Understanding the Indoor Soundscape in Public Transport Spaces: A Case Study in Akköprü Metro Station, Ankara

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Abstract

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1. Introduction

The term *soundscape* was coined by Schafer in the late 1960s, during his studies of acoustic ecology. Schafer defines a soundscape as "an environment of sound (sonic environment) with emphasis on the way it is perceived and understood by the individual, or by the society (1). In September 2008, an ISO/TC 43/SC1/WG 54 working group for the "Perceptual Assessment of Soundscape Quality of the International Organization for Standardization" was established to propose the first international standardization for soundscape definitions and measurement techniques (2). Brown et al. (2011), proposed a taxonometric system to use as a "common framework or a checklist" to classify all sound sources. In the framework, the acoustic environment was divided into two main categories according to place: *indoor acoustic environment* and *outdoor acoustic environment*. The outdoor environment was then divided into four sub-categories: *urban*, *rural*, *wilderness* and *underwater*, but the framework only classified sound sources in the urban acoustic environment. For the other environments, sound sources were noted as *ditto*, which means that the classifications for the urban environment should be applied to the other environments. ISO/TC 43/SC1/WG 54 working group proposed Part 1 of the standard ISO 12913 with basic definitions, where a soundscape is defined as the following: "[An] acoustic environment as perceived and experienced and understood by people, in context" (3). Other aspects are delayed to subsequent parts of the standard which are still under discussion. In this regard, the focus is shifted from sound energy to the context and perception of the sound. However, this approach still lacks a standard measuring tool (2,4,5); the current rules and regulations regarding a sound environment only demand the simple measurement of sound levels (SPL), but it is clear that sound levels on their own are not enough to evaluate a soundscape (2,4,6).

Recent consensus on the soundscape approach suggests that the soundscape exists through perception; it is individuals' or society's understanding and perception of the auditory environment and meaning associated with it (7,8) that provides its context.

Over the decades, researchers have proposed various methods to explore and evaluate the outdoor soundscape. Some use the *soundwalk* method (walking around an area to identify the sounds associated with it) to investigate the urban soundscape (9–11), while others use binaural recordings and psychoacoustic measurements (8,12,13). More-subjective evaluations of soundscapes consist of analyzing questionnaires, interviews, and semantic differential scales (9,11,14–16) on perceived sounds. However, a well-accepted evaluation method has not yet been established for indoor soundscapes.

Every space has a unique sound environment; soundscapes, the underlying sound sources and the acoustical requirements differ in each space (17–21). The requirements for acoustical comfort regarding the indoor spaces are varied and more complex ; correspondingly, auditory perception differs due to factors such as building geometry, finishing materials, activities and reverberation (7,22). Indoor spaces have much more complex acoustical environments than outdoor spaces; for example, metro stations, high schools, restaurants and hospitals all have different soundscapes. For these reasons, sound sources should be classified through case studies that consider various types of indoor and outdoor acoustic environments, and different environments within the same type (e.g., different concert halls and hospitals) (6,23–25).

This study presents an indoor soundscape study on the Akköprü metro station in Ankara, Turkey. Some researchers have conducted a series of investigations that consider the relationship between physical elements of long-enclosure spaces (e.g., metro stations, railway stations, underground spaces) and the perceptual sound environment identified in these spaces (26-29). They have studied on sound propagation in long enclosures (26,27), while still more have conducted perceptual studies of train stations to investigate the auditory environment (e.g., sound fields, soundscapes, auditory way-finding systems) identified in them (28,29). More-quantitative research of underground urban spaces includes developing a space syntax method (30) and improving a data-based quantitative method to create a model that interprets the relationship between factors affecting underground urban spaces and their capacity (31).

Tardieu et al. (2008) revealed that in public spaces such as metro stations, users learn how to use the space and how to understand their location in a space based on the sounds within it (28). The authors 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 developed guidelines for acoustically measuring enclosed spaces such as evaluating different materials for providing optimum acoustical conditions in such spaces (32).

The aim of the current study is to explore the following questions: (1) Is there any relationship(s) between auditory perception and different space types? (2) Can users recognize a space solely by hearing recordings from it? (3) Is there any relationship(s) between demographic factors and space recognition? Since few indoor soundscape studies exist, our results from the indoor soundscape in a metro station provide valuable information to show how the built environment affects pedestrians/passengers and how they perceive their auditory environment.

2. Method

Akköprü metro station, including an adjacent urban park, was chosen as the case site. In three spaces (platform level, entrance level and park) within a “degree of enclosure” context which means they have strong relation each other with a hierarchy as open (park), semi-open (entrance level) and enclosed space (platform level), we conducted objective and subjective measurements to analyze the perceived indoor and outdoor soundscapes. As objective measurements, we measured A-weighted equivalent continuous sound levels (LAeq) and sound pressure levels (SPL) in each space. We conducted subjective measurements through noise annoyance surveys on site and through listening tests in a semi-anechoic chamber in the Turkish Radio Television (TRT) Corporation, Ankara. We analyzed all gathered data using the SPSS 13 Statistical Package.

2.1. Site Description

Akköprü metro station's attributes of being a public space, ANKAmall Park adjacent to it and its continuous flow of pedestrians were the main factors in our case selection. The metro 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, Turkey's veterinary services department and the Ankara fire department headquarters are all nearby (Figure 1).

Figure 1: Site view of Akköprü metro station, Turkey

ANKAmall Park, a greenspace approximately 50 meters from the station and 20 meters in diameter, sits between Akköprü metro station and ANKAmall. The park includes a promenade with 18 seating areas on either side and 11 decorative pools along the middle axis, each five metres in diameter. The park directly faces the shopping mall (Figure 2).

Figure 2: View of the ANKAmall Park and Akköprü metro station from ANKAmall

Akköprü metro station consists of two levels, an entrance level with pay gates and ticket offices, and an underground platform. The entrance level, with large doors that create a great flow of pedestrians and air, works as a transition between the underground platform and the outdoors. 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 the suspended aluminum ceiling, and 7.33 meters from the metro rails to the top of the metro tunnel. The floor is artificial marble in 40 cm x 40 cm squares. On the entrance level, the walls are mostly glass brick and marble, and the 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 materials on the ceiling or the walls to help to control the acoustical environment (Figure 3).

