REFLECTIONS ON THE SPATIAL SOUND IMAGINATION OF COMPOSERS

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1 INTRODUCTION

The acoustical quality of concert halls has been discussed predominantly from the point of view of the audience and the performing musicians. Even if historic performing conditions such as the acoustic properties of historic halls have been of interest, the question has been hardly explored of whether the composers were aware of the influence of the room acoustics on the orchestral sound when they were writing their symphonies. Naturally there is no doubt that they could imagine the melodic lines as well as the harmonic and rhythmic structure of their works. But did they reflect on the influence of the acoustics of the ambient room? Unfortunately, there do not exist written notices from the composers which definitely relate to specific acoustic properties. Therefore this question shall be discussed by analyzing a large number of symphonies whether or not it can be proved that audible spatial effects were assumed by the composers.

From the acousticians' point of view, these effects can be divided into effects that are predominantly caused by the direct sound, effects that are mainly created by the diffuse sound field, and effects that are strongly influenced by early reflections. Related to the listeners' sound impression of the music, these three effects could be described by the ability to localize certain instruments or voices, a sense of the reverberation in the hall - sometimes with a masking effect -, and the feeling of spaciousness from the perception of a tonal broadening of the sound like a "blooming up". Looking for examples that are obviously related to these criteria, the scores (not recordings!) of eighty symphonies were examined, which leads to a very large number of analyzed passages. Therefore a complete documentation of the examples is not possible and the following presentation has been reduced to some typical examples of the spatial criteria used in the study and summarized results for the individual composers.

2 EFFECTS OF THE PERCEPTION OF SPATIAL SOUND

2.1 Effects based on the direct sound

The simplest way for creating a spatial effect into the musical sequence consists of a positioning of single instruments or instrument groups off stage so that they are localized separately by the audience. Mainly, this tonal separation can be effected by different directions of the (arriving) direct sound, but may be supported also by additional reverberance, loudness or even tone coloration. For the entire orchestra on stage, more detailed spatial effects can be generated if the listener is able to localize different instruments or instrument groups. It might be mentioned that the composer Hector Berlioz wrote in his "Traité d'instrumentation": "Certain groups of the orchestra are chosen by the composer to enter in a dialogue-like interchange". Therefore he demands a sufficient distance

between these groups in order to fulfill the composer's intention. This may concern the string and wind instruments as well as percussion instruments[1].

In this connection, the positioning of the individual string sections plays a particular role. As is well known, about 1777 the famous Mannheim orchestra introduced the concept of separating the first and second violin sections to the left and the right side of the conductor. This arrangement - the so-called - German seating arrangement - was subsequently taken by many European orchestras and finally worldwide in common use until the 1940s. Among others, this arrangement supports the presence of the second violins in dialogue-like passages with the first violins and the audibility of the second violins in thematically important passages.

But the localization of different instrument groups not only enhances the clarity of the tonal structure of the music, it also contributes to a spatially broad and uniform sound effect if the sound source consists of a large number of incoherent individual sources. In this case, it is not only the "spread" of the direct sound coming from different directions that contributes to the broad tonal effect, but the temporally spread lateral reflections also play a role. That effect is particularly interesting for the entire sound of the violin sections: Listening tests performed with a real orchestra have shown that the tonal difference between the case that only the first violins play and the case that both violin sections play *unisono* is definitely greater if the violin sections are distributed on both sides of the podium than when they sit together on the left side of the podium.

2.2 Effects based on the diffuse sound field

The reverberation of a room may support a rounded sound impression, but also it can make the localization more difficult and restrict the clarity. Naturally this depends in the musical structure to a high degree. For example the reverberation is critical if it masks the following notes; on the other hand a rather short reverberation can make the sound dull and may lead to energetic problems in large halls. Therefore the composers' desire for an appropriate reverberation seems to be logical.

