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ASSESSING SOUNDSCAPE IN PUBLIC LIBRARIES: THE CASE STUDY OF YILDIZ TECHNICAL UNIVERSITY ŞEVKET SABANCI LIBRARY

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ABSTRACT

Libraries are constantly evolving, and as a response, the acoustic requirements of the space are changing too. Nowadays, they serve several purposes, from group discussions to private, quiet study areas. This study analyzes the perceived sound environment in Şevket Sabancı Library. The library has a four-storey plan layout with different functions such as multimedia rooms for group working as well as quiet study areas, resulting in a total of 2500m^2. 30s-long binaural recordings are taken from eight different locations in the library, showing their respective functions' soundscape identity. Simultaneously, the spaces' sound pressure levels (SPL) are measured in situ. Twenty different people listened to all recorded clips in a listening room and assessed the perceived sound environment through a semantic differential scale. The participants evaluated the recorded sounds through thirty pairs of adjectives in the Turkish language using a five-point bipolar scale and sound sources. The initial findings indicate variations in the acoustic environment across the chosen spaces, as assessed in terms of their assessment and appropriateness, which also exhibit a positive correlation. Furthermore, the acoustic composition of the soundscape recordings differs across the locations, particularly in terms of the dominance of different sound sources.

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1. INTRODUCTION

Libraries have always embraced multipurpose facilities like different study spaces, including those for solo or group work. Following numerous technological advancements, they also adapted to digital developments. As libraries introduced more social amenities like cafes, theaters, and galleries, the number of actual books and storage areas likewise reduced over time [1-2]. However, conventional reading areas remain the primary purpose [3].
Sound plays a vital role in perceiving the indoor library environment. Research shows that a group of people need to have silent spaces to study. On the other hand, group study spaces' loud atmosphere does not influence the user as much as expected [4]. This shows that perception has a vital role in the learning process [4]. Soundscape terms identify a place in terms of its users' perception. The soundscape is influenced by context, sound sources, acoustic environment, auditory sensation, interpretation of auditory sensation, responses, and outcomes [5]. Schafer categorized sound sources into three categories as natural sounds, human sounds, and technological sounds [6].
The major difference between indoor soundscape and urban-outdoor soundscape is architecture [7]. Indoor soundscapes consist of contextual experience, sound environment, and built entity. It is defined by demographical factors, psychological factors, space usage factors, functional factors, spatial factors, indoor

environmental factors, physical factors, acoustical factors, and psychoacoustical factors [7].
This research focuses on three open study areas in Yildiz Şevket Sabancı Library. It aims to understand the library's indoor sound environment and its overall assessment. The library consists of small-big group study areas, a digital study room, library offices, and storage areas. The sound recordings taken from various locations are being evaluated by 30 different Turkish adjective pairs [8] and Schafer's criteria [6,9]. This study aims to provide further insight about the indoor soundscape characterization of libraries by using as a case study one of the libraries of Turkey's largest universities.

2. METHOD

2.1 The Case study: Yildiz Technical University Library

Yildiz Technical University has two different campuses, each having its respective libraries in İstanbul. The current study focuses on the Beşiktaş campus library. This campus is located near Barbaros Boulevard, which is the noisiest road in the Beşiktaş district, with sound levels of over 75 dB [10]. The library includes group and private study areas, an exhibition hall, and book storage areas. The building, built in 1983, has a rectangular grid plan resulting in a total of 2500 m^2.
The library's outer façade, which is in front of the boulevard, is made of concrete, and its inner walls are painted with plaster. On the other hand, the opposite side of the library façade used a transparent design involving glass and steel construction materials. That transparent style helps to see the gardens of the campus and the public park on Barbaros Boulevard. The library's floor material is ceramic and carpet. Especially in the silent study spaces, the used floor material is carpet. The ceiling has an exposed concrete waffle slab, as seen in Figures 1, 2, and 3. The indoor furniture, such as tables, storage, and chairs, is mainly made of wood. In some places, there are moveable chairs made of plastics and textiles.
The university library does not accept members from the university. Its archive can host members from the engineering and architectural discipline. Usually, the library is mainly crowded during midterm and final weeks. In this library, many students prefer to study with their personal computers or the library's computer room on the ground floor.

Figure 1. Basement Floor Recording Points Perspectives.