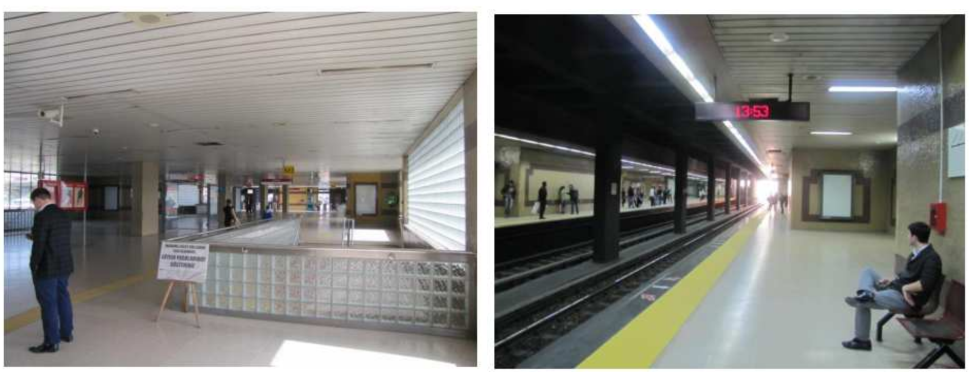

Figure 3: Entrance level (left) and underground platform (right) in the Akköprü metro station

2.2. Acoustic Measurements

In-field measurements were taken with a B&K 2230 sound level meter. The acoustic measurements were taken at eight different spots in the three spaces on a Saturday between 14:00 to 17:00 (Figure 4). In all three spaces, LAeqs and SPLs were measured, at height of 125 cm, over 15 minute time intervals. All measurements were conducted simultaneously while the participants filled in the noise annoyance surveys and conducted soundwalks.

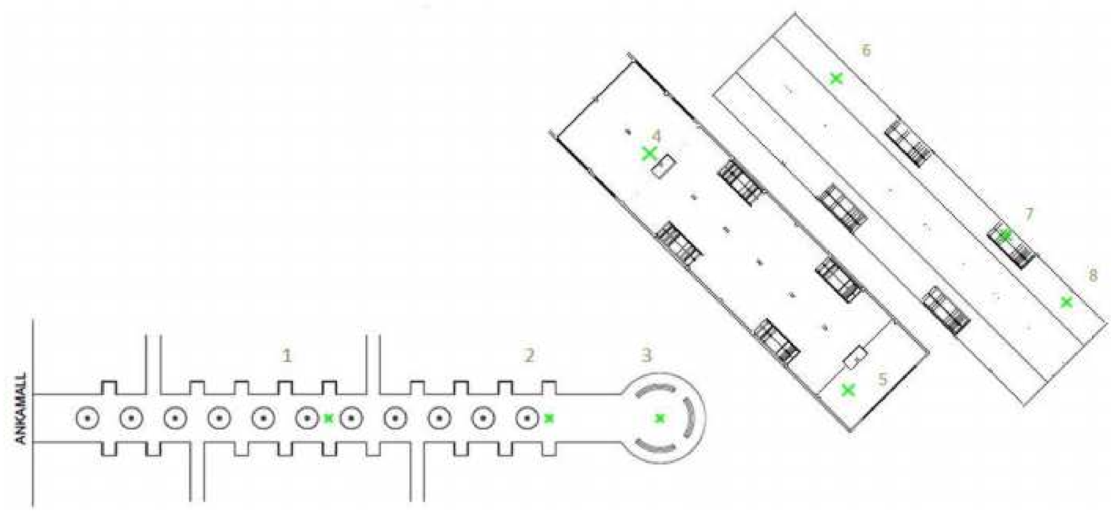

Figure 4: The eight spots on the plans used for objective and subjective measurements (1-3: ANKAmall Park; 4-5: metro station entrance; 6-8: metro station underground platform)

2.3. Questionnaire on Site

In addition to the objective parameters, we analyzed the subjective parameters of noise annoyance, sound recognition and soundmarks.

Noise Annoyance Survey: Noise annoyance can be defined as unwanted feelings of disturbance or irritation due to a specific sound. What is considered noise annoyance depends on users' sound preferences and varies from one person to another. Thus, there are no measurement parameters, but methods such as semantics help researchers understand user behaviors under different circumstances (22).

We prepared a noise annoyance questionnaire based on previous studies (22,25) for each of our and three case areas: ANKAmall Park, Akköprü metro station's entrance and the station's underground platform. The survey aimed to measure the effect of the areas' sounds on pedestrians/passengers and whether the sounds were annoying and/or disturbing.

For the survey, we randomly chose 60 participants at the site (20 from the park, 20 from the entrance level and 20 from the platform level). Each survey consisted of 10 questions. Participants were asked to fill in demographic information (gender, age and education level), site usage frequency and to grade from 1 to 5 (1 - Very low, 5 – Very high) the general noise level and their annoyance level with the overall noise, as well as the annoyance level from different sound sources.

2.4. Listening Tests

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. In sound recognition, the relationship between sound and social context must be well understood. In *The City Image and Its Elements*, Lynch (40) discusses the relationship among soundmarks, city images and sound and space recognition. Venot and Semidor (34) explain that relationship: "Every sound event can be preserved in a way which enables us to identify it". Lynch maintains 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 (35). A study (36) in Overseas Chinese Town in Shenzhen, China, presents an example of the diversity of sound environments in big cities, comprising nature soundscapes (nature sounds with few man-made sounds), neutral soundscapes (nature and man-made sounds) and man-made soundscapes (man-made sounds with few nature sounds).

One measurement method for sound recognition is the above-noted soundwalking, which aims to specify all the sound sources that form an area's soundscape. 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 sound sources and architectural situations. Another way to conduct this method is to record the sound in 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 (34).

Figure 5. An interviewee in the semi-anechoic room

In the current study, we conducted sound recordings that we collected to the site via a Soundwalk for using in the listening tests. A total of 34 30-second-long sound recordings were made in the selected eight spots (Figure 4).The recordings were kept short to avoid subject distraction during the listening tests. We collected sound recordings with objective measurements with a ZOOM Handy Recorder H2 and distributed the noise annoyance questionnaires at the site simultaneously, as recommended by ISO/TS 15666 (33).

For the listening test, we randomly chose 90 uninformed participants who work at Turkish Radio Television (TRT) Corporation far from the selected sites, but who all use the metro as transportation. The age distribution of the participants varies from 16 to 59, with females (50%) and males (50%) in general. Vast majority of the participants were graduated from master (47%) and PhD program (19%).

Listening tests were conducted in a semi-anechoic room with Bose Quiet Comfort 3 Acoustic Noise Cancelling headphones. In a semi-anechoic room, each participant took the listening test alone, supervised by a researcher (Figure 5). The survey used in the listening test was prepared considering the researchers' personal experiences of soundwalking. Each participant listened to each recording twice, for a total of three recordings, and filled out a questionnaire. The questionnaire was approached to determine whether the eight spaces could be recognized or understood through the listening test alone.

