. The Pyramid of Acoustical Needs previously presented by this author [8] still seems to be relevant.

4.6. Maskers

Consistent loudness and the levels of potential maskers in the performers’ listening appear to be significant. “Potential maskers” could be any combination of sounds that perceptually compete with the sound signal the musician wants to hear, and this would vary from situation to situation, room to room, and even from one second to another. Among masker components are: other instrument groups, own instrument group and own instrument, and the early and late reverberant sound corresponding to each of the former components. Most often perhaps, potential maskers would be the total sound of other instrument groups including their reverberant sound. Another potential masker would be one’s own instrument group making it difficult to hear one’s own instrument.

The significance of masking and the listening conditions of orchestra musicians have been suggested by authors, though not very comprehensively. Two statements emphasizing balance and masking are quoted below:

“The results from the orchestra collaborations indicate that the following are of most concern for players regarding acoustic conditions: hearing all other players in the orchestra clearly and having sound from others well balanced with the sound of their own instrument and the acoustic response from the main auditorium. These subjective aspects appear to relate to complex perceptual effects like the precedence effect, masking effects and the various cocktail-party effects. When relating these effects to physical conditions, a narrow and high stage enclosure with the stage highly exposed to the main auditorium appears most beneficial.[3]”

“The art of designing good on-stage acoustics boils down to providing just enough early energy to help with coordination, but not so much as to mask audibility of the late-energy room response. [4]”

Attention has indeed been drawn towards the problems of hearing balance and masking in musicians’ listening conditions. Thus, the paradigmatic shift from the aspiration for sufficient hearing of others, to the aspiration for “just sufficient”, is to be expected. “The more the better” is contradicted by “less is more”, and ultimately replaced by the optimum “not too little, not too much". However, the fact that one instrument (or group) that is being a masker in one instant can be unwantedly masked in the next instant, makes the hearing balance much more delicate than previously understood , see Table 5.

Table 5

Source of information = Potential Maskers
Own instrument
Own voice group
Other voice groups
Whole orchestra
Impulse or transient sound (temporal masking)
Bass components (spectral masking)

Moreover, when specifying all the sound components involved in the auditive image of an orchestra musician, understanding that all these can have alternating roles as maskers an information sources, we realize that balanced listening is not a question of finding a delicate but static balance between a source of interest and its potential maskers, like a signal-to-noise ratio. Instead, it is a complex and dynamical issue. Complex because of the many components involved. Dynamical, i.e. changing from time to time, not only because the level balance between the components changes with the running music all the time, but also due to the alternating roles of the components.

In this context any further discussion over the significance of direct sound, early sound, late sound, etc., these channels of information should also be considered potential channels of masking, see Table 6.

Table 6

Channels of information and maskers
Direct sound
Diffracted sound (around orchestra members)
Early reflected sound
Late reverberant sound
Echoes

Even if perceptual training and ability plays an important role, e.g. the aforementioned cocktail party effect, the listening conditions in terms of acoustical measures determines the basic conditions for what is possible to perceive and what is not. In addition to pure level balance, time profile and timbre of the components are likely to be significant due to temporal masking and spectral masking respectively. Adding even more to the complexity of the issue, different musicians and groups rely differently on auditive information in ensemble play. This could be a mixture of individual preference and habits, but is also likely to be instrument specific. E.g., violinists rely on the visual ques in the bow movement of the colleagues up front, in particular of the Concert Master.

4.7. Investigating the difference between too much and too little

Interviews with the violinist in this pilot study indicated that there are differences in preference associated with differences in the balance parameters between rooms. E.g. the too high DRB in the big rehearsal room is associated with lacking source enlargement and lacking fullness of tone. On the other hand, in ensemble situations, rooms with too low DRB and FBB are associated with over-saturated sound and lack of auditive transparency. Investigation of such differences is to be included in further work. In terms of critical radius r_c, and a linear ensemble dimension d, over-saturation corresponds to r_c/d being too small, while too weak background would correspond to r_c/d being too big.