Figure 2. First Floor Recording Point Perspectives. (The left photo shows C and B point and right photo shows A point)

Figure 3. Second Floor Recording Point Perspectives.

2.2 Audio recordings

In the scope of this study, five-minute-long binaural sound recordings were taken in eight different locations (Figure 4) of the library on each floor to comprise the majority of the possible soundscapes that can occur in this building. In basement floor, sound sources recorded in private rooms, group study space and near the window area. In first floor, sound recorded window side study area which is C, book storage area and study spaces which is A (Figure 2). For this purpose, Zoom H6 and 3Dio binaural microphones were used. Later, those recordings were tailored to be 30 s long for feasibility issues to be used in listening tests.

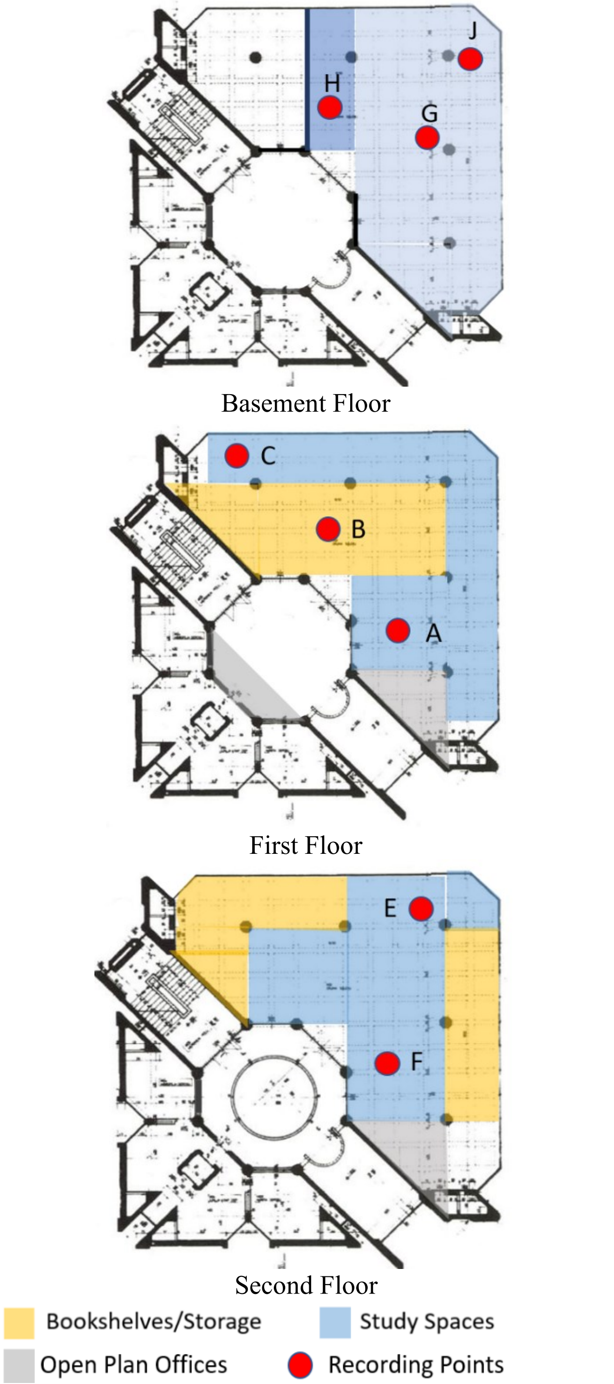

Figure 4. Yildiz Technical University Şevket Sabancı Campuses Library Floor Plans.

At the same time, to characterize the space in terms of sound levels, objective measurements of the Sound Pressure Level (A-Weighted, dB) were taken by a Bruel & Kjaer 2236 Sound Level Meter for 5 minutes as well. Their values were averaged and shown in Table 1 for each respective location.

Table 1. SPL(A, dB) Levels in each location

Space location	SPL (A,dB)
A First Floor study area	34
B First Floor Bookshelves	34.2
C First Floor Near the window	42.5
E Second Floor Near the window	47.5
F Second Floor Study area	42.5
G Basement Floor Public study area	41.3
H Basement Floor Private study area	50.2
J Basement Floor Study area	43.8

2.3 Listening tests

Twenty university students/faculty members, frequent users of the space, of which thirteen were female, and seven were male, participated in the study. 30% of the participants were between 18-24 years old, and the remaining were between 25 and 34 years old. All the participants reported normal hearing prior to beginning the listening tests.