The questionnaire consisted of nine pages with two parts. In the first part of the survey, participants were asked closed-ended questions to determine demographic information (gender, age, education level). In the second part, a random sound recording from one of the three spaces was played twice; each session took 30 minutes. For each sound recording, participants were asked to explain (1) the function of the recorded spaces, (2) guess whether the recorded space was the urban park, station entrance or underground platform and (3) define the sound sources. Further, (4) to describe the sound environment of the selected spaces, participants were asked to choose from 17 pairs of adjectives for each recording, as per Table 3 and evaluated via differential semantic ratings (see Table 3 for adjective pairs) (37).

3. Results

3.1. Sound Pressure Levels and A-Weighted Equivalent Sound Levels Measured at Akköprü Metro Station

The LAeq levels and SPL results show that the measurements (see Table 1) were higher than the permissible limit according to Turkey's Ministry of Environment and Forestry's Regulation on the Assessment and Management of Environmental Noise (38).

Table 1: Permitted and measured sound pressure levels in defined spots

Measurement Spots (1-8)		Permitted Sound Pressure Level (SPL), dBA	A-weighted Equivalent Sound Level (LAeq), dBA	Sound Pressure Level (SPL), dBA
Urban Park	1	60	66	63
	2	60	59.7	61
	3	60	69	75
Station Entrance	4	55	60.1	60.2
	5	55	70	76
Underground Platform	6	80	64	66.3
	7	55	60.7	65
	8	80	90	75

3.2. Subjective Parameters Measured at Akköprü Metro Station

3.2.1. Questionnaire Results on Site

Noise Annoyance Survey:

The results of the noise annoyance surveys show that in the park (Figure 6) and at the station entrance, LAeq levels, 55 - 60 dBA, were almost similar to each other, while noise annoyance levels were higher in the station entrance (Figure 7).

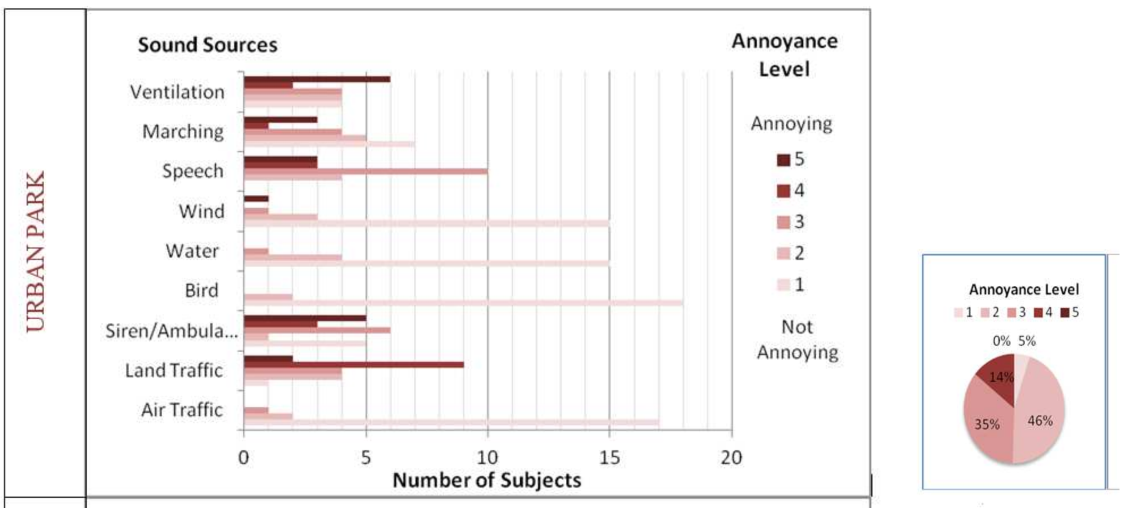

Figure 6. Subjects' noise annoyance ratings of specified sound sources and noise annoyance chart in ANKAmall Park

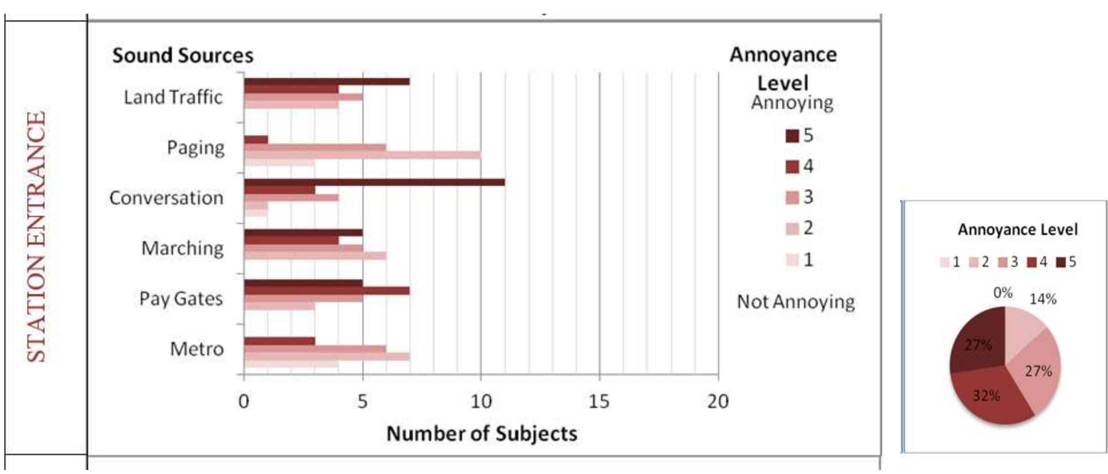

Figure 7. Subjects' annoyance ratings for specified sound sources and noise annoyance chart for the metro station entrance

On the underground platform, LAeq levels were lower than in the station entrance, yet noise-annoyance levels were similar to each other (Figure 8).

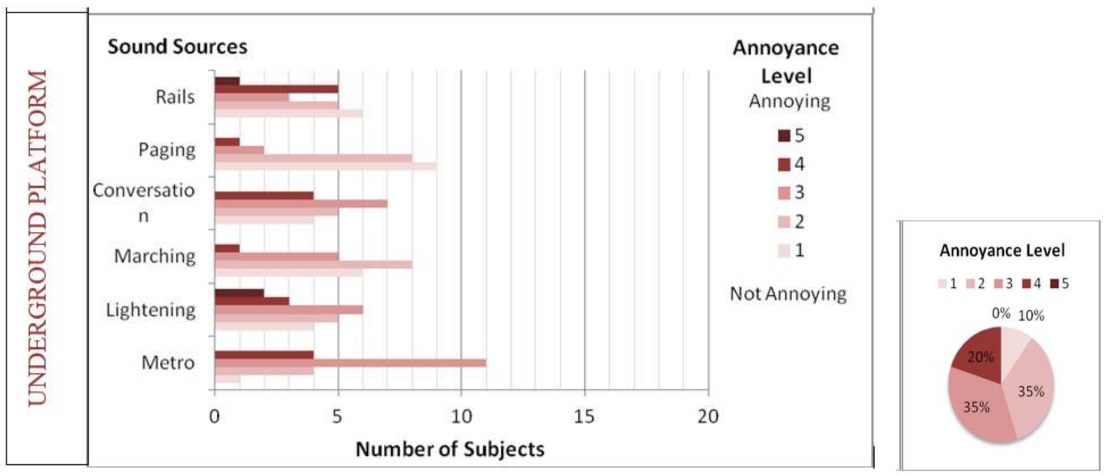

Figure 8. Subjects' annoyance ratings for specified sound sources and noise annoyance chart on the underground platform

3.2.2. Listening Test Results from the Semi-Anechoic Chamber

Sound Recognition:

The results show that all participants identified the park correctly. On the contrary, most of participants failed to identify the metro station's entrance (Figure 9). Further, only half the subjects were able to determine the correct functions of the spaces.