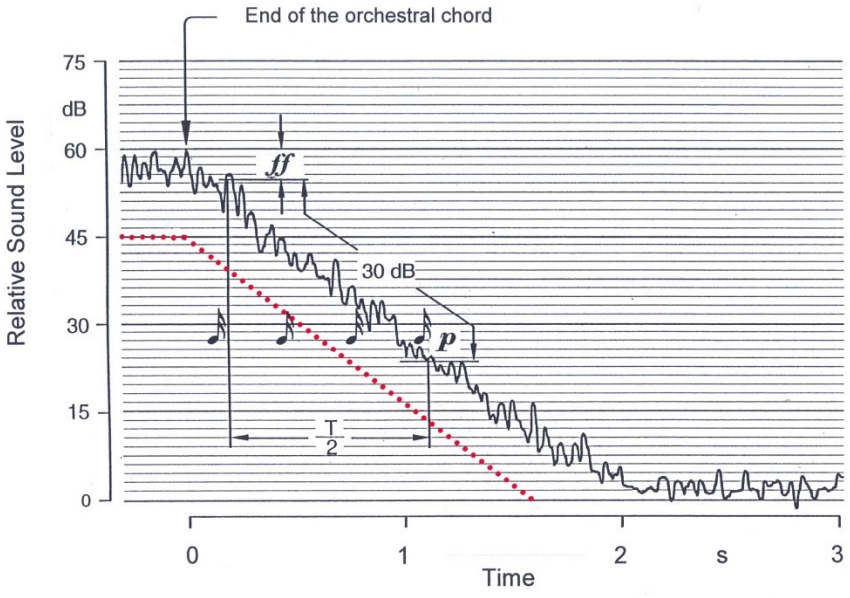

Figure 1, Reverberation of a loud orchestral chord
dotted line: threshold for localization of following *piano*-notes

The reverberation has an extremely disturbing effect if a *piano* or *pianissimo* figure of a single string voice or a single wind instrument immediately follows a loud *tutti* chord of the orchestra. To find the degree of masking the width of the dynamic step is crucial: it can be calculated from the sound power level of the *tutti* when playing *forte* or *fortissimo* and that of the following single voice playing *piano* or *pianissimo*, if the size of the orchestra is known. The first *piano* notes only can be localized if their level is softer by not more than 10 dB than the present level of the decaying reverberation[2], as shown in Figure 1.

If the reverberation time and the musical tempo of a composition are known it is possible to calculate the temporal point at which masking is released. If these factors are known it becomes possible to find evidence of whether the composers has considered the acoustic effect of the room: for example in the musical repertoire there are many passages where after a *forte* breaking off a following *piano* is separated by a sufficiently long rest.

On the other hand there also exist situations in which the reverberation of the room seems to be necessary and its effect is not only tolerated, but even demanded or expected by the composer. Examples are mainly free-standing single chords on high dynamic steps that are followed by a rest.

2.3 Effects based on early reflections

The tonal effect of early lateral reflections naturally existed for age. Therefore one can assume that the “blooming up” of the sound during a great *crescendo* has been felt by musicians and listeners a long time before the physical reason has been found. Today it is clearly known that the sensation of the spaciousness - that is that one senses that the front hemisphere of the listener seems to fill up with sound more and more with increasing loudness - begins at a level that depends on the strength of early lateral reflections. According to Kuhl[3] Figure 2 shows the increasing number of “steps of spatial impression” with increasing loudness of the orchestra.

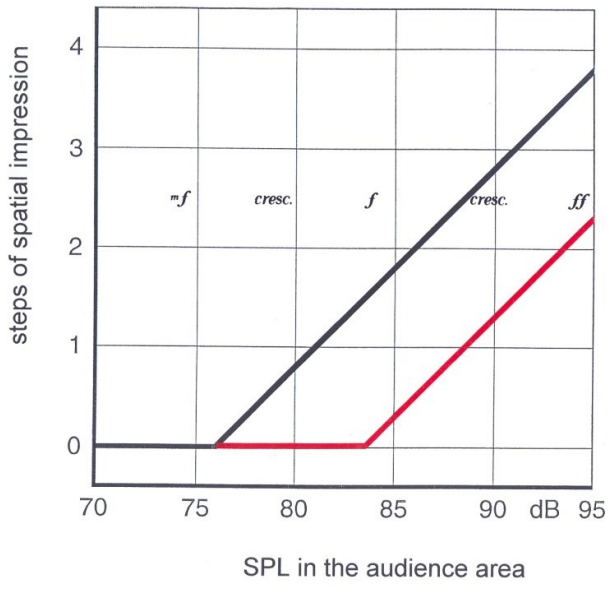

Figure 2, Dependence of the spaciousness with increasing loudness of the orchestra
black line (left): strong early lateral reflections,
red line (right): less strong early lateral reflections

