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Review of aspects that shape the aural experience in worship spaces

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Abstract

Physical measurements of architectural acoustics do not precisely reflect the human acoustical experience in worship spaces. While many studies focus on architectural acoustics, aural architectural analysis that includes perceptual and cultural aspects, in addition to the physical aspects, and provides more comprehensive understanding of the aural experience, is afforded less attention. Worship spaces require complicated acoustical environments that allow both the hearing of sound clearly and the experiencing of sound aesthetics. This experience can create emotional effects through the perception of sound; therefore, there is the need for further study on the relationship between the qualitative and quantitative acoustical characteristics of religious buildings. This review paper provides a comparative analysis of previous studies in terms of physical, perceptual and cultural aspects of acoustics, and further clarifies the research gap in this area. Finally, it recommends strategies for studying the aural experience in worship spaces through the interaction between the cultural influence that affects how a specific sound is perceived, and the architectural elements that change acoustical parameters, thus playing an important role in the perception of the sound in the space.

Keywords: aural architecture, soundscape, auralization, perception, worship spaces.
Review of Aspects that Shape the Aural Experience in Worship Spaces

1 Introduction

‘But I don’t want to hear a pin drop, I want to hear the orchestra!’ Leo L. Beranek (1962).

The measurements of architectural acoustics do not precisely reflect the aural experience. This can be clearly seen when two concert halls have the same reverberation time but different acoustical qualities; which can be explained by distinguishing between architectural acoustics and aural architecture. While architectural acoustics mostly focus on the physical measurements of sound inside the space, aural architecture includes perceptual and cultural aspects.

Although perceptual acoustics are connected to psycho-acoustics, nonetheless, it is important to clarify that the focus of this study is the psychological effect resulting from spatial design more so than the sound itself. In order to illustrate this, music can create a psychological effect when heard using headphones. Nonetheless, the focus of this study is directed towards the psychological effects resulting from sound reflections from the architectural surfaces, which change our perception of sound, such as spaciousness.

‘Aural spaciousness’ is an example of aural architecture that highlights the interaction between physical acoustics, perceptual acoustics, and cultural acoustics. In religious buildings, it is important to enhance the feeling of majesty (Ergin et al.), which is related to ‘cultural acoustics’. This feeling is connected to the perception of being surrounded by sound ‘perceptual acoustics’, and is affected by the late reflections of sound, which is created by side walls, especially when the reflections from each side is different between about 100 and 300 milliseconds [1] ‘physical acoustics’. Hence, the important question for architects is ‘Which design variable should be changed to get a specific aural experience?’ Therefore, researchers seek to find equations that translate the perceptual experience into numbers so as to allow for predicting the effect and accordingly solve the problem during the design phase—which is where additional important questions arise, including ‘To what extent should architects try to control the aural experience? Does the increase in control help in enhancing the experience?’

2 Aural Architecture Aspects

This section includes examples of the studies explaining the role adopted by physical, perceptual and cultural aspects in shaping the aural environment. It also includes examples that emphasize the importance of the interaction between the three aspects.

2.1 Physical Aspects

Takahashi et al. explained how the design of the sound diffuser can affect our perceptions of sound, with the research showing that periodic diffusers can create sound coloration if the listener
is very close to the diffuser, the reason for which is that reflection delay in the critical distance is within the perceptual threshold of coloration [2].

Robinson et al. carried out a study aimed at exploring the role of architectural surfaces in localizing sound source. According to the study, sound absorbers and flat surfaces allowed for easier localization than sound diffusers [3]. This occurs because diffusers create homogenized reflections in each direction, which makes distinguishing the location of the source more difficult.

Vorländer et al. compared the effects of the objective measurements of reflective, absorptive, and diffusive surfaces in subjective measurements; the objective measurements indicated that the diffusive surfaces resulted in lower Early Decay Time (EDT) and a higher number of peaks (Np) in the impulse response. The subjective results also linked between the subjects’ preferences of sound, the decrease in EDT and increase in Np, meaning that the physical acoustics can be used to control the perceptual acoustics, and that the perceptual experience can be predicted using objective measurements [4].

