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ARCHITECTURAL ACOUSTICS: RECENT DEVELOPMENTS AND EDUCATION

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1. INTRODUCTION

Architectural acoustics became a science only round the turn of the century, when W. Sabine proposed his well known theory of reverberation. However, it was not until the early 1960s that the physical sound world and architectural design started developing a creative relationship between each other. This has been mainly the effect of better understanding of the subjective significance of sound, as well as of more liberal thinking in architecture looking for functional design. This is particularly clear in the domain of auditorium acoustics and the present paper will refer to this.

2. ROOM ACOUSTICS RESEARCH AND THE DESIGN OF MODERN AUDITORIA

The understanding of the subjective significance of sound enjoyed an immense development in the early 1970s, when for the first time modern psychometric methods were introduced into auditorium acoustics research [1]. This made it possible to identify subjective acoustic qualities in a scientific way.

The basic tool used for measuring subjective responses is the so-called semantic rating scale. This scale consists of a straight line the poles of which are described by opposite labels; for instance,

live __________V_________________________ dead

Subjects are asked to place a mark at an appropriate distance from the poles, to indicate where their assessment falls.

The data from a number of rating scales can then be analyzed according to multidimensional analysis, which is a mathematical model capable of summarizing the rating scales in terms of a small number of uncorrelated dimensions (or factors). The dimensions are descriptors of the basic acoustic qualities looked for (Fig. 1). The idea of this operation is based on a fundamental theory of psychology, namely the semantic differential theory, which postulates that the perception of any concept is organized psychologically on a small number of uncorrelated dimensions.

Since the 1970s a number of studies have been reported in the literature [2, e.t.c.] which have followed the modern psychometric approach in the investigation of the acoustics of concert halls. By and large, these studies have indicated a consensus view about room acoustical qualities and their associated physical acoustic criteria. Results are shown in Table I.

At the same time, the relevance of the subjectively significant physical criteria to the architectural design of auditoria has been explored. Applications of the results can be seen in a number of successfully built auditoria around the world.

The concert hall of the Berlin Philharmonie is an outstanding example of successfully built modern auditoria. The design of this hall is the first which solved the question of provision of early lateral sound in modern large concert halls, in which side walls are pushed widely apart in order to accommodate as large an audience as possible. Recent research has demonstrated that early lateral reflections are responsible for an important subjective acoustic quality, namely the spatial impression. This effect is amply achieved in the Berlin Philharmonie concert hall thanks to the inventive arrangement of its seating area in free form raked segments (Fig. 2). The vertical steps created by these segments provide important surfaces for laterally reflected sound.

The entire building of the Berlin Philarmonie is a distinctive example of German expressionist architecture, in which architectural forms follow the principle "form follows function". Architectural design and acoustic needs are so well tied up here that one wonders, if the daring and creative plastic forms of the 20th century material - the reinforced concrete, have been mainly inspired in this building by acoustics.

Following the Berlin Philarmonie concert hall, the principle of segmented seating area has been applied with success in a number of other large auditoria. Examples are the Muziekcentrum in Vredenburg, Utrecht Germany, the Roy Thomson hall in Toronto Canada, the Concert Hall in Athens Greece which was opened a few months ago e.t.c.

Another example of creative applications of acoustic principles into architectural design, can be seen in the hall of the University of Warwick Arts Centre in Warwick, England [3]. An outstanding feature of this auditorium is the entirely exposed roof structure, with its open lattice trusses, walkways, ventilation ductways e.t.c. (Fig. 3). All these elements greatly encourage the provision of diffuse late sound to the entire audience area. The subjective significance of late sound re the early sound portion in concert auditoria has been demonstrated in a number of studies over the recent years [4, e.t.c.]. At the same time these features are symbols of modern technology promoting liberal technological fantasy, and they are reminiscent of their startling predecessor the "Pompidou" cultural centre in Paris France.

By and large technological acoustic knowledge for the design of auditoria is available.

What is important now is that this knowledge is presented to the designer in his own language.

It is the task of teachers to present acoustic knowledge to architectural students translated into architectural vocabulary. For this purpose teachers can use their creative imagination, together with good resources of translations some of which have been described above. Of course, the use of architectural vocabulary into poetic expressions in buildings will still remain the skill of the designer.

