24th INTERNATIONAL CONGRESS ON SOUND AND VIBRATION
23–27 July 2017, London

CREATING A PSYCHOLOGICALLY SUPPORTIVE ENVIRONMENT THROUGH AURAL ARCHITECTURE

Alaa Algargoosh

University of Michigan, Taubman College of Architecture and Urban Planning, Ann Arbor, Michigan, USA.
email: alaas@umich.edu, alaa.algargoosh@gmail.com

Being the field that integrates the physical aspects of architectural acoustics with the perceptual and cultural aspects, aural architecture is to provide a high-quality acoustic environment which responds to human needs and enhances their well-being. Providing a framework of understanding environments, the Reasonable Person Model (RPM) has been applied to several studies to analyze how the design of environments affects humans based on their information-processing system, which includes three domains: model-building, effectiveness and meaningful actions. This research applies RPM to provide an understanding about the role of the aural environment in the three domains of information processing: first, how sound reflections from different shapes, materials and volumes of architectural spaces plays a significant role in creating a soundscape that contribute to understanding the environment and generating a mental map of the place; next, how sounds created by these reflections act as a sensory stimulus, which affect human effectiveness by resulting in attention-fatigue and how acoustic aesthetics can act as an involuntary fascination that allows for attention restoration; and last, how creating a preferred aural architectural design through applying the preference-matrix model can lead to a supportive environment.
Keywords: aural architecture, architectural acoustics, psychoacoustics, supportive environment, reasonable person model.

1. Introduction

Our behavior is directly affected by our environment as humans, we need to understand it to feel comfortable; said understanding is achieved through the information-processing system. Although complicated, there are some studies which have attempted to build models that can allow us to explain this. Offering us with some explanation concerning how we make sense of our surroundings, the Reasonable Person Model is one of the models that demonstrates how this process influences our behavior.

Used in many studies to analyze the information-processing system of environments, the Reasonable Person Model deals with physical and non-physical environments [1]; some researchers have used it as a tool to find tactics for encouraging sustainable behavior and minimizing energy use [2]; and others have used it to design healthcare systems or computer software programs [3]. People tend to spend large amounts of time inside buildings; therefore, buildings are considered as a type of environment. However, architects spend great effort designing how the building will look, but less in how it is going to sound. Aural architecture deals with physical, perceptual and cultural aspects of sounds inside buildings. Aiming to explore the role of the aural architecture in perception and model building, this study additionally focuses on the effect of designing supportive aural environments based on preference. It also explains how the three previous factors are related to attention capacity in a way that they can contribute to attention-fatigue or attention-restoration.

2. Aural Architecture and the Reasonable Person Model

Aiming to provide further details regarding the application of the Reasonable Person Model, this section analyzes how perception, model-building, attention and preference play key roles in creating a supportive aural environment.

2.1 Perception and Model-building

Understanding the environment is essential for humans to feel comfortable, a process involving two mechanisms: perception and building models (cognitive maps) [3].

Relating to the creation of internal representation of objects by extracting the salient features, perception can be achieved by study of some features, such as the location and contours of an object and with repeated exposure to the same object in different experiences (e.g. different context, angle view, etc.), the common salient features are built without high details. Therefore, humans can recognize the object even with just partial input, as well as the speed of making conclusions concerning the object is prioritized over accuracy [1]. In terms of sound perception, the internal representations (sound objects) are generalized abstract copies of the acoustic information in different situations based on past experiences: these sound objects are used to create mental maps of the auditory scene and space where this scene occurs.

There are two aspects that affect perception: definiteness and stability. Although we can perceive sound clearly even if the stimulus is vague or disturbed (the reason being our past experiences allow us to make the best guess, which can be close to the exact object) [1], definiteness increases accuracy in the perceiving of an object. For instance, although they are not very clear, we can listen to certain pieces of music that we are familiar with in a place with high reverberation and accurately guess the words. The echo effect minimizes definiteness and creates an indirect form of illusion; this can be positive in some cases, as well as, indeed, negative in others. An application of utilizing the effect of sound illusion is when the sound of a specific note mixes with the echo of another note in a reverberant place to produce different note: for instance, the notes C, E and G can create an illusion of a C major cord in a highly reverberant space [4]. On the other hand, the lack of definiteness due to echo might disturb speech understanding in other activities such as attending a lecture which will maximize the use of directed attention and negatively affect the place users, and this will be explained more in the attention section. Furthermore, perception is the interaction between humans and their environment [5] and stability is an additional significant factor in distinguishing an object from a background. Although change is important for perceiving the environment, it can affect perception negatively if too rapid [1]. As a way to localize the source, we move our heads to gather more information concerning the direction of the sound; however, if we consider being on a rollercoaster in a dark, enclosed space, such as the Rock 'n' Roller Coaster in Walt Disney Studios® Park, Paris, it would be extremely difficult to localize the sound speaker—or even get a sense of our location in the space because of the fast movement.

