

## INVESTIGATING THE SPACE RECOGNITION AND SOUNDMARKS IN OPEN SEMI-OPEN AND ENCLOSED SPACES VIA SEMANTIC RATINGS

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### Abstract

*The aim of the study is to increase the samples in enclosed soundscape studies and as a public space; metro stations have been aimed to be included into the literature. This study is a subjective approach; examines the relationship between soundmark a space and space recognition within "degree of enclosure" context in order to gain data, sound recordings were taken from site and a listening test applied to investigate if spaces could be recognized/understood just by hearing. For each sound recording, subjects were asked to explain the recorded space (if they are open/semi open/enclosed space), and define the sound sources. Besides, in order to understand sound quality of the selected spaces, subjects were asked to choose from 17 pairs adjectives for each recording, which were selected from the previous studies. Results showed that, all of the subjects determined open spaces correctly, enclosed spaces were determined with 84% while 95% of the subjects have failed to identify the semi open spaces. Only half of the subjects were able to determine the usage of the spaces. As soundmarks, bird, wind, and water sounds were defined in the open space, pay gates and coin sounds were defined in the semi-open space, and the metro itself, as well as its brakes, doors, and announcement system were defined in the enclosed space. For open spaces, subjects tended to choose adjectives as "pleasant", "calming", "natural"; while for enclosed spaces tended to choose "unpleasant", "stressing", "artificial", etc.*

### 1 Introduction

In 2011, Brown, Kang and Gjestland suggested a taxonomic system to use as a "common framework or a checklist" that classifies all sound sources [1]. In their framework, the acoustic environment is divided into two main categories according to place: *indoor acoustic environment* and *outdoor acoustic environment*. Outdoor acoustic environment is then divided into four sub-categories: *urban acoustic environment*, *rural acoustic environment*, *wilderness acoustic environment* and *underwater acoustic environment*, but the framework only classifies sound sources in the urban acoustic environment. For the other environments, sound sources are depicted as "ditto", which means that the classifications for urban acoustic environment should be applied the other acoustic environments.

The authors maintained that the sound sources of the urban acoustic environment were sufficient as a common framework, and all studies of different acoustic environments could refer to those. However, it is known that, every space has its own unique sound environment; soundscapes, the underlying sound sources and the acoustical requirements differs [2,3]. This requirements gets varied and more complex in enclosed spaces, correspondingly, auditory perception will differ because there interferes factors such as building geometries, finishing materials, activities and reverberation (to name only a few); all contribute to the acoustic environment. [4,5]. For these reasons, the classification of sound sources should be elaborated with different case studies that consider all types of acoustic environments. And in addition to outdoor sound quality studies, indoor sound quality in different environments also needs investigation.

Until the 2000s, researchers focused on soundscapes in outdoor urban environments [6, 7, 8, 9]; there was a lack of case study on enclosed spaces. In 2007, Tardieu, Susini and Poisson became prominent

names in soundscape studies for their work in train stations [10]. They indicated that in public spaces such as metro stations, users learn how to use the space and how to understand their location in a space. Researchers then aimed to understand *how* users learn and memorize the soundscapes of such spaces. With their studies of Ankara and Warsaw metro stations, Su and Caliskan drew guidelines for acoustically measuring enclosed soundscapes [11,12]. There is a series of soundscape studies in outdoor environments, mostly investigated by the ISO-led standardization group as well as some case studies on enclosed spaces such as shopping malls and metro stations [13, 14]. However, to the best of our knowledge, there is no research in the literature that compares outdoor and indoor soundscape quality.

This study is designed to determine negative and positive aspects of the indoor acoustic environment in a metro station, and compare the station's outdoor and indoor perceived sound qualities. For this comparison, Akköprü Metro Station and Ankamall Park adjacent to it were chosen as a case study in Ankara, Turkey. The study explored the following research question: "Can users recognize a space just by hearing recordings from a location?" This study hypothesizes that open spaces and enclosed spaces different acoustic environments, and thus "Users will not be able to differentiate between semi-open and enclosed spaces from an audio recording."