3. MUSICAL COMPOSITION AND ARCHITECTURAL DESIGN

With the introduction of electroacoustic media into contemporary musical composition, the possibilities for musical expression have been largely enhanced, and this has resulted in an increasing awareness amongst composers that there are intrinsic relationships between music and the architectural space.

An illustration of this idea can be seen in the "Musik fuer ein haus" composed by Stockhausen and first performed in 1968 at the Masonic lodge in Darmstadt.

The choice of a masonic lodge for the performance of this composition was important, since movement through the sequential space in this kind of building offered itself for the purposes of the composition. The musicians performed in four rooms spread over two floors, while visitors could walk from one room to another. At the same time the musical ensembles in each room changed in size and composition as musicians moved at times from room to room. Music was picked up by microphones in each room and was played through loudspeakers into the rest of the rooms [5].

This novel arrangement changes the traditional order between musicians and audience and gives extra meaning to the ceremonial context of architecture. The music does not consist any more a single view point for the audience, but it changes in space as the listener is moving simultaneously through the building and through the musical sound effect.

A typical example of architecture inspired by the above idea has been the West German Pavillion at the Osaka World Fair of 1970. Stockhausen composed his electronic music for the Pavillion, but also he specified the architectural design of the Pavillion into which he integrated the elecroacoustic media.

The Pavillion was a spherical space-frame structure, with 50 loudspeakers mounted on the inside boundaries of the sphere. Music was rotated from one loudspeaker to the next in horizontal, vertical and diagonal circles or in looped spirals, and as several paths of sound could occur simultaneously polyphonic layers of music were created in space, just like the listening to birds flying across the forest [5].

It is clear in these examples that the architectural space is now involved in the musical composition, not only in terms of its acoustical properties but also in terms of its ceremonial as well as its visual aesthetic context.

The role of education in architectural acoustics here is broader than before. The designer needs also to understand a little of the structure of contemporary music effects, in order to grasp the specifications of the composer and translate these into architectural expressions. This understanding can be very useful for both sides, i.e. for the composer and the designer, and can enhance the meaning of the architecture of auditoria.

The idea of association of the visual space with the musical composition has been further elaborated in our days by the Greek composer and architect Iannis Xenakis. An early but typical example of his work has been the Philips Pavillion at the Brussel's World Fair of 1958, for which Xenakis used as a resource his musical composition "Metastasis". "Metastasis" is based on the idea of long glissandi (glissando is a rapid sliding up or down the musical scale) sufficiently interlaced, so as to produce a sonic space of continuous evolution. If glissandi are likened to straight lines then a set of ruled surfaces can be produced, for instance a synthesis of hyperbolic paraboloids (Fig. 4) which is the geometric equivalent of the sonic space [6]. This is exactly the idea on which the design of the Philips Pavillion was based (Fig. 5).

The role of education in architectural acoustics here becomes even broader. The search for architectural forms which can express visually a musical piece is an open question which requires solutions from both the designer and the composer. Understanding space geometry is a prerequisite in this search. Furthermore, research methods are available for the investigation of relationships between the audio and visual environmental perception; As an example reference is made to modern psychometric methods which were discussed in section 2. A review of such methods is necessary to be incorporated in the teaching of architectural acoustics so as to awaken the research oriented architect as to the possibilities emerging from the application of modern scientific methodology.

4. CONCLUSIONS

Developments in architectural acoustics over the last thirty years or so, have transformed the boundaries between the physical acoustic world and architectural design into a creative interface. At this point architecture is capable of enhancing its meaning and its overall aesthetic context.

Of course, education in architectural acoustics plays an important role in the fulfilment of this idea. For this purpose: First, it is essential that technological acoustic knowledge is presented to the designer into architectural language, so as to awaken his artistic sensibilities. Secondly, it is essential that the designer broadens his understanding of the structure of contemporary music effects. Last, education in architectural acoustics should also be administered to the research oriented architect. With respect to this, the architect should become aware of the questions arising at the interface between the two disciplines i.e. the physical acoustic word and architecture, and modern scientific methods suitable to investigate such questions should also be reviewed.