It is a remarkable experience that the apparent source width essentially contributes to the musical dynamics of the orchestral sound as felt by the audience. But as the spaciousness starts at a level that depends of the strength of early lateral reflections, it does not reach the same degree in different rooms. Therefore one may assume that not all composers had a chance to experience this tonal effect. Consequently a look at the great orchestral *crescendi* may be helpful, but in this connection it should not be ignored that the trumpets contribute only a little to the lateral reflections because of their sharp directivity of the higher frequencies. On the other hand loud *tutti* passages including trombones can lead to a high degree of spaciousness and experienced composers may have considered this dynamic effect.

Furthermore it is possible to enlarge the room-filling character of the orchestral sound by doubling several orchestral voices with additional players who are positioned separately in the hall. If these players play the same notes as the players on the podium, the room-filling effect is supported not only by their direct sound, but particularly by the lateral reflections of their sound.

3 EXAMPLES FOR SPATIAL EFFCTS IN SYMPHONIES

3.1 Examples demanding localization

In the symphonic repertoire instruments outside the podium are rather unusual. But a well known example is found in Hector Berlioz' "symphonie fantastique". Figure 3 shows this dialogue between an English horn inside the orchestra and an oboe "lontano", i.e. in some distance. Later, Gustav Mahler made an extensive use of brass instruments outside the podium: In his third symphony, a post horn has to imitate even the impression of changing distances. In his sixth symphony, cow bells and usual orchestra bells are requested behind the scene, and in the final part of the eighth symphony, four trumpets and three trombones shall be "posted isolated". Also Richard Strauss demands a large brass section like hunting horns behind the scene in his "Alpensymphonie".

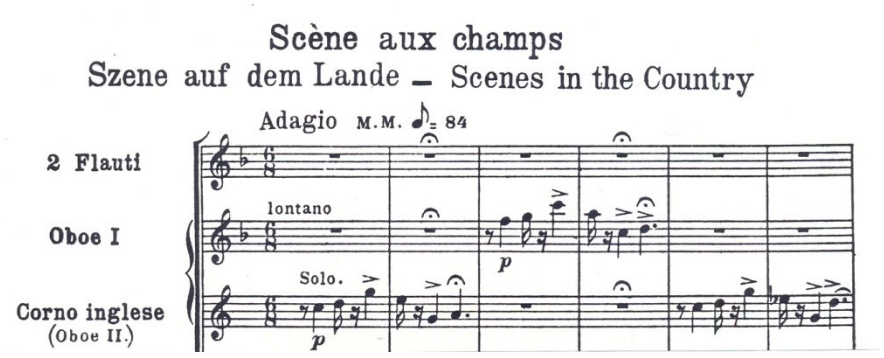

Figure 3, Hector Berlioz, symphonie fantastique, begin of the third movement

Whereas for instruments outside the podium clear descriptions are written in the scores, instructions of how to arrange the different voices inside the orchestra are not usual. But certain imaginations of the composers can be deduced from the kind of orchestration, particularly with regards to the seating positions of the first and second violins. For example, typical dialogue passages are found in Joseph Haydn's later symphonies (beginning in the 1770s), they show a clear sound imagination of separately positioned violin sections. By the way, such passages occur in his last 30 symphonies more often than with other composers even if nearly all composers of the classic and Romantic period use this kind of orchestration - maybe except for Tschaikovsky. The most remarkable

example of the combination of both violin sections is found in Mahler's sixth symphony: there is a passage in which the violin groups are playing *unisono*, however are notated with opposite *crescendi* and *decrescendi* so that the sound receives a spatial motion (Figure 4). That is a clear proof that Mahler had expected the violin groups sitting on both sides of the podium.

