

Understanding the indoor soundscape in public transport spaces: A case study in Akköprü metro station, Ankara

Building Acoustics
2017, Vol. 24(4) 325–339
© The Author(s) 2017
Reprints and permissions:
sagepub.co.uk/journalsPermissions.nav
DOI: 10.1177/1351010X17741742
journals.sagepub.com/home/bua


Semiha Yilmazer and Zeynep Bora

Abstract

Metro stations can be included in the indoor soundscape literature. This study examines the relationship between space recognition and soundmarks. Sound recordings were taken at various sites in and around a metro station and a listening test applied to investigate whether spaces could be recognized only by the sounds associated with them. For each sound recording, participants were asked to describe the recorded space from 17 adjective pairs and define the sound sources. The results are as follows: (1) only half of the participants were able to correctly determine the function of the spaces; (2) bird, wind, and water soundmarks were identified in the urban park near the metro station; pay gates and coin sounds were identified in the station entrance; and the metro train itself, as well as its brakes, doors, and announcement system, were identified on the underground platform; (3) for outdoor spaces, participants tended to choose adjectives such as pleasant, calming, or natural, while for indoor spaces they chose words such as unpleasant, stressing, and artificial; and (4) females on average are able to identify 30% more sounds correctly than males are, and younger age groups' correct identification rate is greater than older groups' by 10% on average.

Keywords

Indoor soundscape, metro station, auditory sound environment, soundwalk, listening test, sound recognition, soundmark

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

Department of Interior Architecture and Environmental Design, Faculty of Art, Design and Architecture, Bilkent University, Ankara, Turkey

Corresponding author:

Semiha Yilmazer, Department of Interior Architecture and Environmental Design, Faculty of Art, Design and Architecture, Bilkent University, Bilkent, Ankara 06800, Turkey.
Email: semiha@bilkent.edu.tr

international standardization for soundscape definitions and measurement techniques.² Brown et al.² proposed a taxonomic 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 pressure levels (SPLs), 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 method³⁰ 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.²⁸ 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. The authors then aimed to understand *how* users learn and memorize the soundscapes of such spaces. With their



Figure 1. Site view of Akköprü metro station, Turkey.

studies of Ankara and Warsaw metro stations, Sü and Çalışkan³² developed guidelines for acoustically measuring enclosed spaces such as evaluating different materials for providing optimum acoustical conditions in such spaces.

The aim of this 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.

Methods

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 SPLs 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.

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).

ANKAmall Park, a greenspace approximately 50m from the station and 20m 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 5m in diameter. The park directly faces the shopping mall (Figure 2).



Figure 2. View of the ANKA mall Park and Akköprü metro station from ANKA mall.

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 m long and 216 m wide. The height of the entrance level is 3.19 m and the height of the platform level is 3.36 m from the base to the suspended aluminum ceiling, and 7.33 m from the metro rails to the top of the metro tunnel. The floor is artificial marble in 40 cm \times 40 cm. 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).

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 and 17:00 (Figure 4). In all three spaces, LAeqs and SPLs were measured, at height of 125 cm, over 15-min time intervals. All measurements were conducted simultaneously while the participants filled in the noise annoyance surveys and conducted soundwalks.

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

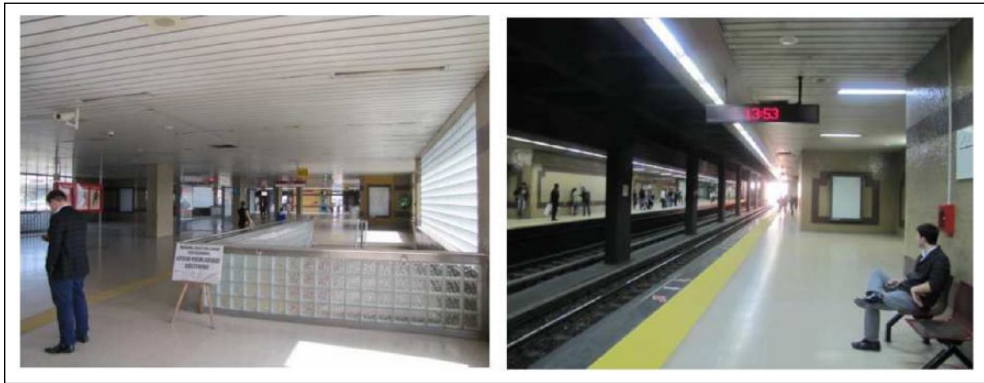


Figure 3. Entrance level (left) and underground platform (right) in the Akköprü metro station.