5. REFERENCES

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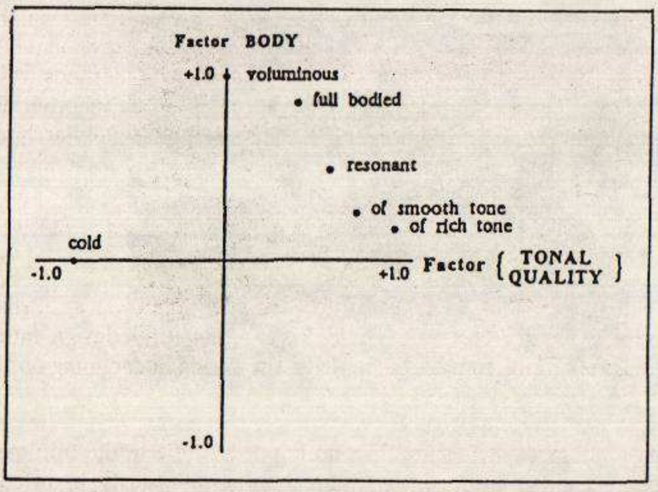

Fig. 1. An example of identification of factors of semantic acoustic space.

Table I. Subjectively significant physical criteria of concert hall acoustics.

Physical Criteria	Subjective Correlates
1. 80 ms late-to-early sound index	Body
2. Early lateral energy fraction	Spatial Impression
3. Total sound level	Loudness, aural Proximity
4. Early decay time	Reverberance, Clarity (negative correlation)
5. Slope per octave of the early decay time	Tonal Quality

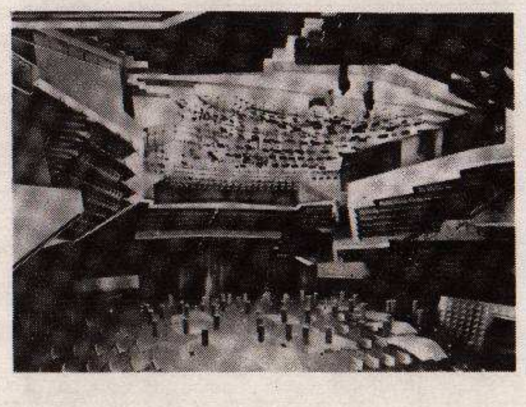

Fig. 2. Inside view of the concert hall of the Berlin Philharmonie (M. Forsyth [5]).

Fig. 3. Inside view of the hall of the Universtiy of Warwick Arts Centre, Warwick, England (courtesy of D.B. Fleming and RHWL).

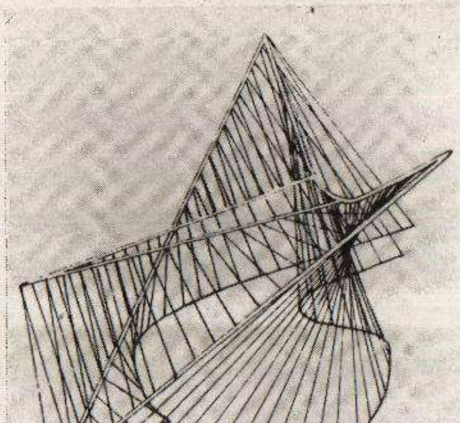

Fig. 4. First model of the Philips Pavillion, Brussels World Fair 1958 (I.Xenakis [6]).

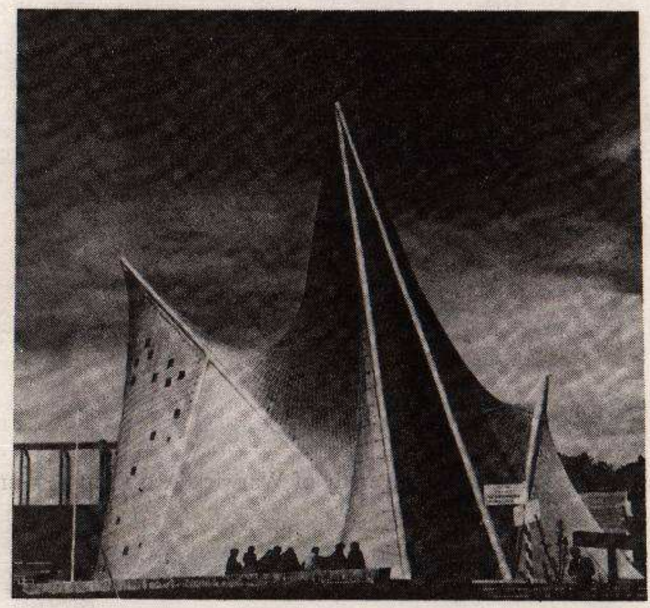

Fig. 5. View of the Philips Pavillion, Brussels World Fair 1958 (M. Forsyth [5]).