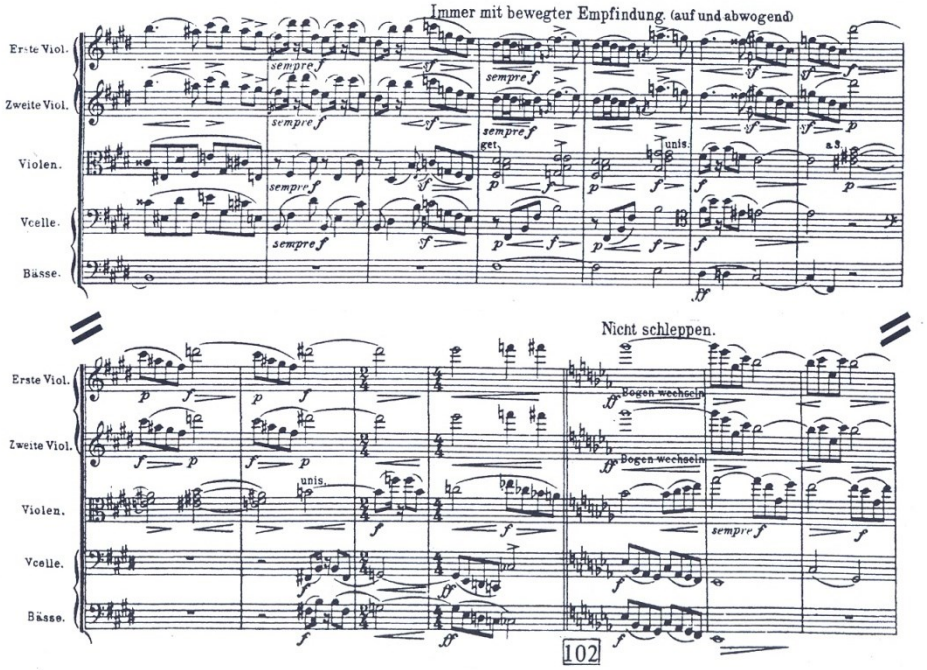

Figure 4, Gustav Mahler, sixth symphony, third movement, measure 164 ff
score excerpt: strings only, please note the dynamics of the first and second violins
"immer mit bewegter Empfindung (auf- und abwogend)" = always with a feeling of motion (increasing and decreasing like waves)

An interesting example for demanding a separation of the violin sections can be found in Johannes Brahms' first symphony: he achieves a special transition from motion in *forte* to calm in *piano* by distributing single notes of rather simple 1/16-runs to both groups in *forte* and together-playing in *piano* (introduction of the last movement, measure 24 ff). On the other hand, there exist a few passages in the symphonic repertoire where a motif runs through all string voices in a rising or falling line. In these cases the question arises whether the composer expected a continuous moving of the motifs through the string sections or a jumping motion or whether they have not thought of the spatial effect. Tschaikovsky liked this technique particularly in the *pizzicato* passages of his third and fourth symphony. Also Beethoven used this kind of orchestration, but only in very rare cases (particularly remarkable in the fourth symphony).

A spatial distinction seems to be desired by the composers not only for the string sections, but also for the wind sections and even the percussion. As a typical example for the brass section, the changing motifs between the horns on one hand and the trumpets and trombones on the other hand in the scherzo of Anton Bruckners' fourth symphony. For the timpani, the fourth symphony of Carl Nielsen may be mentioned: the composer had obviously the idea of a large distance between single instruments: In the original score, there is a remark from his own hand that the timpani II should be positioned opposite the timpani I at the edge of the orchestra close to the audience. By the way, this remark indicates that the composer did not expect listeners behind or besides the orchestra.