Figure 1: Rock 'n' Roller Coaster in Walt Disney Studios® Park, Paris [6]

Additionally, the conflict between the change in the sound that we hear, as well as the change of the physical environment that we perceive the sound in, affect our perception of the environment. Consider listening to a live performance in a concert hall with movable panels that reduce the ceiling height; in this case, there will be no conflict between the aural experience and the physical environment. Conversely, because the sound that we hear includes the acoustic cues generated by the sound reflections in the original concert hall where the sound was recorded, by both the digital space synthesis and the reflections from the room where we are listening to the sound [4], when listening to a piece of recorded music of the same concert in another space, the relationship between the sound and the cognitive map that we build of the aural environment differ.

Furthermore, the harmony between the senses also contribute to stability, and therefore affect perception, meaning the information the brain receives regarding what we hear and what we see should be consistent; and if they are not, the conflict creates difficulty in perceiving the environment, therefore making it uncomfortable. It also adds more load on using the direct attention in order to make sense of the surroundings [1] . In terms of aural architecture, we are constantly experiencing different sounds and connecting them with visual characteristics; for example, when walking on a wooden floor, we expect it to create a certain sound; similarly, upon entering a space with a large marble-covered dome, we anticipate echoes. Conversely, sitting in a place with headphones in our ears creates a disconnection between what we see and what we hear, which may negatively affect our perception of the environment [4]; hence, when architects or acoustic engineers try to eliminate the effect of the architectural surfaces by covering them with highly absorptive materials and then try to reproduce the spatial characteristics of a reverberant space using loudspeakers to get more control of sound reflections, the different inputs that we receive can create a sensation of discomfort. Thus, the full control that they achieve does not necessary result in a more pleasant environment; therefore, it cannot be considered a supportive environment that enhances our perception of the space.

In addition, researchers demonstrated that as well as the perception of the environment, the auditory cues are important in the perception of our movement [7]; an example that demonstrates the effect of sound cues in our movement is walking with and without headphones; when doing this, we may notice that the first case requires more attention, as it can force us to make more effort to gather visual information about the surroundings to avoid falling or hitting an object.

Furthermore, stability can influence definiteness. The perception process is easier when the background is stable and the object is moving, as the latter involves distinguishing the object from the background [1]. If we return to the example of the rollercoaster, we may find that the absence of stability affects definiteness at the same time, therefore creating a sensation of scariness due to the lack of being able to perceive the environment.

Previous perception fundaments concepts contribute to forming internal representations which create the base of the mental maps. The more we get exposed to the same object in different situations the stronger internal representation; since environments contain large amounts of information, we create an abstract internal representation depending on experiences in different situations, which acts as representation of the original object. One example is identifying a melody even after transposing or sound compression, as well as even recognizing it when being played with different instruments. The abstract form contains the salient features which are, in this case, the pitches.

Based on building networks that connect the objects with rich structures of knowledge (formed through relation to space, experience, or time of an event), the next stage after perception is knowledge. Repeated experiences tend to make humans at ease, and promote anticipation of what happens next, allowing for increased precision of prediction, and he role of aural architecture is to enhance this process, since the cognitive maps allow us to interact with the physical and nonphysical environment.

The human information-processing system involves creating mental maps of the space using different cues that the senses provide; auditory cues play a key role in forming such maps, especially considering they, unlike the visual cues, allow us to receive spatial information without the necessary need to move our heads [8]. Since spatial audio cues depend on the reflection of sound from the surrounding surfaces, architectural elements have major effect in creating the mental map; Blesser *et al.* demonstrated the effect of architecture in echolocation, as well as explaining how architects can design spaces that distort the size and intensity of the speaker [4]. Robinson *et al.* have investigated the role of sound diffusers, reflectors, and absorbers in locating the sound source, concluding sound diffusers tend to cause difficulty in localizing the sound source because they provide a homogenous special and temporal reflections [9]. Having the possibility of resulting in attention-fatigue, the auditory illusion influences the process of mental map creation, and requires more directed attention. Additionally, complex auditory scenes could require more attention [10] because of the complexity being possibly resulted by being in multiple acoustic arenas, especially when it is difficult to distinguish a sound event from another. This will be explained in further detail in the preference section.