2.2 Perceptual Aspects

Cook et al. studied the effect of the design of the interior architectural surfaces of ancient structures in humans’ brain activity using Electroencephalography (EEG). The research demonstrated a shift in the regional brain activity, which creates emotional feelings at the frequency 110 Hz (the primary resonance frequencies in the ancient structures). Cook et al. noticed significant rocks tilted in specific angles, suggesting that this might be intentionally done in order to change emotions and support rituals since the buildings were used for religious purposes [5].

Sudarsono et al. compared psycho-acoustic and physio-acoustic measurements to test which one provides more accurate results for the optimum reverberation time for music in concert halls; the results of the physio-acoustic using EEG were closer to the calculated reverberation time than the results of psycho-acoustics, as based on paired comparison [6].

Zündorf et al. conducted a research that focused on identifying the part of the brain that shows response when localizing a sound source in a crowded and noisy environment using functional magnetic resonance imaging (fMRI) and EEG [7]. Although the study focused on direct sounds, it provided information that can be used to test the effect of architectural surfaces in localizing sound.

2.3 Cultural Aspects

Crunelle analyzed the architectural elements shaping the acoustical environment of traditional Western architecture, such as Acoustical vases and Whispering galleries. The analysis illustrates that acoustical designs were not accidental, and that they were based on experience [8]. Therefore, further research in this area is required in order to establish more about the acoustic tradition in different cultures.
Ergin applied a similar approach through examining the soundscape of sixteenth-century Istanbul mosques. The study included an analysis of the main activities, such as Qur'an recital, and how the architect considered the acoustical requirements of these activities in designing the mosque, which resulted in a reverberation time, allowing for understanding the words of Qur'an and adding aesthetics to the sound at the same time [9].

Thompson further studied soundscape and considered it an importance part of the history of a specific culture. The focus was in the early-twentieth century (1900–1933) because of the technological changes that appeared during that period. The use of new materials changed the sound behavior in space, and there was more separation between space and sound. The electronic devices allowed for more sound control, with the reflections of the architectural surfaces becoming unnecessary. Therefore, more absorptive materials were used to illuminate any additional reflections from architectural elements, which made the sound in different spaces very similar [10].

It should be pointed out that some of the studies mentioned above involve more than one aspect, but the categorisation of this paper is based on the main focus of each research. Figure 1 provides a summary of the methodologies used by researchers for physical, perceptual and cultural acoustics.

Figure 1: Examples of the methodologies used by researchers for physical, perceptual and cultural aspects.

3 The Interaction between Aural Architecture Aspects

The following section provides examples that emphasize the importance of studying the interaction between physical, perceptual and cultural aspects in studying aural architecture.
3.1 Physical and Cultural Aspects

Elicio et al. argued that it is important to consider acoustics as cultural heritage; they examined the role of architectural elements in shaping the acoustics of the space by using field measurements (microphone arrays) to analyze the acoustics of the Orthodox Church of San Nicola in Bari. The researchers found that, although this church was relatively more recent, it has similar acoustical characteristics of other Orthodox churches because it has similar architectural main features. On the other hand, Catholic churches experienced many changes in architectural features, which resulted in different acoustical characteristics as a response to changes in liturgy [11].

The study of Suárez et al. supported Elicio et al.’s argument, and further claimed that archaeoacoustics with virtual reality auralization techniques provide an opportunity to recover the acoustical experience or memory of a destroyed building, such as the Maior Ecclesia in Cluny. Simulation software allows for constructing the physical elements of the space and generate sound though auralization that mimics the actual sound of the space [12].

Woszczyk further used simulation and auralization to create a virtual model of Hagia Sophia. The researcher also used field measurements as a reference for the realistic acoustical characteristic. The measurements were taken at different locations of the space to record a combination of impulse responses; this provided the reverberation time in these location, which created a moving render of auralization that reflects a similar acoustical experience of being in Hagia Sophia [13].

3.2 Physical and Perceptual Aspects

Schröder et al. explained the details of the moving render of auralization, which they refer to as ‘real-time auralization’. This system has a screen and multiple speakers at different locations. The screen shows a view of a virtual space, and as the camera moves and the visual changes, the impulse response is recalculated. The reason for the recalculation is that direct sound, and early and late reflections provide cues concerning the sound source and the room, and further have different values at different locations. In real-time auralization, the direct sound is required to be recalculated if the source or receiver moves few centimeters, while the late reflections that provide information about the volume of the room need to be recalculated if any of them moves more than one meter. Another important factor is sound direction, which is important in creating more accurate auralization because humans recognize the location of the sound source by assessing the difference in sound pressure level at each ear. [14].