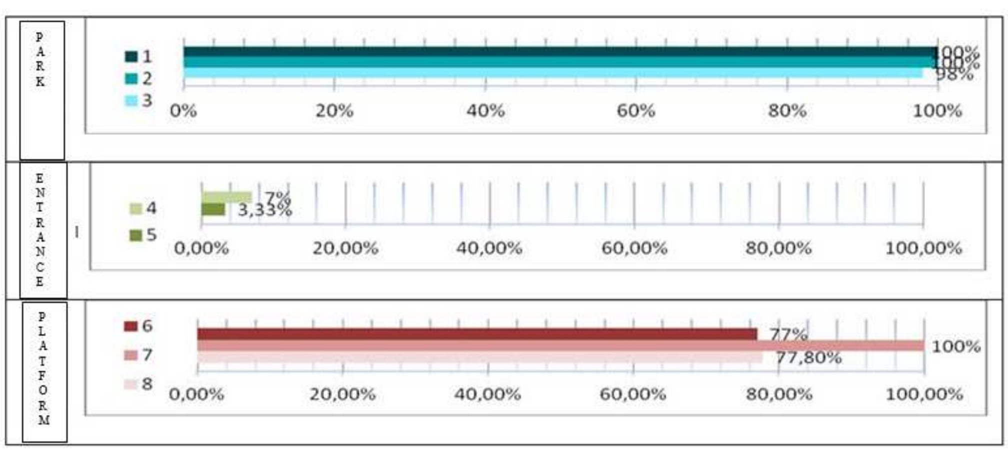

Figure 9. Listening test results: defining space types (urban park (spots 1-2-3); station entrance (spots 4-5); underground platform (spots 6-7-8)). See Figure 4 for measurement points

In our study, we applied a t-test to subsamples of gender and age groups, and to both groups together. The results show gender, age and space recognition (if participants correctly recognize spaces as urban park, entrance level, or underground platform, and recognize the spaces) did not show any correlation with ~.000 significance factor. In the subsamples where participants correctly identified the recordings for both the location and function of the spaces, the t-statistics clearly reject the null hypothesis, with a p-value of < 0.01.

Table 2. Listening test results: Sound sources and soundmarks identified by the listening test and site analyses (see Figure 4 for measurement points)

Transport Spaces	Sound Sources	Soundmarks
Urban Park	Heavy Traffic Decorative Pool Weather Conditions Flow of People	Bird Sound Wind Sound Water Sound Marching Sound Speech and Child Sounds Traffic Sound; horn and siren
Station Entrance	Ticket Office Pay Gates Flow of People Heavy Traffic	Coin Sound Pay Gate Sound Marching Sound Speech and Child Sounds Traffic Sound; horn and siren
Underground Platform	Metro Loudspeaker Flow of People	Marching Sound Metro Sound; brakes and door Paging Speech and Child Sounds

Through the listening tests and site analyses, participants also identified sound sources and soundmarks (Table 2). The order of the sound sources listed by participants gave indications of how users perceive sounds in an environment (8). The results of our site studies show that the soundscape features of the three spaces differ. In the station (both at the entrance and on the underground platform) the soundscape is all man-made, for example, metro sounds, loudspeaker paging. The urban park's soundscape can be considered mostly neutral; man-made sounds such as traffic are as noticeable as natural sounds such as birdsong, wind and water elements.

In terms of soundmarks, marching, speech and children were perceived similarly in all three spaces. Traffic sounds such as horns and sirens were perceived similarly in the park and at the station entrance. Birdsong, wind and water sounds were identified as soundmarks in the park;

pay gates and coin sounds were identified at the station entrance and trains, brakes, doors and loudspeakers were identified on the underground platform (Table 2).

3.3. Semantic Differential and Correlations

The current study used Zwicker and Fastl's metrics (39) with Özçevik and Can's (40) adjective pairs. To understand the sound quality of the selected spaces, participants were asked to choose between 17 adjective pairs to describe each recording, taking into account the relationship between sound quality metrics and all pairs of adjectives (Table 3). In this study, the adjective pairs were also evaluated via semantic differential ratings.

Table 3. Relationship between sound quality metrics, adjective pairs and soundmarks

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 their effect on the space
		strange-common	Familiarity of the soundmarks

We conducted a series of Spearman rank-order correlations to determine whether any relationships emerged between the adjective pairs selected in the listening tests. A two-tailed test of significance indicated that there were significant positive and negative relationships among the adjective pairs and between different space types.

The prominent result of the correlations is that for all eight recordings, users tended to correlate the same adjective pairs. σ^{i}_{jk} represents the correlation between adjective pairs $j.k \in \{ 1...17\}$ in the recording set $i \in \{1....8\}$. They felt discomfort in spaces perceived as unpleasant ($\sigma^{1\text{-}8}_{2.3}$) and stressed in spaces perceived as unpleasant and disturbing ($\sigma^{1\text{-}8}_{2.4};\ \sigma^{1\text{-}8}_{3.4}$). Spaces perceived as comfortable and relaxing were preferred over spaces perceived as disturbing and stressful ($\sigma^{1\text{-}8}_{3.8};\ \sigma^{1\text{-}8}_{4.8}$). Users tended to define light spaces as exciting ($\sigma^{1\text{-}8}_{15.16}$) and to correlate the adjectives exciting and joyful.

3.4. Relationship between Demographic Factors and Sound Recognition

In the current study, we conducted hypothesis test in between space recognition and gender (M=.27, SD=.44), space recognition and age (M=.27, SD=.44), space recognition and education (M=.27, SD=.44), defining space types (e.g. urban park, station level, and underground platform) and gender (M=.04, SD.20), defining space types and age (M=.04, SD=.20), defining space types and education level (M=.04, SD=.20).The results show that there is a statistical differences between defining space types and the age groups 16-26 and 27-37 (t-stat:-32.00, p=0.00; t-stat:-22.51, p=0.00, respectively). The age groups of 38-48 and 49-59 show no significant differences.