We prepared a noise annoyance questionnaire based on previous studies^{22,25} for each of our and three case areas: ANKA mall 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.

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*, Lynch³⁵ discusses the relationship among soundmarks, city images, and sound and space recognition. Semidor³⁴ explain that relationship: "Every sound event can be preserved in a way which enables us to identify it." Lynch³⁵ 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. A study³⁶ 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

In this 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-s-long sound recordings were made in the selected eight spots (Figure 4). The recordings were kept short to avoid subject distraction during the listening

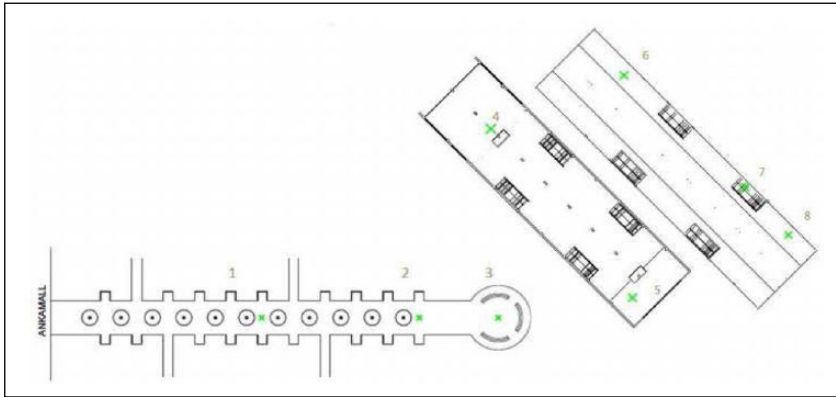


Figure 4. The eight spots on the plans used for objective and subjective measurements (1–3: ANKA mall Park; 4–5: metro station entrance; and 6–8: metro station underground platform).

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 15666.³⁷

For the listening test, we randomly chose 90 uninformed participants who work at 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 min. For each sound recording, participants were asked to explain¹ the function of the recorded spaces,² guess whether the recorded space was the urban park, station entrance or underground platform and International Organization for Standardization³ define the sound sources. Furthermore, Davies et al.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).³⁸

Results

Sound pressure levels and A-weighted equivalent sound levels measured at Akköprü metro station

The LAeq levels and SPL results show that the measurements (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.³⁹



Figure 5. An interviewee in the semi-anechoic room.

Subjective parameters measured at Akköprü metro station

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).

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

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). Furthermore, only half the subjects were able to determine the correct functions of the spaces.

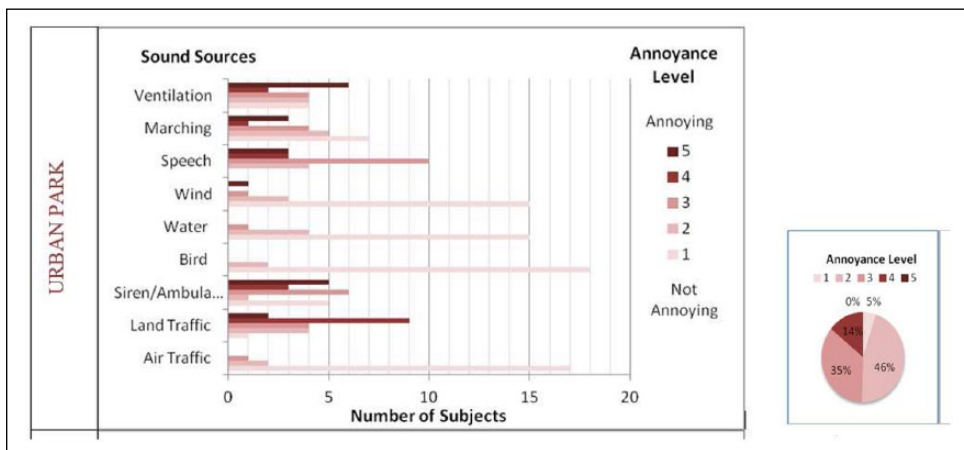
In our study, we applied a *t*-test to subsamples of gender and age groups, and to both groups together. The results show gender, age, and space recognition (if participants correctly recognize spaces as urban park, entrance level, or underground platform, and recognize the spaces) did not show any correlation with $\sim .000$ 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 $< .01$.