Vorländer et al. compares the existing simulation and auralization tools, and adds that virtual reality is a promising tool for analyzing sound perception in architectural studies, but requires further development to overcome some challenges, such as simulating sound insulation and diffraction [15].

Sheridan et al. stated that, although simulation is powerful in analyzing the acoustic characteristics, it has some limitations when adopted as a design tool [16]. An example is the lack of capability of simulation programs to predict the diffusion of the small architectural elements.
3.3 Perceptual and Cultural Aspects

In order to analyze the aesthetics of the sound that can be perceived in a specific place, Pentcheva conducted a study that follows a phenomenological approach by examining descriptive text of Hagia Sophia and comparing it with an auralization of a Byzantine chant in the same space. Poetry was used by art historians to describe object shapes; therefore, the author used Byzantine ekphrasis to describe the experience. Pentcheva stated that Byzantine ekphrasis ‘both documents and sustains this interaction between the real, the perceived, and the imagined’, and therefore used them to draw a connection between the visual and aural perceptual aspects, and spiritual needs, as based on the cultural background of the users. An example of this is how the long reverberation is connected to the Holy Spirit [17].

Arkette also used phenomenology to describe the soundscape of the city, and further pointed out that studying the social and cultural aspects of soundscape is rarely considered, although it can help in understanding social relationships between communities. Soundscape can create an illusion by connecting or isolating people. Listening to the radio is an example of connecting with people from far distance, and listening to music using headphones is an example of being isolated from surrounding people [18].

4 Aural Architecture of Worship Spaces

Worship spaces require complicated acoustical environments because they involve spiritual needs that enhance faith, such as the presence of the divine [19]. Although religious buildings share some common characteristics, the worship activities differ between religions. This emphasizes the importance of considering the cultural aspects in analyzing the aural architecture of worship spaces. In order to fulfill the cultural requirements, there is a need to understand how acoustics can create certain perceptual effects when physical parameters are manipulated.

Researchers point out that the reason behind the low acoustical quality of some concert halls is the lack of understanding the physics of sound propagation in space, the psychoacoustics of how sound is perceived, and the aesthetics of how sound is preferred to be heard [20]. Ando et al. presented a comprehensive approach by developing a model that allows for optimizing the design of concert hall depending on listeners’ preferences. This was achieved by analyzing the temporal and spatial acoustic parameters affecting preferences, and accordingly linking them to human sensations, such as sound loudness and localization (Figure 2). This is also achieved by correlating the same parameters with auditory percepts using neural analysis, then applying Genetic Algorithm to modify the shape of the hall to satisfy the largest number of listeners [21]. This research has provided guidelines for designing concert halls; nonetheless, there is a need to study the applicability of this approach for other types of building that have different cultural requirements, such as places of worship, especially in the sense that there is a limited number of studies on the acoustics of worship spaces in comparison to concert halls.
In addition, designing religious buildings induces many challenges, such as creating perceptual effects, such as the ‘Holy Spirit’, which indicate the importance of developing parameters that allow for measuring the subjective qualities of sound for worship activities. The parameters also will help in predicting and providing guidelines for designing the aural architecture of worship spaces: for instance, a third column can be added to Figure 2 to connect cultural requirement, such as the presence of the Holy Spirit, and the sensation associated with it.