There was a relationship between participants' average correct defining of the spaces in the listening tests and gender and age group. Although there was diversification across genders in the sample, there was a heterogeneous sample across age groups, and the differences between each group's sound recognition did not numerically represent this diversification. Therefore, in the regression the constant term is omitted. Both AGE (β: .10, p< .01) and GENDER (β: .29, p< .01) have positive significant coefficients at the 1% and 10% levels, respectively. The results can be interpreted as follows;

- Younger participants on average identify spaces 10% more correctly than older participants do.
- Females on average correctly identify approximately 30% more sounds than males do.

4. Discussion

This study confirms that there is a significant relationship between auditory perception and different space types, such as an urban park, metro station entrance and a metro station's underground platform. This study also reveals that some users can not recognize certain parts of a metro station (entrance and underground platform) solely by sound recordings of the related spaces and there is correlation between space recognition and age group and gender. A literature review identified that there have been a few studies to compare noise annoyance ratings between indoor and outdoor spaces.

Since few indoor soundscape studies exit, we believe that our paper would be an interesting contribution to the emerging field of soundscape of indoor spaces. We think that it would provide valuable information to show how to the built environment affects passengers and how they perceive their auditory environment. Below, we posit a number of reasons for these results.

Users' auditory perceptions in this study were identified by noise annoyance surveys and a semantic scale based on adjective pairs in a listening test. As recommended by the International Commission on the Biological Effects of Noise, the noise surveys gathered general socio-demographic data and presented a verbal annoyance scale. The results of the current study show that users' noise annoyance was highest on the underground platform of the metro station and lowest in the urban park.

In terms of the relationship between sound recognition and space types, as noted above, all participants identified the urban park correctly, however they failed to identify the metro station's entrance. Further, only half the participants were able to correctly determine the function of the spaces. These results confirm the hypothesis that the entrance and indoor spaces could not be recognized just from their sounds. In the literature, similar studies show 100% space recognition in listening tests, which means all participants correctly recognized the function of spaces and understood the space types, regardless of whether if it was an outdoor or indoor space (28,41). For example, Tardieu and his colleagues (28) took acoustic measurements, used the soundwalk method to investigate the role of soundscapes on space recognition in train stations and conducted a listening test. They find that 44 sound samples out of 66 were recognized by more than 50% of participants.

Evaluating the studied spaces in terms of soundmarks, marching, speech and sounds of children were perceived similarly in all three spaces. Traffic sounds were perceived similarly in the urban park and in station entrance. Birdsong, wind and water sounds were identified as soundmarks for the urban park, pay gates and coin sounds were identified for the station entrance and train sounds and the loudspeaker were identified for the underground platform level of the building. Yang and Kang (8) study the importance of auditory perception in user choice of an urban space and user preferences in an urban square. They used a sound preference survey similar to the noise annoyance survey in the current study. Interviewees were asked to describe three sounds they heard in the space, classify 15 verbally described sounds on a three-scale rating as *favorite*, *neither favorite nor annoying* or *annoying*. Interviewees were also asked to select their preferred sound sources/environments. Yang and Kang's findings show similarities with the current study in the following ways: As soundmarks, water sounds from fountains were identified as the first-noticed sounds. As secondary sound sources, traffic noise, road construction and human speech were identified. And finally, both studies agreed that the loudest sounds are not necessarily the first-noticed sounds in an environment (8).

All adjective pairs were analyzed with correlations and a t-test. Participants tended to choose adjectives such as *loud*, *unpleasant*, *disturbing*, *stressing*, *artificial*, etc. for the underground platform. These results provide an answer to the first research question of this study: that there is a statistically significant relationship between auditory perception and different space types. It should be noted, however, that this result may have been affected by the poor acoustic quality of the metro station.

The above-noted differences in results in terms of space recognition may be caused by several factors:

- In the current study, marching sounds, speech and sounds of children were perceived similarly in all three spaces, thus making it difficult to determine a specific space by those sounds alone. Further, traffic sounds were perceived similarly in the urban park and at the station entrance, thus making it hard to differentiate between the two.
- The types and levels of noises may have been why most participants failed to identify the station entrance; high background noise (which occurs with pay gates and coins) may have made some participants think the recording was from a completely indoor space, which some metro stations pay gates are found in. On the other hand, background traffic noise may have led others to identify the space as outdoor.

The results regarded to relationship between demographic and sound recognition correlate with our hypothesis and provide insight into our third research question. In the literature, Dökmeci and Kang (42) find significant effects between noise annoyance and demographic factors (such as gender and education level), and Yang and Kang (8) find a significant relationship between age and sound preferences and a somewhat less significant relationship between sound preference and gender. However, Chen and Kang compare noise annoyance and different activities and they find no significant relationships between the two factors (43).

5. Conclusion

This study finds that every space has a unique sound environment and acoustical requirements. These requirements become more varied and complex in indoor spaces because of factors such as the geometry of the indoor environment, the materials used and/or the activity occurring or the function of the space (17-25, 44). Correspondingly, auditory perceptions will differ. This statement is the most important aspect of the study's hypothesis. This study also reveals that there is a statistically significant relationship between auditory perception and different space types. Further, demographic factors (e.g., age group and gender) and space recognition are significantly related to each other. To strengthen these findings, similar studies should be conducted with different space types and with sound preference surveys. In further studies, indoor soundscape variables should also be taken into consideration, and more case studies, especially in indoor spaces, would be necessary to approach international standardization.

6. References

1. Schafer MR. The Soundscape [Internet]. Book. 1993. Available from: http://www.amazon.ca/exec/obidos/redirect?tag=citeulike09-20%5C&path=ASIN/0892814551
2. Brown AL, Kang J, Gjestland T. Towards standardization in soundscape preference assessment. Appl Acoust. 2011;72(6):387–92.
3. ISO:2014. ISO 43/SC 1/WG 54, 12913 - 1 Acoustics - Soundscape - 1: Definition and conceptual Framework. Zurich: Internail National Standart Organization; 2014.
4. Davies WJ, Adams MD, Bruce NS, Cain R, Carlyle A, Cusack P, et al. Perception of soundscapes: An interdisciplinary approach. Appl Acoust. 2013;74(2):224–31.
5. Mackrill J, Jennings P, Cain R. Exploring positive hospital ward soundscape interventions. Appl Ergon. 2014;45(6):1454–60.
6. Mackrill J, Cain R, Jennings P. Experiencing the hospital ward soundscape: Towards a model. J Environ Psychol. 2013;36:1–8.
7. Schulte-Fortkamp B, Fiebig A. Soundscape analysis in a residential area: An evaluation of noise and people's mind. Acta Acust united with Acust. 2006;92(6):875–80.
8. Yang M, Kang J. Psychoacoustical evaluation of natural and urban sounds in soundscapes. J Acoust Soc Am [Internet]. 2013;134(1):840–51. Available from: http://asa.scitation.org/doi/10.1121/1.4807800
9. Brambilla G, Gallo V, Asdrubali F, D'Alessandro F. The perceived quality of soundscape in three urban parks in Rome. J Acoust Soc Am [Internet]. 2013 Jul;134(1):832–9. Available from: http://asa.scitation.org/doi/10.1121/1.4807811

10. Liu F, Kang J. A grounded theory approach to the subjective understanding of urban soundscape in Sheffield. Cities. 2016;50:28–39.