All eight recordings were listened to by 20 participants with Sennheiser binaural headphones in a quiet room at Yildiz Technical University. After listening to the soundscape recordings, they were asked to complete a questionnaire of three parts. The first part asked for information about their demographic data. As sound sources play a crucial role in soundscape assessment, the second part of the questionnaire was concerned with identifying dominant sound sources using "Method A" ISO/TS 12913-2:2018. The evaluation measured the dominance of sound sources at each location on a 5-point scale ranging from "Do not hear at all" to "Dominates completely." The sound sources were classified into four categories: technological sounds, other sounds, sounds from human beings, and natural sounds [11]. Moreover, the following questions were related to the sound environment's perceived overall quality and appropriateness. The participants responded to the statements using a 5-point scale, where 1 represented "Strongly Disagree" and 5 represented "Strongly Agree."

The last part of the questionnaire adapted a semantic differential scale composed of thirty bipolar adjectives in the Turkish language available in the existing literature [12-13] to assess the subjective quality of the acoustic environments. Every participant responded to the bipolar metrics on a 5-point scale. The whole process took approximately 40 minutes for every subject.

2.4 Statistical Analysis

Firstly, descriptive statistics were employed to evaluate the sound source composition of the recordings. Afterwards, to examine whether there were any variations in the assessment and appropriateness of the soundscape environments across different locations, the data was analyzed using One-Way ANOVA in SPSS 26, followed by a post-hoc test. Furthermore, Spearman's correlation test was utilized to investigate potential correlations between appropriateness and assessment, as well as the dominant sound sources. The same test was employed to explore any potential correlations between the objective sound pressure level (SPL) and appropriateness, assessment, and perceptual attributes of the indoor soundscape.

3. RESULTS

The internal reliability of the used instrument provided by Ozcevik-Bilen and Can [8] was tested through Cronbach's alpha, resulting in an acceptable value of 0.754 for the bipolar semantic scales. The responses regarding the sound source dominance for the recordings from eight different spots were averaged and shown in Figure 5.

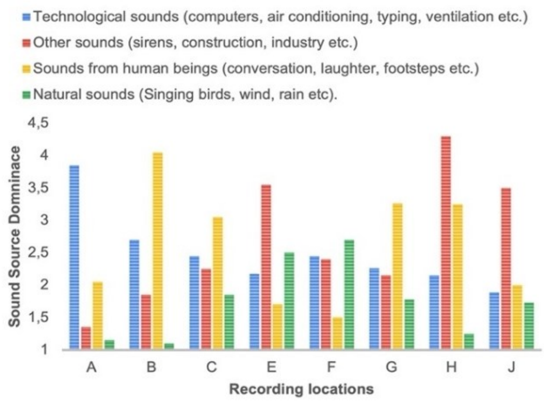

Figure 5. Sound source dominance at different locations.

As can be inferred from Figure 5, the soundscapes recordings in the selected library are mostly a combination of technological, human, and other sounds. Natural sounds are missing in most of the audio clips. However, for the soundscape recording taken from the F location, which is near the window, it can be seen that natural sounds are slightly dominant. Moreover, technological sounds are primarily dominant in the A location, which is a silent study area on the first floor. The most prevalent sound sources in the B, C, and G locations are from humans, such as conversation and footsteps. It is interesting to notice that other sounds, such as sirens and construction sounds, are more prevalent in the remaining areas (E, H, and J). Even though those sounds might be unusual in terms of the function of the selected building, it is not surprising to hear them indoors in central and very crowded locations in Istanbul, such as where this building is.

The appropriateness and users' perceived soundscape quality assessment for the eight library locations were subjected to One way ANOVA F test in SPSS 26. Results reveal a statistical difference in soundscape quality assessments between the groups ($F=2.666$, $p=0.012$, $p<0.05$). A Bonferroni Post Hoc test indicates a statistical difference between the sound appropriateness and subjective evaluation of the acoustic environment in the F and H locations. The soundscape of location H includes many construction sounds, making this environment distinct from the others. On the other hand, the audio clips taken from the F location are a balanced combination of the four sound source types mentioned previously.