## 2 Method

### 2.1 Site Description

The entrance of the Akköprü Metro Station was chosen as a semi-open public space and the platform level of the station was chosen as an indoor environment/enclosed public space. Akköprü Metro Station's attributes of being public, the Ankamall Park adjacent to it and its continuous flow of pedestrians were the main factors for its selection for this study. The station is located in Akköprü, Çankaya, one of the most crowded areas of Ankara, at the intersection of Fatih Sultan Mehmet Boulevard and Mevlana Boulevard. Ankamall Shopping Center, Ankara's municipal transportation department, the Turkey's veterinary services department and the Ankara fire department headquarters (Figure 1) are all nearby.



Figure 1: Site view of Akköprü Metro Station

The park sits between Akköprü Metro Station and Ankamall. It contains a small square approximately 50 metres from the station and 20 metres in diameter. The square is connected to a promenade with 18 seating areas on either side it and 11 decorative pools on the middle axis, each five metres in diameter. The square directly faces the shopping mall (Figure 2).



Figure 2. View of the Urban Park and Akköprü Metro Station from Ankamall Shopping Center

Akköprü Metro Station consists of two levels: an entrance level with pay gates and ticket offices, and a platform level. The entrance level, with its large doors that create a great flow of pedestrians and air, works as a transition between the platform level and the outside. The station is 895 meters long and 216 meters wide. The height of the entrance level is 3.19 meters and the height of the platform level is 3.36 meters from the base to under the suspended aluminum ceiling, and 7.33 meters from the metro rails to the top of the metro tunnel. The floor is artificial marble 40 cm x 40 cm. On the entrance level, walls are mostly glass brick and marble as well as columns and stairs are covered with glass brick. On the platform level, the columns are covered with acrylic paint. Ballast stone is used in the rails. There are no sound absorptive material used neither on ceiling or walls to help to control the acoustical environment of the station. (Figure 3).



Figure 3: Entrance level (Left) and platform level (Right) of the Akköprü Metro Station

## 2.2 Methodology

### 2.2.1 Space Recognition

Sound recognition refers to a process of understanding what a specific sound is, what its source is and where it is in a specific environment. To understand this process, the relationship between sound and social context must be well understood. In *The Image of the City*, Lynch discusses the relationship among soundmarks, city images and sound and space recognition. Venot and Semidor explained that relationship with these words: "Every sound event can be preserved in a way which enables us to identify it" [15]; the authors maintained that hearing an activity creates a mental image of the sound source, the activity and the environment, which may not be as strong as a visual source but is nonetheless important.

One measurement method for sound recognition is called *soundwalking*, which aims to specify all the sound sources that form the soundscape of an area. The duration of this activity can change according

to certain factors, such as the size of the area, number of people in the group or number of sound sources. After the walking session ends, participants discuss the sound sources and architectural situations. Another way to conduct this method is to record the sound sources of an area for specific durations, then have subjects listen to the recordings and write down the sound sources they hear and whether they recognize the recorded space.

In the current study, a total of 34 sound recordings were taken from selected spaces in eight spots (Figure 4). The duration was kept short to avoid subject distraction. Listening tests were conducted in a semi-anechoic room with noise cancelling headphones.