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 sound, and water sound 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).

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
	2	60	59.7
	3	60	69
Station entrance	4	55	60.1
	5	55	70
Underground platform	6	80	64
	7	55	60.7
	8	80	90

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

Semantic differential and correlations

This study used Zwicker and Fastl's⁴⁰ metrics with Özçevik and Yüksel's³³ 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.

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_{jk}^i represents the correlation between adjective pairs $j \cdot k \in \{1, \dots, 17\}$ in the recording set $i \in \{1, \dots, 8\}$. They felt discomfort in spaces perceived as unpleasant ($\sigma_{2,3}^{1-8}$) and stressed in spaces perceived as unpleasant and disturbing ($\sigma_{2,4}^{1-8}$; $\sigma_{3,4}^{1-8}$). Spaces perceived as comfortable and relaxing were preferred over spaces perceived as disturbing and stressful ($\sigma_{3,8}^{1-8}$; $\sigma_{4,8}^{1-8}$). Users tended to define light spaces as exciting ($\sigma_{15,16}^{1-8}$) and to correlate the adjectives exciting and joyful.

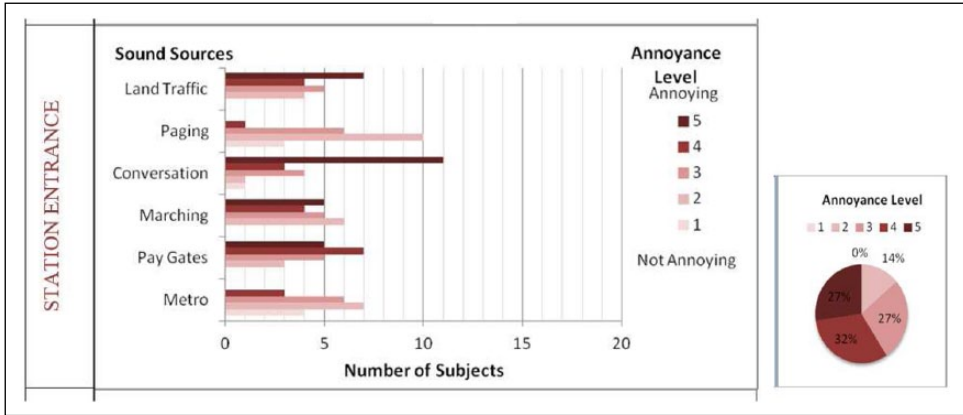


Figure 7. Subjects' annoyance ratings for specified sound sources and noise annoyance chart for the metro station entrance.