Similarly, a significant difference was found between the location groups regarding appropriateness ($F=5.924$, $p=0.00$, $p<0.05$). Further analysis shows that the soundscape in the A, C, F, and G locations differs significantly from the one in H. Also, there is a significant difference between the appropriate appraisal of users between the F and E locations.

Further investigation was done to understand the existence of any correlation between appropriateness and assessment and different dominant sound sources. By employing Spearman's correlation test, soundscape assessment was found to be in a negative correlation with other sounds ($rho=-0.283$, $p=0.000$, $p<0.05$) and a positive relation with natural sounds ($rho=0.243$, $p=0.000$, $p<0.05$) Likely, appropriateness is negatively correlated with other sounds ($rho=-0.451$ $p=0.000$, $p<0.05$) and has a slightly significant positive correlation with natural sounds ($rho=0.193$, $p=0.015$, $p<0.05$).

Moreover, those data were averaged and analyzed in terms of recording locations and SPL (A, dB) objective values. Results shown in Figure 6 indicate the soundscape assessment (*1-Very bad and 5- Very good*) follows the same trend as the appropriateness. Spearman's rho correlation test sustained this positive correlation (*rho=0.509, p=0.00, p<0.05*) between assessment and appropriateness of the acoustic environment. The overall assessment and appropriateness were not correlated with the objective sound pressure values. For most of the selected library locations, the appropriateness and the evaluation is at an acceptable range except for the H and E locations. The presence of other sounds, such as construction and sirens, not only increases the SPL (A, dB) values of the environments but also renders them inappropriate for their function.

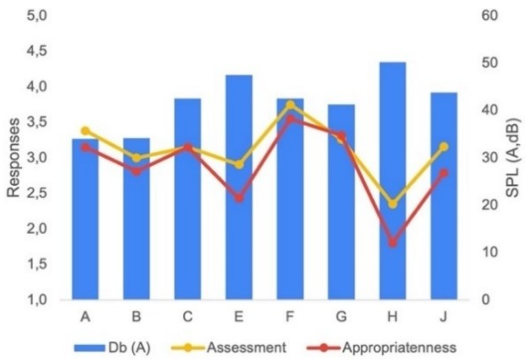

Figure 6. Appropriateness and Soundscape assessment of the locations and SPL(A) values.

To correlate SPL measurements with users' perceptual responses, Spearman's correlation test employing the thirty bipolar adjectives and SPL(A, dB) measurements was run. Table 2 shows that ten of the thirty pairs are significantly but weakly correlated with the sound pressure level of the space. Two adjective pairs, "Heavy-Light," and "Unclear-Distinct" has a weak negative correlation with SPL (A, dB) for the 99% confidence interval.

The average values of individual responses for each adjective pair in every specific location were interpreted according to the radar plot in Figure 7. A score of 5.0 represents complete agreement with the adjective on the right side, while a score of 1 represents full agreement with the adjective on the left side.

For the A location, a low mean score of 1.95 was for the discordant-harmonic and common-strange adjective pairs inferring that this environment is not harmonic and quite common. For the acoustic environment at the B location, a low mean score of 1.95 in the unpleasant-pleasant pair, and a high score of 4.33 in the deserted and lively pair, indicates that this acoustic environment is unpleasant and at the same time lively. The soundscape in the C location is lively (mean=3.9) and common (mean=1.95). The most extreme responses were given for the acoustic environment on the Basement Floor (H). Due to its unusual sound sources, not appropriate for a library, its soundscape is labeled mostly as loud, unpleasant, disturbing, stressing, not preferred, discordant, hard, disorganized, unsteady, heavy, and eventful. Lastly, for the J environments, the mean scores of the responses refer to this environment as boring and non-preferred.

Table 2. Correlations between Adjective pairs and SPL levels

Adjective pairs	**SPL(A,dB)**
Loud-Quiet	**-0.186***
Unpleasant-Pleasant	-0.105
Disturbing-Comfortable	-0.145
Stressing-Relaxing	-0.135
Artificial-Natural	-0.13
Agitating-Calming	-0.07
Boring-Exciting	**-0.162***
Not Preferred-Preferred	**-0.171***
Open-Enveloping	-0.035
Discordant-Harmonic	-0.08
Hard-Soft	**-0.196***
Not Sharp-Sharp	**0.175***
Crowded-Uncrowded	0.018
Disorganized-Organized	-0.128
Far Away-Nearby	**-0.157***
Discontinuous-Continuous	-0.102
Steady-Unsteady	0.091
Deserted-Lively	**-0.168***
Empty-Joyful	-0.106
Gloomy-Exciting	-0.132
Weak-Strong	0.128
Soft-Loud	0.006
Dark-Light	-0.124
Muffled-Shrill	0.025
Dull-Sharp	-0.115
Heavy-Light	**-0.221****
Rough-Smooth	0.071
Unclear-Distinct	**-0.234****
Common-Strange	**0.198***
Calming-Eventful	0.129