Creating a mental map of the space includes collecting information about the temporal and the spatial characteristics of the aural environment. In a concert hall, the temporal characteristics controls the length of the note which gives us the feeling of being in a large room (speciousness), and spatial characteristics transforms the note and gives the feeling of being surrounded by sound (envelopment) [4]. By adding more sound diffusers to the hall, the speciousness can be accomplished, and envelopment can be achieved by locating the sound diffusers or reflectors in a fashion which allows for hearing different reflections in each ear. On the other hand, creating highly diffusive and absorptive places, such as the acoustic champers, results in losing sense of space. Since it is difficult to define the original direction of the sound source as opposite to having a spectral reflector that focuses the reflection in one direction and therefore giving a clearer cue of the location of the sound source, extremely high homogeneity in the reverberation from different directions create the sensation of flying [4].

2.2 Attention

There are two categories for attention: directed attention and involuntary fascination. The first, directed attention, is linked to the state of mind that is required to voluntarily respond to stimuli, focus on ideas, perform tasks (which are important, although not interesting), and avoid distraction; the second, involuntary fascination, is related to the effortless attention as involuntary response to stimuli. The directed attention is finite and there are many situations that can result in directed attention-fatigue, which is the state of mind resulting from the overuse of the direction attention. Therefore, overusing directed attention for long periods of time without taking a rest or using involuntary fascination to restore it will most likely result in the inability to remain focused, the tendency to make unreasonable decisions, and promote difficulty in productivity [1].

Stating the fact that there are two strategies for dealing with attention-fatigue, Kaplan says the first is limiting extensive use of directed attention; the second is attention restoration [11]. Therefore, minimizing the use of directed attention, architects can hence create a space that enhances the ability to locate sound source. Attention restoration can be achieved by being exposed to involuntary fascination [11], a considered source of which are aesthetics [2]. Blesser *et al.* stated that listening to a sound with the special characteristics in an ideal room can create the feeling of being in the original place where the sound was recorded, especially when eyes are closed [4]; this is considered an application of involuntary fascination. Additionally, aesthetics can be linked to peoples' preference of listening to sound in a specific place, depending on many acoustical parameters, some of which being reverberation time, which also depends on the physical properties (e.g. geometry and materials) of the space [12]; an example is a study conducted by Ando *et al.*, where they designed a concert hall based on the listeners' preference [13]. The next section will provide more details about creating preferred environments and their effect.

3.3 Preference

Being environments that support the information processing, therefore enhancing health and effectivity [1], preferred environments are based on the fundamental features that contribute to feeling comfortable, rather than depending on individual differences; this will be clarified further in the following paragraphs.

Kaplans' preference-matrix model of environmental preference suggests that the highly-preferred environments are the ones which are easy to understand and allow for more exploration; this understanding minimizes the use of directed attention and the exploration creates involuntary fascination.

The four features of Kaplans' preference-matrix are coherence and legibility that contribute to understanding, and complexity and mystery that contribute to exploration.

Table 1: Kaplans' preference-matrix [14]

	Understanding	**Exploration**
Immediate	coherence	complexity
Inferred/ predicted	legibility	mystery

First, coherence is linked to pattern recognition, such as spectral balance, decay rate, initial delay and onset shape. Additionally, it is related to sound grouping and identifying objects, distinguishing them from the background, since the space directly affects the way we hear sounds; the change and development in music styles also shaped musical spaces [4]; the architectural design of Catholic churches additionally has responded to the change in liturgy [15]. Claiming that many ancient structures were built according to the musical ratios as a way to enhance the music played in such places, Hale states an example of this is that the Gregorian chant uses the golden mean, and the latter is also used in designing architectural worship places [16]. The ratios contributing to the coherence of sound reflections inside these places (because, as Hale mentioned, the shape of the performance place was the same as the performance), another example is the Rosslyn Chapel in Scotland: Mitchell inevistigated the relationship between the shapes of the cubes in the arches of the Chapel, and found that the patterns in the cubes and the arrangement they were placed has a high relationship with the music that used to be played in the chapel; hence, he considers the cubes to be a frozen version of the music [17].