Another challenge architects may face is related to the degree of control of the aural environment in achieving the goal of creating a high-quality experience. It might be argued that the role of architectural surfaces is not very important as the acoustics can be controlled using electroacoustic enhancement systems. An example of this could be creating spaciousness in a worship space using sound speakers [22]; in this case, the effect of the architectural surfaces needs to be eliminated by using sound absorbers [23]. Unlike concert halls, where the goal is to create a uniform acoustical environment, religious buildings have different acoustical parameters’ requirements for different source locations: for example, the apses should be designed in a way that reinforces early reflection for speech when the worshipers are close to the worship leader, and the dome should be designed to create late reflections for music when the worshipers at different locations [11]. Hence, although the electronic system can achieve the main goal in creating spaciousness, nonetheless, it could create some results that partly contradict with required aural experience in worship spaces, such as creating the sense of mystery, which sometimes is a result of the surprising reflections the worshipers experienced at different parts of the place and in different periods of time. Furthermore, some worship activities require the movement of the sound source as an essential part of the experience, such as bowing. Accordingly, while the religious leader is bowing and the worshipers are also bowing, their
experience of listening to the natural sound of the leader when he is moving will be different, while it might be the same if the leader is using a microphone. This could provide an example of what Marshall McLuhan meant when he said ‘speech gives a structure or an ‘invisible architecture’ to . . . space’ [22].

Furthermore, the architectural surfaces play an important role as an extension of musical instruments [22]. In order to illustrate this point, let’s compare the experience of perception of sound resulting from two different scenarios, namely A and B. Scenario A includes listening to music in a reverberant place, such as a church, while Scenario B includes listening to a recording of the reverberation of music of the previous scenario. Now, let’s imagine repeating the two scenarios again. When repeating Scenario A, the perception of the sound could be different on the second occasion because the direction of the sound source moved, meaning the angles of the reflected sound change. However, when repeating Scenario B, the sound will be exactly the same. Therefore, when listening to recorded music, you will hear the same sound exactly, but the joy of going to the event place is that there will be something different—a surprise that adds richness to the aural experience.

Since it is difficult to focus on how to design a space with better acoustics, researchers focus on minimizing sound defects [1]; to do that, they try to find the solution that works for different scenarios in the best way, which means that we will lose the best solution for each individual scenario by trying to find the solution that work for all, and since aural architecture has qualitative values, the task will be more challenging. An example for that is designing a worship space for different religious groups based on the optimum reverberation time. While this will work for different kinds of worship, the best reverberation time for a specific worship activity might be lower than another type. This does not mean that we cannot design one worship space for different groups, but rather could mean creating a flexible design that allows for modifying the acoustics according to the required activity. An example of flexible acoustic architectural elements is the cymatic diffusers that can provide a variety of visual and acoustical design solutions by re-arranging the diffusers [24] as shown in Figure 3.

![Figure 3: Cymatic diffusers](source)
This leads to another important point, which is the relationship between the visuals and auditory sensations, and how they affect the perception of space. Blesser et al. clarified how the conflict between what we hear and what we see makes us uncomfortable [1]. This can explain the difference between experiencing spaciousness created by the sound reflections from the architectural surfaces and the spaciousness created by electroacoustic systems in a room covered with absorbers. The visual attributes of the detailed ornamental elements ‘muqarnas’, which the architect Sinan designed in Turkish mosques in the sixteenth century [9] create a harmony between the senses as the surfaces diffuse sound and light at the same time. Blesser et al. pointed out that the harmony between the senses is important in creating positive emotions [1], and since emotions is important in worship places, the aural architecture (not only the physical acoustics) of such buildings becomes more critical. Elkins pointed out that there is a large number of examples of art work that bring viewers or listeners to tears [25], and since architecture is art, Blesser et al. stated that creating such effects using aural architecture is rarely found, although it has high potential [1].

5 Final Remarks

Since worship spaces require a unique aural environment that is essential in supporting the ritual activities, there is a need for more research in this area in an effort to understand the role of architectural elements in creating certain perceptual effect that fulfills the cultural requirements. In addition, previous studies indicate a strong correlation between audio and visual perceptual aspects; therefore, controlling acoustics using electroacoustic enhancement systems is not sufficient in achieving high-quality aural environment. Since sound perceptions depend on physical attributes that can be controlled to some extent—and cultural aspects that are difficult to predict or control—trying to create an aural controlled environment is a challenge; even if it able to be achieved, it might lack some aesthetical qualities. On the other hand, aural architecture offers a comprehensive approach involving interaction between physical, perceptual, and cultural aspects of acoustics; therefore, the development of the parameters of the subjective qualities of worship spaces will provide guidelines for architects to design religious buildings with high aural architectural qualities.

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References