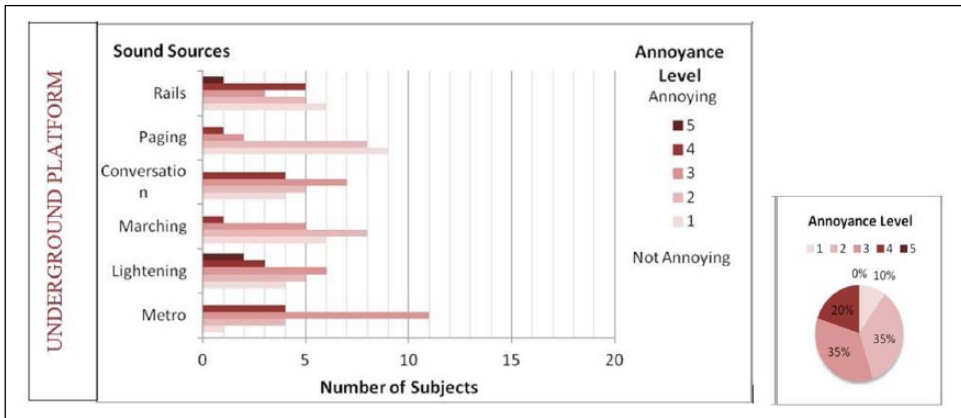


Figure 8. Subjects' annoyance ratings for specified sound sources and noise annoyance chart on the underground platform.

Relationship between demographic factors and sound recognition

In this 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 difference between defining space types and the age groups 16–26 and 27–37 years (t -stat: -32.00 , $p=.00$; t -stat: -22.51 , $p=.00$, respectively). The age groups of 38–48 and 49–59 years 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

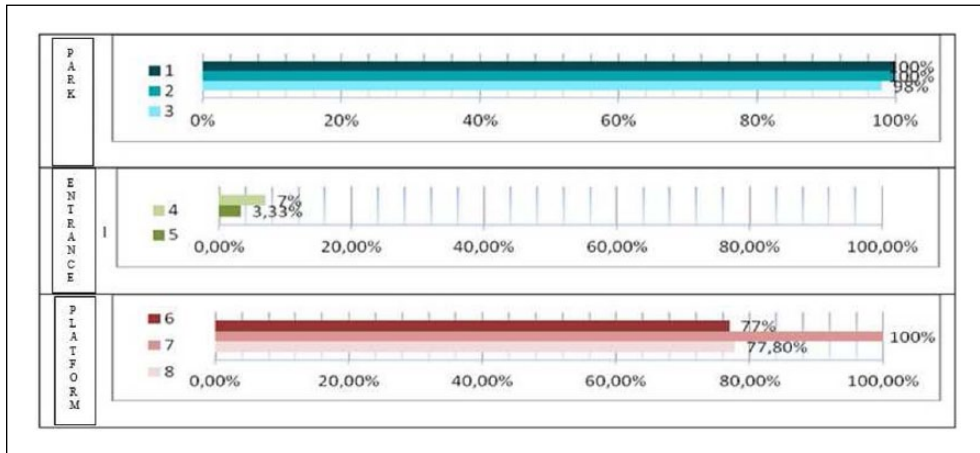


Figure 9. Listening test results: defining space types (urban park (spots 1–3); station entrance (spots 4–5); underground platform (spots 6–8)). See Figure 4 for measurement points.

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	Bird sound
	Decorative pool	Wind sound
	Weather conditions	Water sound
	Flow of people	Marching sound
		Speech and child sounds
		Traffic sound; horn and siren
Station entrance	Ticket office	Coin sound
	Pay gates	Pay gate sound
	Flow of people	Marching sound
	Heavy traffic	Speech and child sounds
		Traffic sound; horn and siren
Underground platform	Metro	Marching sound
	Loudspeaker	Metro sound; brakes and door
	Flow of people	Paging
		Speech and child sounds

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.

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

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 cannot 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 exist, we believe that our article 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 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 this 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. Furthermore, 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 et al.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 sound, and water sound 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 Kang⁸ 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 this 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 this 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*, and *artificial* 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 this 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. Furthermore, 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, Dökmeçi and Kang⁴² find significant effects between noise annoyance and demographic factors (such as gender and education level), and Yang and Kang⁸ find a significant relationship between age and sound preferences and a somewhat less significant relationship between sound preference and gender. However, Chen and Kang⁴³ compare noise annoyance and different activities and they find no significant relationships between the two factors.