Second, as explained in the model-building section previously, legibility is connected to navigating a space through spatial sound cues; for instance, in terms of the temporal aspect so it has a behavior that contains three regions attack, sustain and decay reverberation shapes the sound in the space. The behavior of sound in each region depends in the listener location [4]. The closer the listener to the sound source the clearer the direct sound, and as the listener moves away from the source towards the walls, the reverberation becomes more dominant, which affects the listener's experience in forming a cognitive map and contribute to preference.

Third, complexity depends on the diversity of sound elements and can be achieved by creating a balance between sound reflection, absorption and diffusion through using different architectural geometrical shapes and materials depending on the space activity. An example of this is achieving a balance between having reverberation and being able to understand the words in worship spaces [18]; a complex aural environment can also be an environment that contains multiple auditory scenes, where each scene is in a different part of the space, or environment that has a background sound, such as a water fountain, in addition to other sound objects. Some may argue that this complexity can create a negative effect and make the perception process more difficult; however, this negative effect may occur only if complex sounds are not coherent [1].

Fourth, by hiding part of information and creating an interest of thinking about it, mystery is achieved. Example of this effect in aural architecture can be the whispering galleries, which are usually circular spaces which transfer sounds through reflections to distant areas and create spots where the sound can be heard clearly, although it cannot be heard in other spots with shorter distances; a similar effect occurs in places with large domes, when the interior curved surfaces create multiple reflections, in which case the reflections create an illusion of unseen sound sources called the "acousmêtre" effect. The same effect is used in some mystery movies, and can be experienced in some worship spaces [19]. Hale stated in her book "Sacred Space, Sacred Sound: The Acoustic Mysteries of Holy Places" that people have associated echoes and reverberation with the spiritual atmospheres because they seem as mysterious sounds from another world, and therefore they heavily used reverberation in worship spaces [16].

As mentioned earlier, creating preferred environments doesn't only mean satisfying individual tastes, as the features of preference are universal, and the individual differences are results of familiarity formed by previous experiences. As well as analyzing how the experience of certain sounds affect the cognitive ability and model-building, researchers have studied the influence of cultural backgrounds in sound preference and perception, which involved comparing the ability of infants and adults in detecting sounds, since infants have minimum exposure to the cultural effects. The results showed that although they were unfamiliar with the sounds, infants were able to group sounds based on similarities; on the other hand, although adults were also able to group sounds based on similarities, they showed a better ability to detect familiar sounds whist it was hard for the listeners to distinguish violations of tones in culturally unfamiliar music. Additionally, the author stated that some music properties (such as rhythmic complexity) can result in emotional effects, even when the sounds are culturally unfamiliar [20]. These results are consistent with Kaplans' preference-matrix, which explains that achieving a balance of the universal preference features (coherence, legibility, complexity, and mystery) will create a preferred comfortable environment; however, it may be more preferred for a specific person but not necessary for another one if the environment included additional individual favorite features. For instance, when the sound can be heard clearly (coherence), and allows for navigation with auditory cues constant with the visuals (legibility) and includes different and balanced direct and reflected sounds (complexity), as well as creating interest by hiding the sound sources (mystery), a preferred aural environment of an exhibit in a history museum can be achieved. This exhibit may be more preferred for a us if we are familiar with the historic music played in the background.

The failure of creating preferred environments creates stress, which can be responsible for attention fatigue, and therefore reducing productivity. The stress can even increase with the lack of privacy, the reason being sounds affect cognitive activities, especially if uncontrollable and/or unpredictable [1].

When Blesser *et al.* clarified that sounds create acoustic arenas (which are the areas where a sonic event can be heard by a group of people), and defined two types of acoustic arenas—the public and the private—the effect of control was explained; a private office represents the private arena when the door is closed, and an open plan office represents a public arena. The person in the private office can decide whether to join or leave the public arena by opening or closing the door, depending on the activity; when the task requires more focus (more direct attention), closing the door will minimize using the direct attention in perceiving the public environment, which may include the sound generated by the person setting in the next office and the people passing by the office; hence, different activities have different requirements which include a variety of acoustical consideration. Others possibly requiring communication where many people need to share the acoustic event, some may require isolation. Again, the architectural elements can determine the boundaries of the acoustic event. Therefore, if these elements fail to do so, humans' productivity can be affected.

The influence of predictability can be experienced when we are trying to write an essay in two different places: the first is a friend's home where predictability is high, and the second is in a coffee shop where it is relatively low; in the second case (the coffee shop), because it is a public space, it is difficult to predict the aural environment. Two friends may come and sit in the next table and start to chat and laugh loudly and affect our ability to focus, in which case this environment is considered un-preferred as it can lead to attention-fatigue.

