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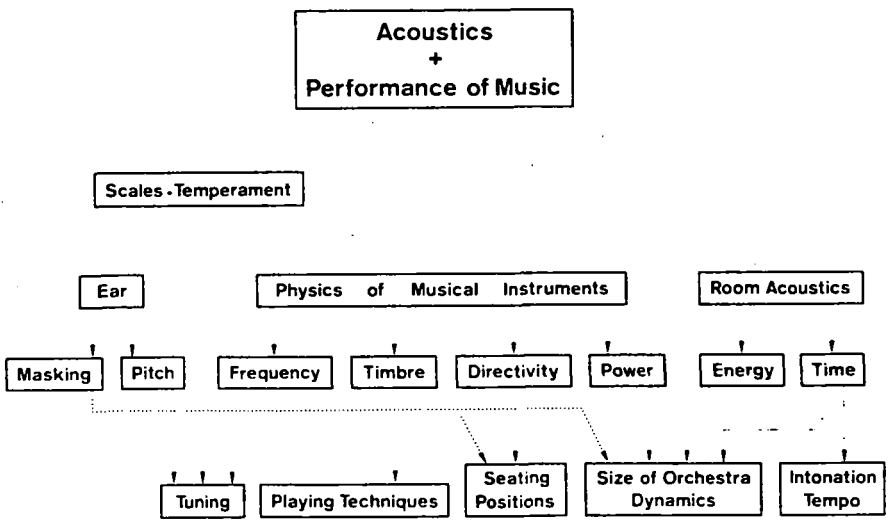
# ACOUSTICS AND THE PERFORMANCE OF MUSIC

J. MEYER

PHYSIKALISCH-TECHNISCHE BUNDESANSTALT BRAUNSCHWEIG

For the musician, findings from various fields of acoustics are of importance, and these findings may have an influence on various aspects of his musical activities. These correlations are shown schematically in the following figure.




Within the field of acoustics, the physics of musical instruments are certainly much to the fore for the musician. However, the properties of the ear and room acoustics are likewise of great importance for the impression of the musical sound pattern. In the figure, these fields of acoustics are subdivided into several subsections. As to the ear, only the masking effect and the pitch perception have been selected from the large number of properties. The functionings of the musical instruments have been classified according to the different points of view from which the radiated sound can be considered. Finally room acoustics have been subdivided into energy storage effects on the one hand and the temporal and directional structure of the sound field on the other.

In the last line of the diagram, subsections of acoustics are contrasted with concepts of practical music making. By "tuning", according to the linguistic

usage of the orchestra members, the choice and realization of the right pitch is meant. The expression "playing techniques" is to comprise the technical feasibilities of influencing timbre and loudness. The "seating positions" refer to the correctly chosen place of the musicians on the podium as well as to the positioning of the musicians to one another. "Size of orchestra and dynamics" means the number of musicians in an orchestra and the level of volume that can thus be reached, as well as the balance between the different groups of instruments. "Intonation and tempo" are the fine structure of the dynamics and the articulation as well as the accommodation of the musical tempo to the room properties.

The correlations between subsections of acoustics and the points of view of practical music making are indicated by arrows and will be explained by some examples.

For all stringed instruments and wind instruments, the influence of the individual parameters of the playing on the frequency of the radiated sound is the basis for proper tuning. In the case of stringed instruments, the frequency of the string vibrations depends solely on the fingering technique, not however on the bowing technique [ 1 ]. With brass instruments, the frequency is only determined by the tension of the lips, not, however, by the air pressure [ 2 ]. In the case of the flute, not only the air pressure but also the position of the lips are of importance [ 3 ]. As far as reed instruments are concerned, three parameters influence the frequency: position of the lips, pressure of the lips and air pressure [ 4 ].

The concept of "proper" tuning naturally presupposes a reference system specifying the nominal values. Such tempered scales have been discussed in the literature for several centuries; in doing so, usually no attention has been paid to the fact that, on the one hand, the demand for consonances without beats loses significance when the single tones are played with different vibrato, as the audibility of beats is extremely reduced, and that, on the other hand, the deviation from an exact mathematical system of frequencies is used as an artistic means of expression [ 5 ]. Finally, the sound intensity and the timbre of the sounds [ 6 ] and even - at least with regard to the fineness of pitch resolution - the degree of training in hearing are also of importance for the perception of the pitch [ 7 ].

In addition to the frequency, sound intensity and timbre are likewise influenced by playing techniques. In the case of wind instruments, these influences cannot be separated, so that every change in the dynamics automatically calls for a tuning correction. For stringed instruments, such a correlation is restricted to the technique of the left hand. The different influences of the three parameters of bowing technique (position of the bow, its pressure and speed) on the intensity of the individual overtone ranges are of great importance for the accommodation of the dynamics to the various sizes of the rooms [ 8 ].

Due to the directivity of the individual instruments the seating position of the musicians can be decisive for the sound effect in the room. In this connection not only the effects of the localizing of the sound source in the sense of a stereophone sound pattern are of importance, but the balance of dynamics and timbre of the individual instruments can likewise be decisively

influenced by changed seating positions. This applies in particular to the three standard arrangements of the strings [ 9 ]. However, not only the sound sources have a directivity but the ear, too. This effect becomes particularly evident for a musician playing in an orchestra, especially when the instrument of the player concerned is held in a position asymmetric to the head. Violin players, for example, hear reflections from the ceiling coming perpendicular from the top better than those incident at an angle of gradient of approx. $45^{o}$. Horizontal reflection surfaces above the group of violins thus improve the contact among the violin players [ 10 ]. It is, however, important that the reflections arrive within the right time interval after the direct sound [ 11 ].

The sound power achievable by the instruments determines the dynamic levels which can be reached in a room whose volume and reverberation time are further influencing parameters. A relative energy density level can be determined from these two data of the room and this level can, for example, be referred to the Grosser Musikvereinsaal in Vienna. It enables the required change of the sound power to be calculated when the same level is to be reached in various rooms. It is left to the interpreter to what extent this change is to be realized by modifying the number of players of the orchestra or by modifying the playing technique.

If the temporal fine structure of the sound field at the place where a member of the audience is sitting is likewise included in these considerations, the different "space impression" of the sound impression can also be taken into account. The fact that the forte of an orchestra is simply loud in some rooms whereas in others, its tonal intensity seems broader and thus gains in "volume", is the basis of these considerations [ 12 ]. As in the second case the dynamics of the forte are obviously more effective, a compensation of the lack of space impression suggests itself in the first case by an additional increase of the level in order to thus arrive at an equivalent forte impression [ 13 ].

Due to the temporal fine structure of the sound field and the transient effects of the room, the musician is faced with the task of adapting his articulation and intonation - and within certain limits the tempo, too - to the respective conditions in the room. The difficulty of this task is, of course, that the player on the podium is exposed to the effects of the room only to a small extent, and it is thus hard for him to sense the impression his playing produces at the various parts of the hall. As in comparison with the number of their appearances on the podium, musicians as a rule seldom listen to concerts from a normal place in the audience, they do not, for example, realize how much lower the sound of short notes of dotted rhythms is heard at the back of the hall when they seem to the player as loud as long notes. The clarity of the total sound conditioned by tempo and articulation should likewise be adjusted to the hearing impression of the audience.

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