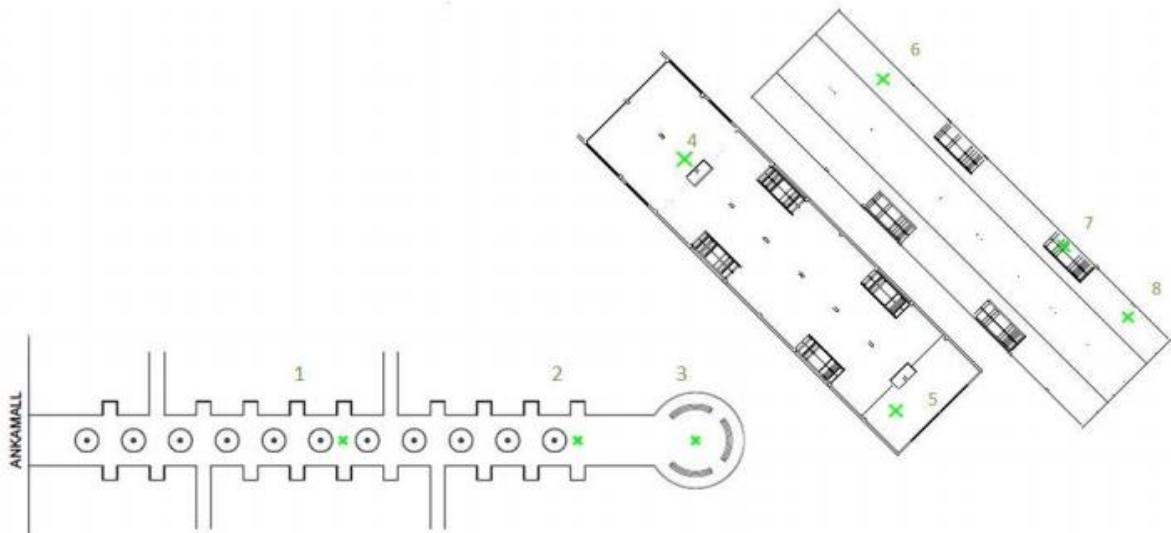


Figure 4. Eight different spots used for objective and subjective measurements (Spots 1-2-3: The park area as open space; Spots 4-5: The entrance level as semi open space; Spots 6-7-8: The platform level as enclosed space)

One recording from each spot was chosen for the listening test. Singly, the 90 uninformed subjects were taken into the semi-anechoic room and attended to the listening test (Figure 5). The participants listened to each recording twice and each session took 30 minutes. The recordings were played randomly to each subject.

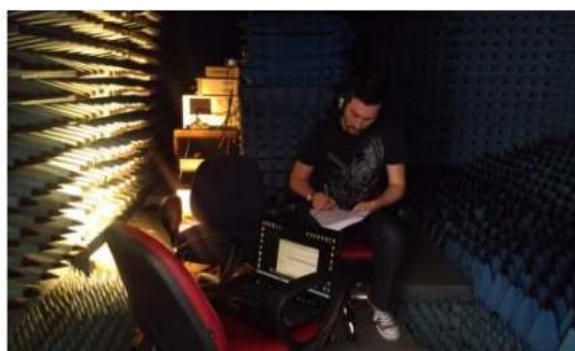


Figure 5. Picture of an interviewee from the anechoic room

The questionnaire consisted of nine pages with two parts. In the first part, interviewees were asked close-ended questions about personal information such as gender, age and education level. In the second part, for each sound recording, subjects were asked to explain the purpose of the recorded spaces (usage of the spaces), guess which type of space it was (open/semi-open/enclosed) and define the sound sources.

## 2.2.2 Soundmarks

Through the listening tests and site analysis, sound sources and soundmarks of the spaces were also determined by the participants (Table 2). The order of the sound source lists written by subjects gave indications of how users perceive sounds in an environment [16].

The Oversea City Town (Shenzhen) presents a clear explanation for the diversities in ecological sound environments in big cities; nature soundscape (consists of nature sound barely man-made sound), neutral soundscape (consists of nature and man-made sound), and man-made soundscape (consists of man-made sound barely nature sound) [17].

## 2.2.3 Psychoacoustic Parameters Measured at Akköprü Metro Station/

Psychoacoustics is a scientific field that aims to explain users' psychological and physiological responses to acoustic conditions in an environment. In 1990, Zwicker and Fastl [18] proposed three basic sound metrics: loudness, sharpness and roughness. In 2013, Özçevik and Can [19] analyzed the relationship between Zwicker and Fastl's metrics and various adjective pairs (Table 1).