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed

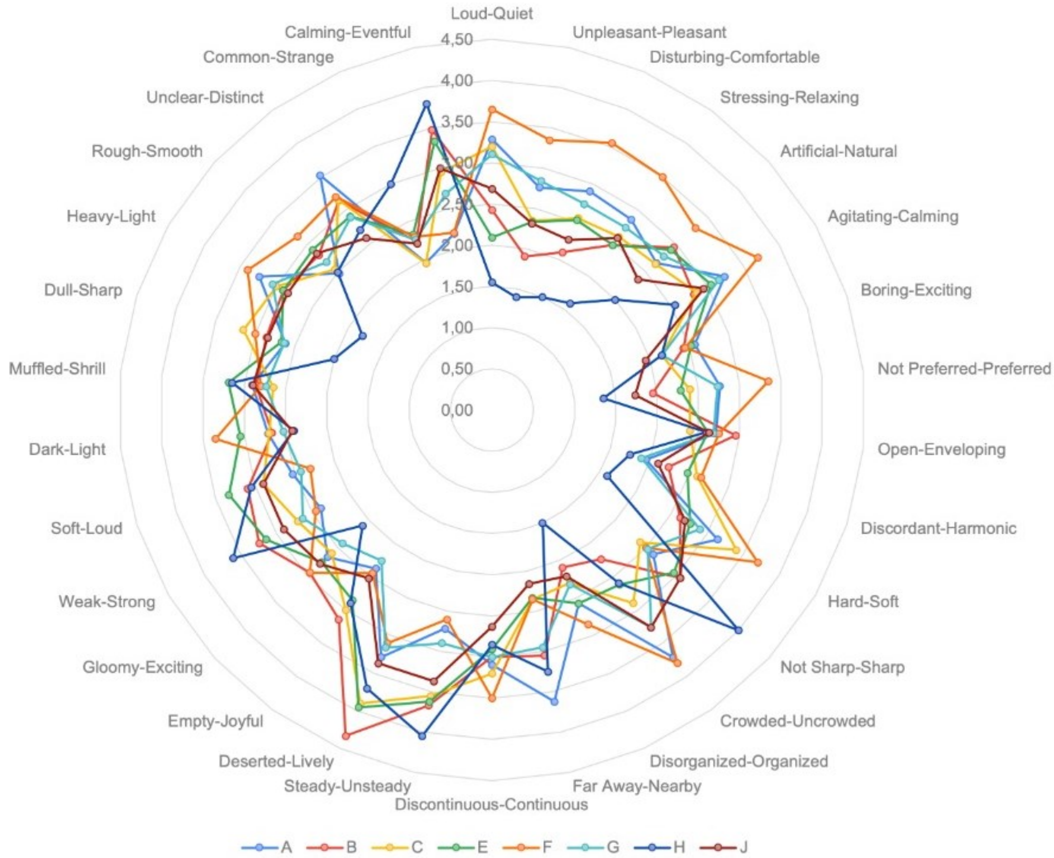

Figure 7. The radar plot for the averaged responses at each recording location.

4. CONCLUSION

The current study focused on assessing the indoor soundscape of Yildiz Technical University Şevket Sabancı library in Istanbul, Turkey. Binaural recordings and sound pressure level measurements were taken in situ in eight different library locations. Listening tests were conducted with twenty healthy users of the space who listened and evaluated the acoustic environment regarding its overall quality (assessment), appropriateness, and thirty bipolar scales. Preliminary results reveal that the acoustic environment differs among the selected spaces according to their assessment and appropriateness, which are also positively correlated. Moreover, the acoustic composition of the soundscape clips varies among locations in terms of the dominance of sound sources. The results show that human sounds and technological sound sources have integrated relations. On the basement floor, facility sounds directly affect the soundscape of the floor with SPL level. In the sound adjective "Common" term is selected in many places.

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