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. Furthermore,

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.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

References

1. Schafer MR. The soundscape, 1993, <http://www.amazon.ca/exec/obidos/redirect?tag=citeulike09-20%5C&path=ASIN/0892814551>
2. Brown AL, Kang J and Gjestland T. Towards standardization in soundscape preference assessment. *Appl Acoust* 2011; 72(6): 387–392.
3. International Organization for Standardization. *ISO 12913-1:2014. Acoustics—soundscape—part 1: definition and conceptual Framework*. Zurich: International Organization for Standardization, 2014.
4. Davies WJ, Adams MD, Bruce NS, et al. Perception of soundscapes: an interdisciplinary approach. *Appl Acoust* 2013; 74(2): 224–231.
5. Mackrill J, Jennings P and Cain R. Exploring positive hospital ward soundscape interventions. *Appl Ergon* 2014; 45(6): 1454–1460.
6. Mackrill J, Cain R and Jennings P. Experiencing the hospital ward soundscape: towards a model. *J Environ Psychol* 2013; 36: 1–8.
7. Schulte-Fortkamp B and Fiebig A. Soundscape analysis in a residential area: an evaluation of noise and people's mind. *Acta Acust United Ac* 2006; 92(6): 875–880.
8. Yang M and Kang J. Psychoacoustical evaluation of natural and urban sounds in soundscapes. *J Acoust Soc Am* 2013; 134(1): 840–851, <http://asa.scitation.org/doi/10.1121/1.4807800>
9. Brambilla G, Gallo V, Asdrubali F, et al. The perceived quality of soundscape in three urban parks in Rome. *J Acoust Soc Am* 2013; 134(1): 832–839, <http://asa.scitation.org/doi/10.1121/1.4807811>
10. Liu F and 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 and Axelsson Ö. Soundscape descriptors and a conceptual framework for developing predictive soundscape models. *Landscape Urban Plan* 2016; 149: 65–74.
12. Vogiatzis K and 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): 420–431.
13. Maristany A, Lopez MR and Rivera CA. Soundscape quality analysis by fuzzy logic: a field study in Cordoba, Argentina. *Appl Acoust* 2016; 111: 106–115.
14. Sudarsono AS, Lam YW and Davies WJ. Soundscape perception analysis using soundscape simulator. In: 45th Int Congr Noise Control Eng 2016, *Inter-Noise 2016*, Hamburg, 21–24 August 2016.
15. Torija AJ, Ruiz DP and Ramos-Ridao AF. Application of a methodology for categorizing and differentiating urban soundscapes using acoustical descriptors and semantic-differential attributes. *J Acoust Soc Am* 2013; 134(1): 791–802, <http://asa.scitation.org/doi/10.1121/1.4807804>
16. Watts G, Khan A and Pheasant R. Influence of soundscape and interior design on anxiety and perceived tranquility of patients in a healthcare setting. *Appl Acoust* 2016; 104: 135–141.
17. Sü Z and Yilmazer S. The acoustical characteristics of the Kocatepe Mosque in Ankara, Turkey Zühre. *Archit Sci Rev* 2006; 50: 37–41, www.earthscan.co.uk/journals/asre