11. Aletta F, Kang J, Axelsson Ö. Soundscape descriptors and a conceptual framework for developing predictive soundscape models. Landscape and Urban Planning. 2016; 149: 65–74.

12. Vogiatzis K, Remy N. From environmental noise abatement to soundscape creation through strategic noise mapping in medium urban agglomerations in South Europe. Sci Total Environ. 2014;482–483(1):420–31.

13. Maristany A, Lopez MR, Rivera CA. Soundscape quality analysis by fuzzy logic: A field study in Cordoba, Argentina. Appl Acoust. 2016;111:106–15.

14. Sudarsono AS, Lam YW, Davies WJ. Soundscape Perception Analysis Using Soundscape Simulator. In: Inter Noise 2016; 6868–75.

15. Torija AJ, Ruiz DP, Ramos-Ridao AF. Application of a methodology for categorizing and differentiating urban soundscapes using acoustical descriptors and semantic-differential attributes. J Acoust Soc Am [Internet]. 2013;134(1):791–802. Available from: http://asa.scitation.org/doi/10.1121/1.4807804

16. Watts G, Khan A, Pheasant R. Influence of soundscape and interior design on anxiety and perceived tranquillity of patients in a healthcare setting. Appl Acoust. 2016;104:135–41.

17. Sü Z and Yilmazer S. The acoustical characteristics of the Kocatepe Mosque in Ankara, Turkey Zühre. Archit Sci Rev [Internet]. 2006;50:37–41. Available from: www.earthscan.co.uk/journals/asre

18. Sü Z, Yilmazer S. The acoustical performance analysis of Bilkent Amphitheater: Proposal for acoustical renovation. Archit Sci Rev [Internet]. 2006;49(2):167–78. Available from: http://www.tandfonline.com/doi/abs/10.3763/asre

19. Sinal Ö, Yilmazer S. A comparative study on indoor sound quality of the practice rooms upon classical singing trainees' preference. EuroNoise2015, June 2015, Maastricht, Netherland ; Available from: http://www.conforg.fr/euronoise2015/proceedings/data/articles/000190.pdf

20. Yilmazer S, Gezginer PM. An experimental study on speech interference in public leisure spaces. 39th Int Congr Noise Control Eng 2010, Inter Noise 2010 [Internet]. 2010 ;2:1060–7. Available from: http://repository.bilkent.edu.tr/handle/11693/28446

21. Kitapci K, Yilmazer S, Erkip F. Effect of speech intelligibility on visual short-term memory performance. Turkish Acoust Soc - 36th Int Congr Exhib Noise Control Eng Inter Noise 2007 Istanbul [Internet]. 2007;5:3594–604. Available from: http://repository.bilkent.edu.tr/handle/11693/27065

22. Dökmeci P, Yılmazer S. Relationships between measured levels and subjective ratings: A case study of the food-court area in CEPA shopping center, Ankara. Build Acoust [Internet]. 2012;19(1):57–74. Available from: http://bua.sagepub.com/lookup/doi/10.1260/1351-010X.19.1.57

23. Acun V, Yilmazer S. Investigating the effect of indoor soundscaping towards employee's speech privacy. EuroNoise2015, June 2015, Maastricht, Netherland; Available from: http://www.conforg.fr/euronoise2015/output_directory/data/articles/000172.pdf

24. Acun V, Yilmazer S, Taherzadeh P. Perceived auditory environment in historic spaces of

Anatolian Culture : A case study on Haci Bayram Mosque. In: 23rd International Congress on Sound & Vibration (ICSV23). 2016: 1–8.

25. Çankaya S, Yilmazer S. The effect of soundscape on the students' perception in the high school environment. 45th Int Congr Noise Control Eng 2016, Inter Noise 2016 [Internet]. ; Available from: http://pub.dega-akustik.de/IN2016/data/articles/000021.pdf

26. Kang J. Acoustics of long underground spaces. Tunn Undergr Sp Technol. 1997;12(1):15–21.

27. Liu JC, Lu PC. Study on sound propagation in long enclosures with a vertical or inclined branch of different dimensions. Appl Acoust. 2009;70(3):522–9.

28. Tardieu J, Susini P, Poisson F, Lazareff P, McAdams S. Perceptual study of soundscapes in train stations. Appl Acoust. 2008;69(12):1224–39.

29. Tang Z, Kang J, Jin H. Experimental study of the sound field in an underground shopping street. Tunn Undergr Sp Technol. 2013;36:1–4.

30. Van der Hoeven F, Van Nes A. Improving the design of urban underground space in metro stations using the space syntax methodology. Tunn Undergr Sp Technol. 2014;40:64–74.

31. He L, Song Y, Dai S, Durbak K. Quantitative research on the capacity of urban underground space - The case of Shanghai, China. Tunn Undergr Sp Technol. 2012;32:168–79.

32. Sü Z, Çalışkan M. Acoustical Design and Noise Control in Metro Stations: Case Studies of the Ankara Metro System. Build Acoust. 2007;14(3):231–49.

33. ISO. ISO/TS 15666:2003 Assessment of Noise Annoyance by means of Social and Socio-acoustic Survey. 2003.

34. Semidor C. Listening to a city with the soundwalk method. Acta Acust united with Acust. 2006;92(6):959–64.

35. Lynch K. The city image and its elements. image city [Internet]. 1960;46–90. Available from: http://www.laboratoriorapu.it/LPU_sito/download/Materiali_Papers/02b_08.03.26_Lynch-anthology.pdf

36. Yu L, Kang J, Hong L, Xie C. Soundscape Identification in Noise Annoyance Evaluation. Inter-noise 2014. 2014;6.

37. Kang J, Zhang M. Semantic differential analysis of the soundscape in urban open public spaces. Build Environ. 2010;45(1):150–7.

38. Regulation TN. Çevresel Gürültünün Değerlendirilmesi ve Kavranması-Türkiye (Regulations of Noise Assessment and Administrations)-Turkey. 2010.