Table 1. Relationship between sound quality metrics, adjective pairs and soundmarks [19]

Environmental Sound Assessment	Sound Quality Metrics	Adjective Pairs	Relationship with Soundmarks
General Assessment	Loudness (5%, 50%, 95%)	"loud-quiet", "unpleasant-pleasant", "disturbing-comfortable", "stressing-relaxing", "agitating-calming", "discordant-harmonic", "hard-soft", "crowded-uncrowded", "empty-joyful", "exciting-gloomy", "loud-soft", "dark-light", "heavy-light - ", "rough-smooth"	
Detailed Assessment	Roughness (%10)	"far away-nearby"	Perception of the soundmarks (distance between soundmarks and the receiver)
	Sharpness (%10)	"sharp-not sharp"	Spectral structure of the soundmarks
		"unsteady-steady"	Stability of the soundmarks in time and its effect to the space
		"strange-common"	Familiarity of the soundmarks

In the current study, Zwicker and Fastl's metrics were used with Özçevik and Can's adjective pairs. In order to understand the sound quality of the selected spaces, the subjects were asked to choose between 17 adjective pairs (see Table 1) for each recording, taking into account the relationship between sound quality metrics and all pairs of adjectives. In this study, the two adjectives were also evaluated via *semantic differential ratings*. The frequency distributions of the adjective pairs for three different space types according to the scalar listening test results are given in Figure 7.

## 3 Results

### *Sound Recognition:*

In terms of sound recognition, the listening test results show that all subjects determined the open spaces correctly and 84% of subjects determined the enclosed spaces correctly, but only 5% of subjects determined the semi-open spaces successfully. Only half the subjects were able to determine the correct usage of the spaces (Figure 6).

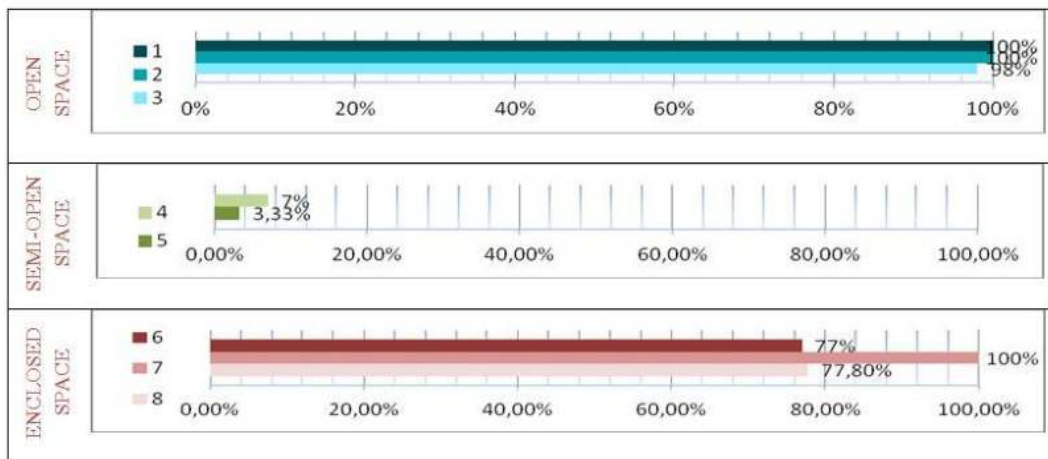


Figure 6. Listening test results - defining space types (as open (spots 1-2-3) /semi open (spots 4-5) /enclosed (spots 6-7-8) see Figure 4 for measurement points )

**Soundmarks:**

In terms of soundmarks, the sounds of marching, speech and children were perceived similarly in all three spaces. Traffic sounds such as horns and sirens were perceived similarly in open and semi-open spaces. Birds, wind and water sounds were defined as soundmarks in the open space; pay gates and coin sounds were defined in the semi-open space and the trains, brakes, doors and sound system were defined in the enclosed space (Table 2).

Results of the field studies showed that sound scape features of both three spaces differs from each other. In station (both in entrance and platform level) sound scape is all man-made; consists of metro sound, loud speaker paging, human speech etc. Sound scape of the park can be considered mostly neutral; man-made sounds such as traffic sound and human speech are as noticeable as the natural sounds such as birds, wind and water elements.