18. Sü Z and Yilmazer S. The acoustical performance analysis of Bilkent Amphitheater: proposal for acoustical renovation. *Archit Sci Rev* 2006; 49(2): 167–178, www.tandfonline.com/doi/abs/10.3763/asre.2008.5104
19. Sinal Yilmazer ÖS. A comparative study on indoor sound quality of the practice rooms upon classical singing trainees' preference. In: *EuroNoise2015*, Maastricht, 31 May–3 June 2015, <http://www.conforg.fr/euronoise2015/proceedings/data/articles/000190.pdf>
20. Yilmazer S and Gezginer PM. An experimental study on speech interference in public leisure spaces. In: *39th international congress on noise control engineering (Inter-Noise 2010)*, 2010, vol. 2, pp. 1060–1067, <http://repository.bilkent.edu.tr/handle/11693/28446>
21. Kitapci K, Yilmazer S and Erkip F. Effect of speech intelligibility on visual short-term memory performance. In: *Turkish Acoustical Society—36th international congress and exhibition on noise control engineering (Inter-Noise 2007)*, Istanbul, Turkey, 2007, vol. 5, pp. 3594–3604, <http://repository.bilkent.edu.tr/handle/11693/27065>
22. Dökmeci P and Yilmazer S. Relationships between measured levels and subjective ratings: a case study of the food-court area in CEPA shopping center, Ankara. *Build Acoust* 2012; 19(1): 57–74, <http://bu.sagepub.com/lookup/doi/10.1260/1351-010X.19.1.57>
23. Acun V and Yilmazer S. Investigating the effect of indoor soundscaping towards employee's speech privacy. In: *EuroNoise 2015*, Maastricht, 31 May–3 June 2015, http://www.conforg.fr/euronoise2015/output_directory/data/articles/000172.pdf
24. Acun V, Yilmazer S and Taherzadeh P. Perceived auditory environment in historic spaces of Anatolian Culture: a case study on Hacı Bayram Mosque. In: *23rd international congress on sound & vibration (ICSV23)*, Athens, 10–14 July 2016.
25. Çankaya S and Yilmazer S. The effect of soundscape on the students' perception in the high school environment. In: *45th international congress and exposition of noise control engineering (Inter-Noise 2016)*, <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 and Lu PC. Study on sound propagation in long enclosures with a vertical or inclined branch of different dimensions. *Appl Acoust* 2009; 70(3): 522–529.
28. Tardieu J, Susini P, Poisson F, et al. Perceptual study of soundscapes in train stations. *Appl Acoust* 2008; 69(12): 1224–1239.
29. Tang Z, Kang J and 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 and 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, et al. Quantitative research on the capacity of urban underground space—the case of Shanghai, China. *Tunn Undergr Sp Technol* 2012; 32: 168–179.
32. Sü Z and Çalışkan M. Acoustical design and noise control in metro stations: case studies of the Ankara metro system. *Build Acoust* 2007; 14(3): 231–249.
33. Özçevik A and Yüksel Z. Yüksek kentsel akustik konforun irdelenmesinde uygulamalı bir işitsel peysaj yaklaşımı. *Megaron* 2014; 9(1): 45–54.
34. Semidor C. Listening to a city with the soundwalk method. *Acta Acust United with Acust* 2006; 92(6): 959–964.
35. Lynch K. The city image and its elements. In: *The Image of the City*, 1960, pp. 46–90, http://www.laboratoriorapu.it/LPU_sito/download/Materiali_Papers/02b_08.03.26_Lynch-anthology.pdf
36. Yu L, Kang J, Hong L, et al. Soundscape identification in noise annoyance evaluation. In: *3th Int Congr Noise Control Eng 2014, Inter-Noise 2014*, Melbourne, VIC, Australia, 16–19 November 2014.
37. ISO. ISO/TS 15666:2003. *Acoustics—assessment of noise annoyance by means of social and socio-acoustic survey*, 2003.
38. Kang J and Zhang M. Semantic differential analysis of the soundscape in urban open public spaces. *Build Environ* 2010; 45(1): 150–157.
39. Regulation TN. Çevresel Gürültünün Değerlendirilmesi ve Kavranması—Türkiye (Regulations of Noise Assessment and Administrations)—Turkey 2010. Internet <http://www.mevzuat.gov.tr/Metin.Aspx?MevzuatKod=7.5.14012&MevzuatIliski=0>.

40. Zwicker E and Fastl H. *Psychoacoustics: facts and models* [Psychoakustik: Fakten und modelle] (Springer series in information sciences, vol. 22). Berlin: Springer, 1990.
41. Dokmeci Yorukoglu PN and Kang J. Analysing sound environment and architectural characteristics of libraries through indoor soundscape framework. *Arch Acoust* 2016; 41(2): 203–212.
42. Dökmeci PN and Kang J. Indoor soundscaping of public enclosed space. *J Temporal Des Archit Environ* 2011; 11(1): 1–6.
43. Chen B and Kang J. Acoustic comfort in shopping mall atrium spaces—a case study in Sheffield Meadowhall. *Archit Sci Rev* 2004; 47(2): 107–114, <http://www.tandfonline.com/doi/abs/10.1080/00038628.2004.9697033>
44. Acun V and Yilmazer S. A grounded theory approach to investigate the perceived soundscape of open-plan offices. *App Acoust* 2017; 131: 28–37.