39. Zwicker E, Fastl H. Psychoacoustics, facts and models; Psychoakustik. Fakten und modelle. Springer, Berlin, 1990, 354 Seiten Series: Springer series in information sciences, Vol. 22. 1990.

40. Özçevik, A., Yüksel Z. Yüksek kentsel akustik konforun irdelenmesinde uygulamalı bir işitsel peysaj yaklaşımı. Megaron. 2014;9(1):45–54.

41. Dokmeci Yorukoglu PN, Kang J. Analysing sound environment and architectural characteristics of libraries through indoor soundscape framework. Arch Acoust. 2016;41(2):203–12.

42. Dökmeci PN, Kang J. Indoor Soundscaping of Public Enclosed Space. J Temporal Des Archit Environ. 2011;11(1):1–6.

43. Chen B, Kang J. Acoustic comfort in shopping mall atrium spaces—A case study in Sheffield Meadowhall. Archit Sci Rev [Internet]. 2004;47(2):107–14. Available from: http://www.tandfonline.com/doi/abs/10.1080/00038628.2004.9697033

44. Acun V, Yilmazer S. A grounded theory approach to investigate the perceived soundscape of open-plan offices, App. Acoust. 2017; 131: 28-37

Figures

Figure 1: Site view of Akköprü metro station, Turkey

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Figure 2: View of the ANKAmall Park and Akköprü metro station from ANKAmall

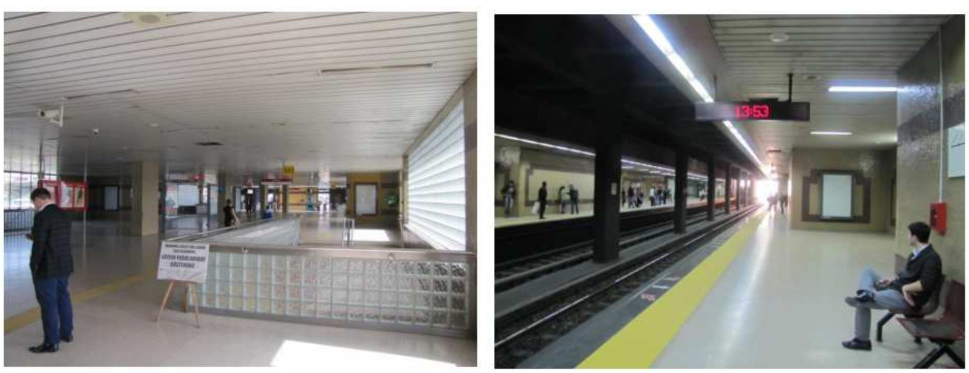

Figure 3: Entrance level (left) and underground platform (right) in the Akköprü metro station

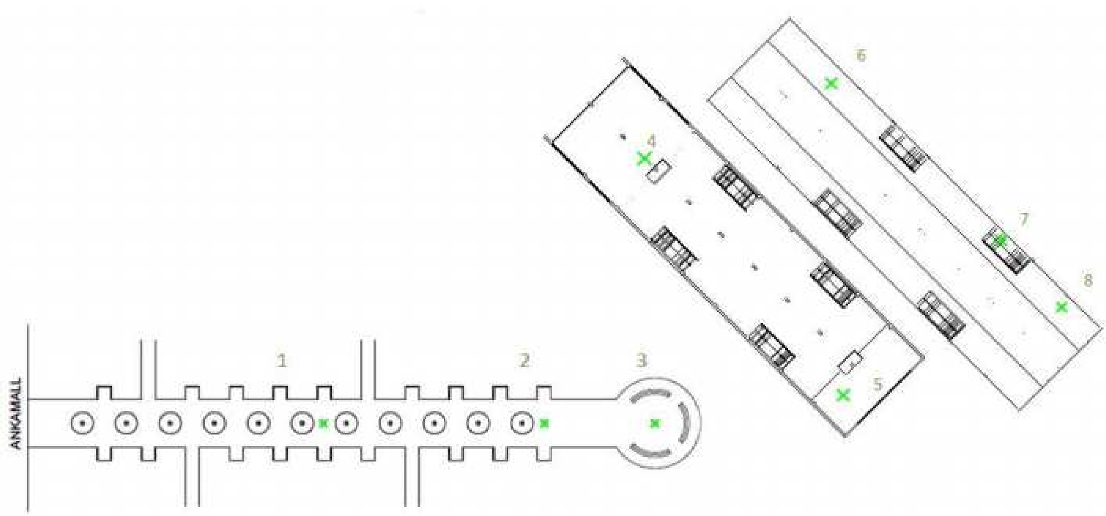

Figure 4: The eight spots on the plans used for objective and subjective measurements (1-3: ANKAmall Park; 4-5: metro station entrance; 6-8: metro station underground platform)

Figure 5. An interviewee in the semi-anechoic room

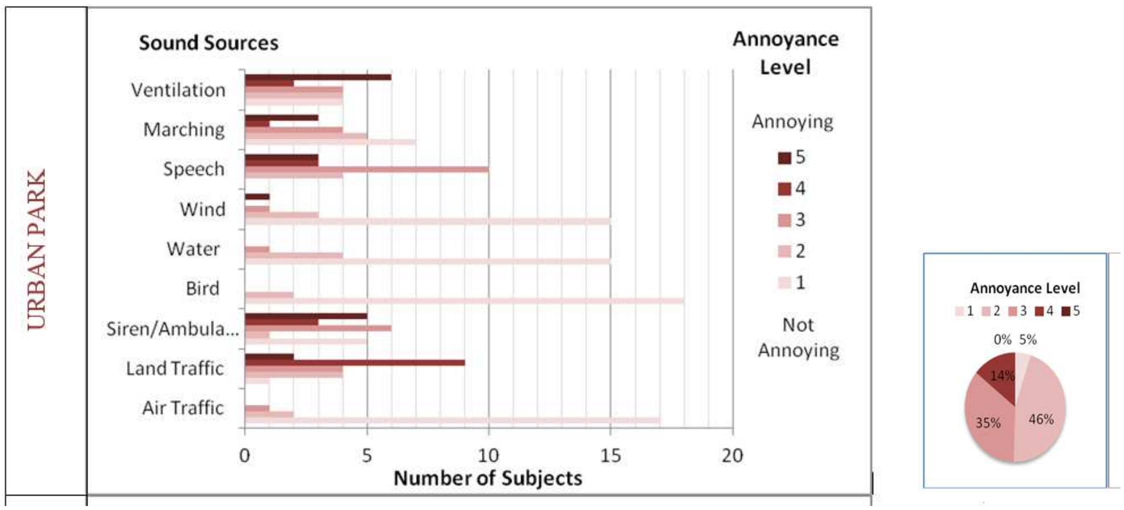

Figure 6. Subjects' noise annoyance ratings of specified sound sources and noise annoyance chart in ANKAmall Park