Spaces	Sound Sources	Soundmarks
Open Space	Heavy Traffic Decorative Pool Weather Conditions Flow of Human	Bird Sound Wind Sound Water Sound Marching Sound Speech and Child Sound Traffic Sound; horn and siren
Semi-Open Space	Ticket Office Pay Gates Flow of Human Heavy Traffic	Coin Sound Pay Gate Sound Marching Sound Speech and Child Sound Traffic Sound; horn and siren
Enclosed Space	Metro Loudspeaker Flow of Human	Marching Sound Metro Sound; break and door Paging Speech and Child Sound

Table 2: Listening Test results - Sound sources and soundmarks determined by the listening test and site analysis (see figure 4 for measurement points)

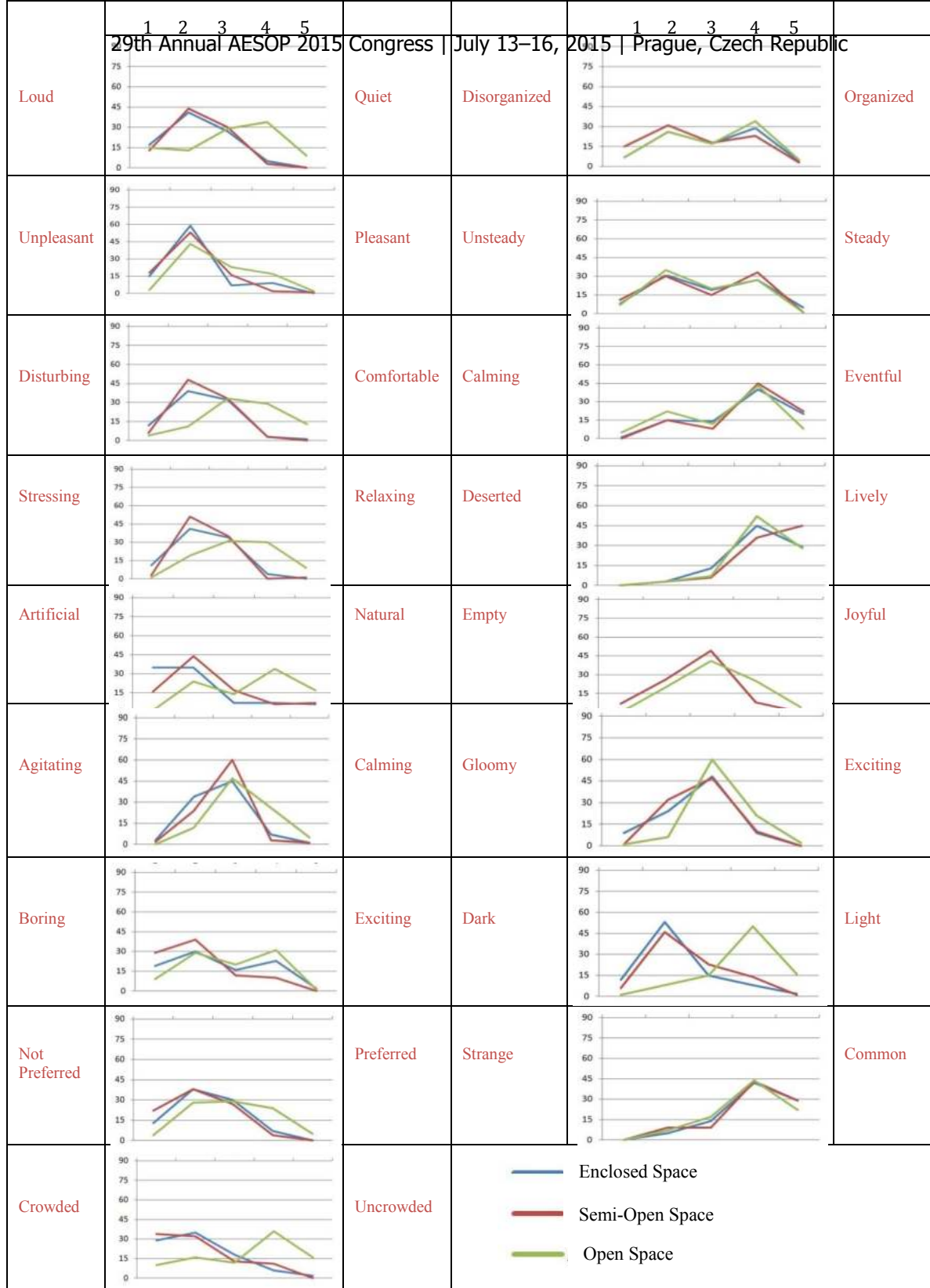


Figure 7: Listening test results- Relationships of adjective pairs / space types

### *Semantic Differential and Sound Quality Metrics*

Özçevik and Can's [18] study on the relationship between sound quality metrics, adjective pairs and soundmarks is well known. Using their pairs, the current study found that Loud-Quiet, Unpleasant-Pleasant, Disturbing-Comfortable, Stressing-Relaxing, Agitating-Calming, Uncrowded-Crowded, Unsteady-Steady, Empty-Joyful, Gloomy-Exciting, Dark-Light and Strange-Common were related with **Loudness** and that Unsteady-Steady and Strange-Common adjective pairs were related with **Sharpness**.

In other words, these adjective pairs can be explained through the related sound quality metrics (Figure 7).

**Semantic Differential and Correlations**

Correlations between the adjective pairs gained from the listening tests were also analyzed. Highly correlated adjective pairs can be seen in Table 3.

Table 3. Highly positive correlated adjective pairs

Correlations	Loud quiet	Unp. Pleas.	Distur. Comf.	Stress. Relax.	Artific. Natur.	Agitat. Calm.	Boring excit.	Not pr. prefer.	Crowd. Uncr.	Disorg. Org.	Unste. steady	Calm. event.	Disert. lively	Empty joyful	Gloo. excit.	Dark light	Stran. Comm.
Loud - quiet		■	■						■								■
Unpleasant - pleasant			■					■									■
Disturbing - comfortable							■	■									■
Stressing - relaxing						■	■										
Artificial - Natural																	
Agitating - calming																	
Boring - exciting								■		■				■	■		