3.2 Effects caused by reverberation

The question whether a composer has considered the influence of reverberation often can be solved from the score alone. Mainly this concerns the sluring effect on the musical flow and the sound rounding effect on free-standing chords. But in some cases particularly due to the masking effect it is useful to look at the original performance conditions including the size of the orchestra and the room acoustics of the hall in which the composer performed his own works as this situation may have influenced his spatial sound imagination. For modern instruments the sound power of an orchestra of a given size can be calculated for different levels[4] and it should be mentioned that the sound power of historical instruments does not essentially differ from that of modern instruments[5,6].

This kind of calculation may be illustrated by an example: A very critical passage is found in the slow movement of Franz Schubert's great C major symphony. There follow after a *fortissimo* chord of the full orchestra including trombones *piano* quarter notes of two clarinets and two bassoons (Figure 5). The first performance of this symphony did not take place until 1839 (i.e. after Schubert's death) in the Leipzig "Alte Gewandhaus". Assuming a size of the string sections as they were usual in the "Gewandhaus-Orchester" at that time (9 - 8 - 5 - 5 - 4) and considering the demanded number of wind instruments (15) for this symphony, a sound power level of 119 dB results for the *tutti* and of 81 dB for the *piano* of the winds; that leads to a dynamic step 38 dB. The hall of the first performance had a reverberation time of 1,2 s[7], thus the masking (10 dB below the reverberation level) would enclose - depending of the tempo chosen by the conductor - little more than one eighth note (including the important onset of the first *piano* note. Perhaps Schubert was aware of this effect. But when this piece is played in a modern concert hall with a reverberation time of about 2 s, and assuming larger string sections as usual these days, the masking effect may cover a whole quarter note - an experience that many concert goers may have heard when listening to this symphony.

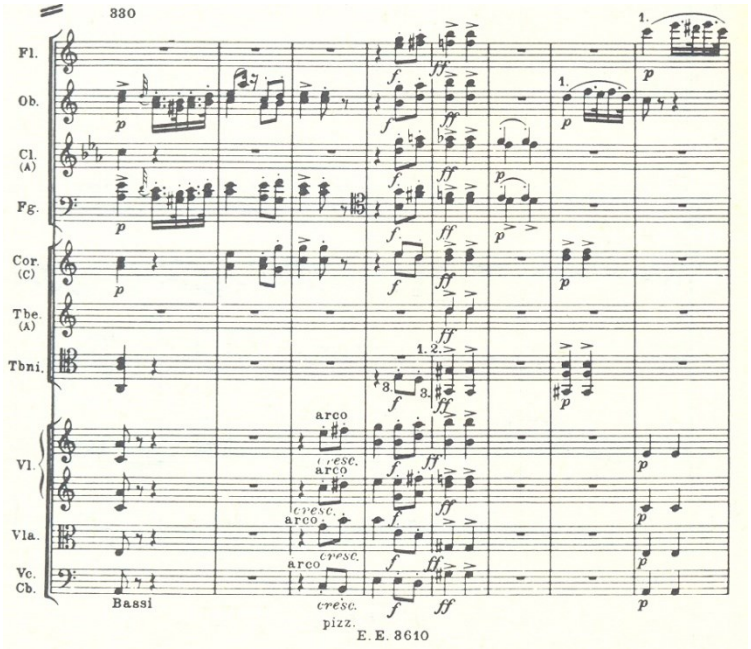

Figure 5, Franz Schubert, great symphony in C major, second movement, measure 330 ff

In the whole symphonic repertoire, such critical dynamic steps are found rather rarely. A few examples occur in Beethoven's first symphony and in Tschaikovsky's third and fifth symphony. The most composers consequently avoid critical dynamic steps by a fuller instrumentation of the following

piano tones or by pronounced rests or even by a fermata over the bar line. But the question remains whether they did it consciously or unconsciously?