5. Conclusions and further work

As a part of the investigation of acoustical conditions for the orchestra musician throughout 4 typical, but very different situations, measurements at the ears and other relevant positions around the musician are to be carried out. A pilot study limited to one violin player has been completed with results close to those simulated in Odeon models. Like in the simulations, the Dry-Reverb-Balance (DRB) appears to be a possible indicator of proper acoustics in different situations. Relating to the title of this paper – consistency in music room acoustics; from simulations and measurement results the candidacy of DRB as a consistency measure cannot be rejected. Like in simulation results the Foreground-Background-Balance (FBB) seems to be a highly relevant parameter whenever other musicians are present, i.e. in all situations except individual rehearsal. Ideas about the relationship between information sources and maskers, and the alternating roles of one and the same source, have been presented for discussion.

In further work, apart from completing a measurement series with 1st violin, including the group rehearsal situation, measurements are to be extended to include instruments from different voices and sections of an orchestra. Situations with less suitable acoustics should be included, as well as situations with suitable acoustics. Significance of the two balance parameters, DRB and FBB, will be tested and subjective differences associated with differences in balance parameters will be investigated. The relationship between critical radius r_c, critical listening distances, and linear ensemble size will be studied further.

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Appendix

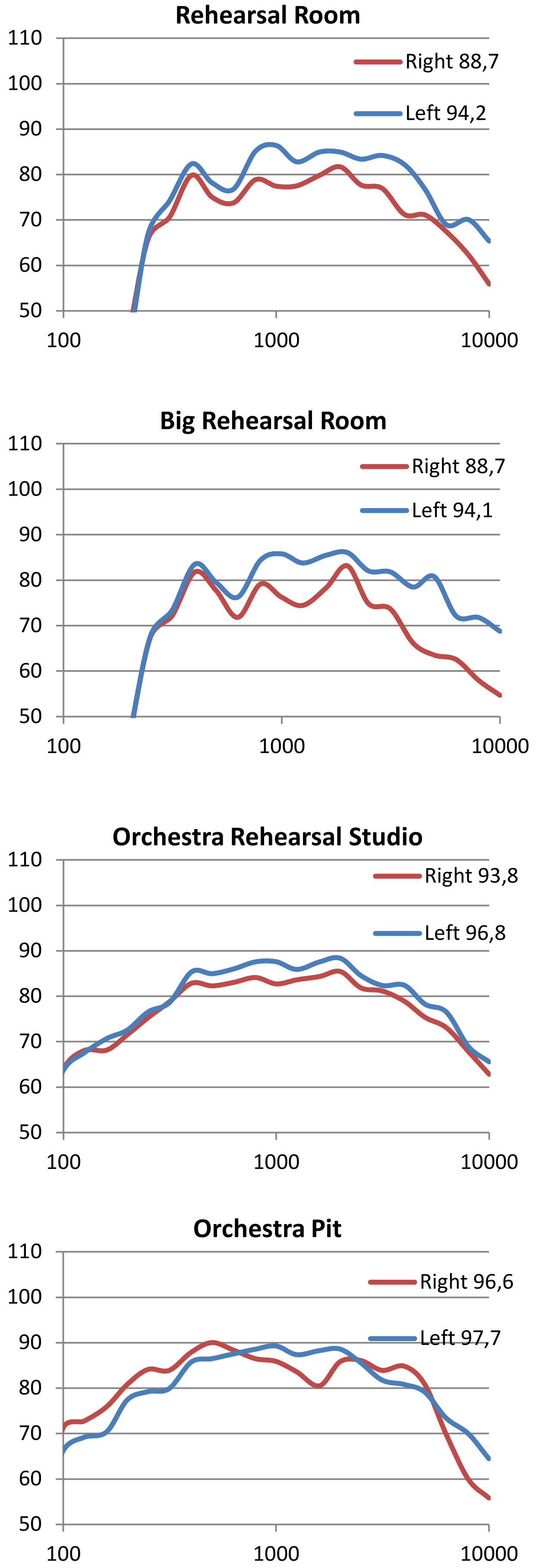

Figure 5 A-weighted sound pressure levels at right ear and left ear of violinist (1st violin voice) while playing a loud (f-ff) part from the intro (Entré) of the music to the ballet Swan Lake by Tchaikovsky, duration 47s, in four different situations. The one-decimal figure at the right of each diagram legend is the $L_{pA,eq,47s}$ at right ear and left ear, respectively. Levels are actual sound pressure levels, not free field equivalents, i.e. not corrected for pressure rise due to head and pinna. In all diagrams, horizontal axis is frequency in Hz, and vertical axis is SPL in dB.