3. Conclusion

Having a great effect in the information-processing system, and being essential for productivity, the Reasonable Person Model provides a framework to understand how we interact with our environments. Based on the model, human productivity depends on creating a supportive environment, depending on the activity, which can be achieved by carefully designing the aural architectural environment in a way that enhances perception and model-building, reduces the use of directed attention, and follows the preference model. The preference model explains how the design of the supportive aural environment is the one that fulfils certain requirements. First, it allows for understanding the surroundings using sound cues generated by sound reflections from the architectural surfaces. Second, it provides a chance for exploration by having a complex aural environment where the sounds create a sense of mystery. The failure of designing a supportive environment may result in attention-fatigue and reduction of our ability to be productive.

REFERENCES

1 Kaplan, R., & Kaplan, S. (1982). Humanscape: environments for people. Ann Arbor, Mich.: Ulrich's Books.

2 De Young, R. (2010). Restoring Mental Vitality in an Endangered World: Reflections on the Benefits of Walking. Ecopsychology, 2(1), 13-22.

3 Kaplan, S., & Kaplan, R. (2009). Creating a larger role for environmental psychology: The Reasonable Person Model as an integrative framework. Journal of Environmental Psychology, 29(3), 329-339. doi:http://dx.doi.org/10.1016/j.jenvp.2008.10.005

4 Blesser, B., & Salter, L.-R. (2007). Spaces Speak, Are You Listening? US: MIT Press.

5 Noë, A. (2004). Action in perception. Cambridge, Mass.: MIT Press.

6 Disneyland Paris Treasures (2014, July 3). Disneyland Paris - Rock 'n' Roller Coaster FULL Ride (HD POV) On-Ride Ridethrough - HD Video. Retrieved from YouTube: https://www.youtube.com/watch?v=5ykTmFOyuzI

7 Pizzera, A., & Hohmann, T. (2015). Acoustic information during motor control and action perception: A review. Open Psychology Journal, 8(1), 183.

8 Stocker, M. (2013). Hear Where We Are : Sound, Ecology, and Sense of Place. Dordrecht: Springer New York

9 Robinson, P. W., Pätynen, J., Lokki, T., Suk Jang, H., Yong Jeon, J., & Xiang, N. (2013). The role of diffusive architectural surfaces on auditory spatial discrimination in performance venues. The Journal of the Acoustical Society of America, 133(6), 3940-3950. doi:doi:http://dx.doi.org/10.1121/1.4803846

10 Pressnitzer, D., Cheveigné, A., Collet, L., & McAdams, S. (2005). Auditory Signal Processing Physiology, Psychoacoustics, and Models. New York, NY: Springer Science+Business Media, Inc.

11 Kaplan, S. (2001). Meditation, restoration, and the management of mental fatigue. Environment and behavior, Vol. 33(No. 4), 480-506.

12 Lokki, T. (2013). Sensory evaluation of concert hall acoustics. Proceedings of Meetings on Acoustics, 19(1), 032004. doi:doi:http://dx.doi.org/10.1121/1.4800481

13 Ando, Y., & Cariani, P. (2011). Neurally-based acoustic and visual design. The Journal of the Acoustical Society of America, 129(4), 2430-2430. doi:doi:http://dx.doi.org/10.1121/1.3587947

14 Kaplan, S. (1987). Aesthetics, affect and cognition_ Environmental preference from an evolutionary perspective. Environment and Behavior. 3-32.

15 Elicio, L., & Martellotta, F. (2015). Acoustics as a cultural heritage: The case of Orthodox churches and of the “Russian church” in Bari. Journal of Cultural Heritage, 16(6), 912-917. doi:http://dx.doi.org/10.1016/j.culher.2015.02.001

16 Hale, S. E. (2013). Sacred Space, Sacred Sound : The Acoustic Mysteries of Holy Places. Wheaton, US: Quest Books.

17 Mitchell, T. (2012). Rosslyn Chapel: The Music of the Cubes Diversions Books.

18 Ergin, N. (2008). The Soundscape of Sixteenth-Century Istanbul Mosques: Architecture and Qur'an Recital. Journal of the Society of Architectural Historians, 67(2), 204-221. doi:10.1525/jsah.2008.67.2.204

19 Pentcheva, B. V. (2011). Hagia Sophia and Multisensory Aesthetics. Gesta, 50(2), 93-111. doi:10.2307/41550552

20 Deutsch, D. (2013). The psychology of music. London ; Waltham, MA: Academic.