On the other hand, the reverberation during rests that follow loud chord may be expected by the composers as a part of the sound impression. Haydn and Mozart seem to see that more or less indifferently as for them the musical structure is the essential base of their works. In Beethoven's symphonies, it often is difficult to decide whether orchestral beats should sound dry or whether a tonal decay in the room is expected for rounding the sound. But undoubtedly, in his ninth symphony the characteristic rests after *forte* or *fortissimo* chords demand reverberation from the room. In the symphonies of the Romantic period, the inclusion of the reverberance of the halls is found very often, particularly in loud passages where it supports the slured lines. For example, as Schumann got his tonal experiences in the Leipzig Gewandhaus, it is not surprising to see that the separated short phrases at the beginning of his first symphony demand some reverberance in order to avoid a dry and dull sound impression. In Tschaikovsky's fifth symphony, there exists a remarkable passage where *pizzicato* chords of all string sections generate a bell-like sound. The use of many open strings underlines the composer's intention to generate a long decay which ought to be supported by the room. Finally it should be reminded, that Brahms, Bruckner and Mahler got their experience in the Vienna "Grosser Musikvereinssaal" and therefore almost certainly have consciously included the reverberation of the hall.

3.3 Room-filling effects and spatial sound balance

The musicians of the 19th century partly may have been aware of the effect that the spatial sound can contribute to an increase of the felt dynamics during a great *crescendo.* For the classical period, one should not assume the same degree of awareness since many performances took place in rather small rooms and sometimes with rather small ensembles. But it may be mentioned that Mozart has written *crescendi* from *piano* or *pianissimo* to *fortissimo* in his symphony K 319 and the serenade K 320. Unfortunately the performance conditions for both compositions are not known. More likely some *crescendi* in Haydn's London symphonies might have been written with the awareness of the spatial effects as he collected valuable experiences during performances in Hanover Square Rooms and the King's Theatre, though he mostly reaches loud passages by clear dynamic steps. A pronounced example of such a dynamic increase is the transition from the third to the fourth movement in Beethoven's fifth symphony where the blooming up of the orchestral sound is evident. As hinted above, in nearly all symphonies of the Romantic period typical examples for great *crescendo* can be found, particularly in the works of Brahms and Bruckner.

Furthermore, full-orchestrated chords or sequences of chords that generate a high degree of apparent sound width and listener envelopment are to be found mainly in connection with the large Romantic orchestras. The row of examples reaches from Berlioz' symphonie fantastique over the works of Schumann and the unfinished symphony of Schubert to Brahms (Figure 6) and Bruckner and even Mahler.

At least for some composers, it seems that the geometric width of the radiated orchestral sound and its influence on the spatial sound balance play an essential role. For example Haydn has distributed the celli and double basses of the relatively large orchestra to both sides of the podium in the Hanover Square Rooms (amazingly: that was noticed and mentioned by the contemporary news paper critic[8]). Naturally, a symmetric tonal balance occurs also if the first and second violin sections are positioned on both sides of the orchestra. Even if that is true for most music, it becomes particularly noticeable if the violins play *unisono* or in octaves. But this kind of instrumentation does

allow to deduce a conscious awareness of the tonal broadening only if both violin sections play *divisi* the same notes as for example in Berlioz' symphonie fantastique (fifth movement) or in Ravel's Bolero. Such an orchestration does not make sense if both violin groups sit closely together.

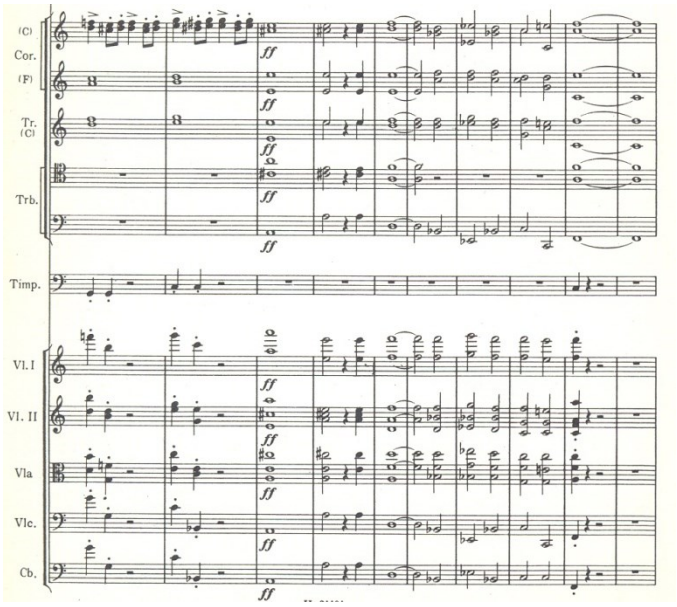

Figure 6 Johannes Brahms, first symphony, fourth movement, measure 405 ff, excerpt without wood winds