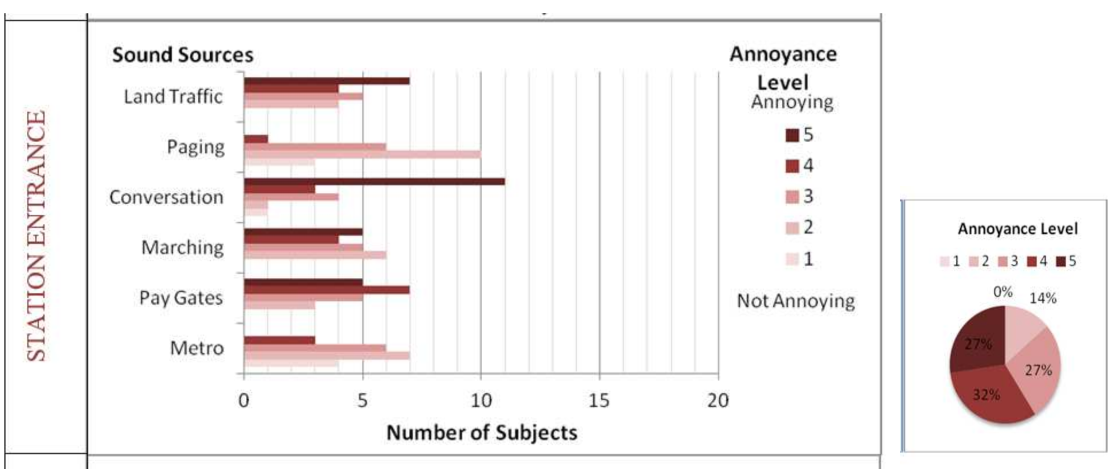

Figure 7. Subjects' annoyance ratings for specified sound sources and noise annoyance chart for the metro station entrance

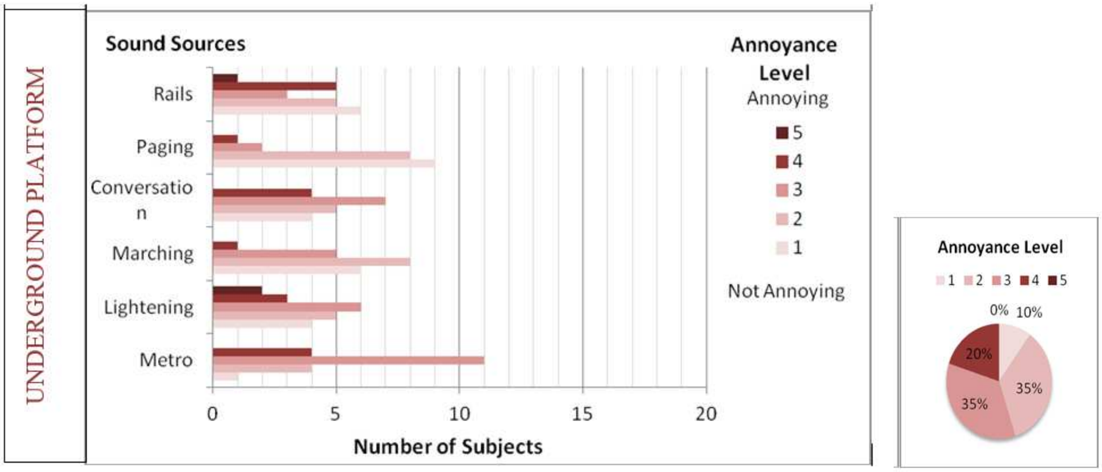

Figure 8. Subjects' annoyance ratings for specified sound sources and noise annoyance chart on the underground platform

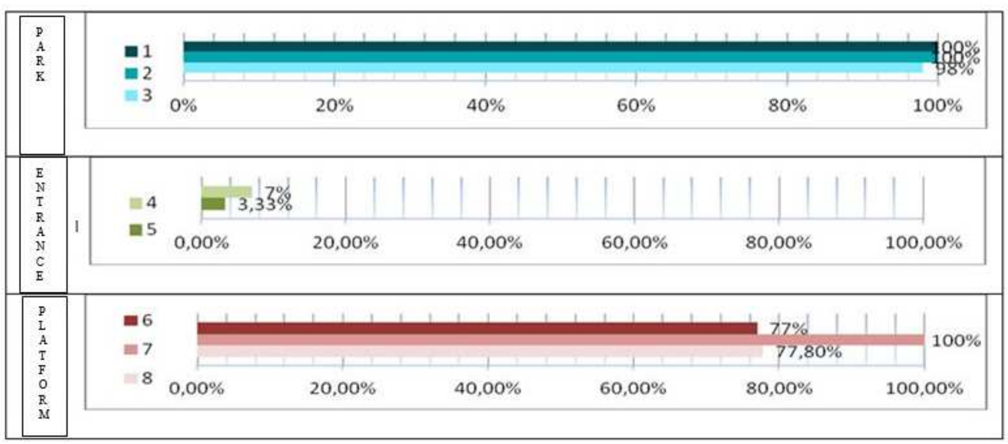

Figure 9. Listening test results: defining space types (urban park (spots 1-2-3); station entrance (spots 4-5); underground platform (spots 6-7-8)). See Figure 4 for measurement points

Table 1: Permitted and measured sound pressure levels in defined spots

Measurement Spots (1-8)		Permitted Sound Pressure Level (SPL), dBA	A-weighted Equivalent Sound Level (LAeq), dBA	Sound Pressure Level (SPL), dBA
Urban Park	1	60	66	63
	2	60	59.7	61
	3	60	69	75
Station Entrance	4	55	60.1	60.2
	5	55	70	76
Underground Platform	6	80	64	66.3
	7	55	60.7	65
	8	80	90	75

Table 2. Listening test results: Sound sources and soundmarks identified by the listening test and site analyses (see Figure 4 for measurement points)

Transport Spaces	Sound Sources	Soundmarks
Urban Park	Heavy Traffic Decorative Pool Weather Conditions Flow of People	Bird Sound Wind Sound Water Sound Marching Sound Speech and Child Sounds Traffic Sound; horn and siren
Station Entrance	Ticket Office Pay Gates Flow of People Heavy Traffic	Coin Sound Pay Gate Sound Marching Sound Speech and Child Sounds Traffic Sound; horn and siren
Underground Platform	Metro Loudspeaker Flow of People	Marching Sound Metro Sound; brakes and door Paging Speech and Child Sounds

Table 3. Relationship between sound quality metrics, adjective pairs and soundmarks

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 their effect on the space
		strange-common	Familiarity of the soundmarks