Not preferred - preferred																	
Crowded - uncrowded																	
Disorganized - organized																	
Unsteady - steady																	
Calming - eventful													■				
Deserted - lively																	
joyful															■		
Gloomy - exciting																■	
Dark - light																	■
Strange - common																	

The correlations suggest that loud environments make users feel unpleasant and disturbed. The users evaluated loud spaces as crowded. They also suggested that they feel very pleasant in comfortable spaces. Agitating environments made users highly stressed and they claimed that they got bored in stressful and disturbing spaces. Comfortable and pleasant spaces were highly preferred to uncomfortable, unpleasant and gloomy spaces. Eventful spaces were labeled as lively and joyful, but eventful, lively and joyful spaces were also labeled as loud and disorganized. Users got bored in empty spaces and found disorganized and gloomy spaces boring. Gloomy spaces were also expressed as empty. Users also found loud, deserted and gloomy spaces as dark. However, empty spaces were preferred more often than joyful spaces. Users found natural spaces gloomy and labeled artificial spaces as exciting. Users became stressed in eventful spaces. Users found eventful spaces crowded, and calming spaces related with more light.

**4 Conclusion**

The study states that, every space has its own unique sound environment and acoustical requirements. This requirements gets varied and more complex in enclosed spaces because there interferes the geometry of the enclosure, nature of the used materials, the activity takes place in etc. Correspondingly, auditory perception will differ. This statement is the most important aspect of the study’s hypothesis. The study shows that there are statistically significant relationships between auditory perception and different space types. The findings prove that Brown, Kang and Gjestland’s above-discussed

taxonometric system (which suggested that all sound sources can be classified using the same categories as for the urban acoustic environment) is not sufficient.

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