A particularly strong room-filling orchestral sound is generated, if some voices of the orchestra are doubled and positioned separately in the hall. Figure 7 shows an example found in the final part of Dmitri Shostakovich's "Festive Overture" where a "banda" (lower three lines of the score) consisting of trumpets, horns and trombones plays exactly the same notes with the same dynamics as the corresponding instruments on the podium. In this situation, not only the direct sound of the banda, but even its early reflections contribute to the room-filling effect.

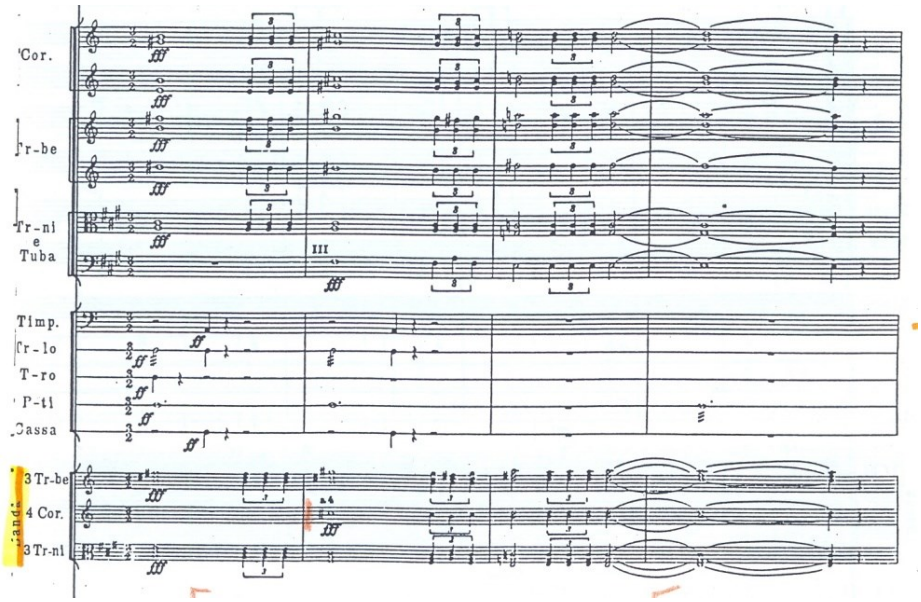

Figure 7 Dimitri Shostakovich, Festive Overture Opus 96, excerpt without wood winds and strings

4 RESUMÉ FOR SOME COMPOSERS OF SYMPHONIES

The present investigation includes all symphonies of Beethoven, Schubert, Schumann, Bruckner and Brahms, furthermore about 30 symphonies of Haydn, the later symphonies of Mozart beginning with K 297, the symphonies no. 3 to 6 of Tschaikovsky and the symphonies No. 3, 6, and 8 by Mahler as well as the symphonie fantastique by Berlioz. Altogether, about 300 symphony movements have been analyzed leading to far more than thousand relevant passages. A summarizing result of the question whether or not and to what extend the individual composers have considered spatial effects is shown in Figure 8. In this table, three steps of localization-related criteria are presented on the horizontal axis and three steps of spatial sound on the vertical axis.

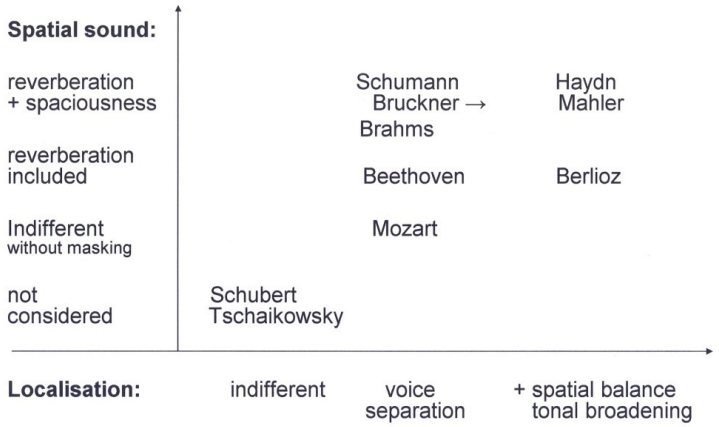

Figure 8 distribution of the composers related to their awareness of spatial criteria

In the symphonies of Schubert and Tschaikovsky any clear indications can be found that they have expected a differentiation of instrument groups by localization, there are any dialogue passages between the violin sections. In Tschaikovsky's sixth symphony, there exists a passage with crossing violin voices which can't be distinguished even under good localization conditions. Both composers seem to be not aware of the reverberation as they have written reverberation-critical dynamics steps.

Mozart often uses dialogue passages between the violin groups. He consequently avoids critical dynamic steps that could impair the fine structure of his musical sequences, but his method of composition does not indicate that he deliberately included reverberation and spaciousness particularly as he very rarely demands extreme dynamic levels.

Reflections on Beethoven's tonal imagination should not be made without taking his hearing problems into account: It is astounding that critical dynamic steps and dry orchestral chords exist only in the first symphony whereas beginning with the second symphony, the number of passages increases that require reverberance as well as a distinction between the violin sections. Moreover in the later symphonies there are found many passages which create a great "blooming up" of the orchestral sound. In spite (or because?) of his increasing hearing problems, Beethoven has included the acoustic influence of the room into his sound imagination.

Berlioz had an exact idea of the positioning of the instrument groups. These expectations show up in the dialogue passages inside the orchestra as well as in the use of instruments outside the podium. He likes the broad sound effect of the strings and the geometrical sound balance of the whole orchestra. He avoids critical dynamic steps, but he obviously expect the reverberance of the room. On the whole, that indicates a pronounced spatial sound imagination and experience.

Schumann used dialogue passages of the violin sections rather rarely, but there occur many passages that obviously demand reverberance of the hall. Critical dynamic steps are consequently avoided. Great *crescendi* and full wind chords may indicate the desire of a high degree of spaciousness. Thus one can assume that Schumann had a pronounced imagination of the spatial properties of the orchestral sound in concert halls.

In Bruckner's symphonies dialogue passages are found not only between the strings, but also between the brass sections. That requires a distinction by a clear localization, on the other hand the spatial separation of the strings leads to a broad sound in *unisono* passages. Reverberation and spaciousness are important components as shown by the typical structuring of rests and fermatas. That indicates pronounced awareness of the seating arrangement and of the effects of spatial sound.

Brahms demands a directional distinction of the violin sections - not only for dialogue passages. He consequently avoids critical dynamic steps, but he sometimes writes chords which really demand reverberation as well as long *crescendi* and full *tutti* chords which lead to a high degree of spaciousness. He obviously had a clear imagination of seating arrangement and spaciousness.

It is remarkable that just the oldest and the youngest composer of this study, namely Haydn and Mahler attach importance to a geometrically well balanced orchestral sound reached by the distribution of the instrument sections. Both they consider and include the effects of room acoustics by avoiding critical dynamic steps and using reverberation as well as spaciousness. Furthermore, Mahler uses additional instruments outside the orchestra, predominantly for dramaturgic effects.

5 FINAL REMARK

The results presented here show that many composers had more or less pronounced imaginations of the spatial aspects of the orchestral sound. But it should not be forgotten that they had only experiences and expectations got in "classical" halls without a surrounding audience. The study may suggest recommendations on this topic not only for musicians and recording teams who desire to reach authentic performances and sound recordings, but also for designers of new halls. Last but not least the results may support the recommendations of acoustical consultants when speaking with architects and concert managers.

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