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Development and testing of Indoor Soundscape Questionnaire for evaluating contextual experience in public spaces

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Abstract: An Indoor Soundscape Questionnaire aiming at the evaluation of indoor public sound environments was designed, statistically tested and presented. It was established through initial pilot studies and three main factors under contextual experience variable are established as (1) psychological factors, (2) space usage factors and (3) demographical factors. In addition to the questions on demographical and space usage factors, detailed questions on psychological factors are designed and statistically tested for expectation, perception and reaction categories of the psychological factor. The questionnaire was applied as part of a case study in enclosed library foyer environments to a group of 270 participants through non-experimental survey data sampling. The reliability and validity scores of the Indoor Soundscape Questionnaire were statistically tested and confirmed. Furthermore, statistical tests were used to derive relationships between contextual experience variables of psychological, space usage and demographical factors. Chi-square test of goodness-of-fit results showed statistical significances of demographical and space usage factors with the psychological factors.

Keywords: indoor Soundscape Questionnaire, public space, sound perception, library

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1. Introduction

During one day from one location to another, human beings in a given context share spaces, by using their personal space to enter and interactively use public domains. Such interactive behaviour, which is addressed as 'space usage', entails several factors for the researcher to consider, including the usage behaviour from the users' point of view. Space usage is studied in several different approaches including green space (Irvine, Devine-Wright, Payne, Fuller, Painter, & Gaston, 2009) and urban space (Cain, Jenings, Adams, Bruce, Carlyle, Cusack, Davies, Hume, Plack, & Cain, 2008) analysis to evaluations related with expectation (Bruce, Davies, & Adams, 2014). The users are the key factors for any soundscape study, so understanding their characteristics, behaviour patterns and psychology is crucial for the indoor soundscaping research as well. Contextual experience aspect of indoor soundscaping that focus on sound and human interaction has been an important topic especially for behaviour related studies (Blake & Cross, 2015; Hopkins, 1994). Although many previous acoustic and soundscape studies have considered the user as the main variable (Lam, Brown, Marafa, & Chau, 2010; Brooks, 2011; Aletta, Botteldooren, Thomas, Vander-Mynsbrugge, De Vriendt, Van de Velde, & Devos, 2017), there is a gap in the design of a fully integrated approach on exploring the demographics, space usage, and the overall psychological process that includes expectation, perception and reaction factors together (Dokmeci, 2013).

Studies concentrating on the different measurement and analyses methods of the sound environment and human perception are mostly related with the urban scale (Kang, 2006; Raimbault, 2006; Truax, 2011; Hall, Irwin, Edmondson-Jones, Philips, & Poxon, 2013; Liu et.al. 2014; Hermida-Cadena, Lobo-Soares, Pavon, Bento-Coelho, 2017) but not primarily on indoor environments. In addition there are several realised soundscape applications that can act as baselines for policy and guideline development for the management and planning of soundscapes (Schulte-Fortkamp, Volz, & Jakob, 2008; Bento-Coelho, 2016; Lavia, Dixon, Witchel, & Goldsmith, 2016). Architectural and room acoustics research consider the theories that have been stated through previous studies, yet indoor soundscaping combines these previous findings and reveals a new understanding through the soundscape approach, in which space, context and users are as much important as the sound itself (Dokmeci Yorukoglu & Kang, 2016). This condensation of different aspects in one totalitarian approach leads to the design of the indoor soundscape research field. Through this perspective, users and their interactions with their environment are also become a dominant part of the evaluation process. These interactions reveal the details of how a space is used and perceived by the occupants.

The investigations on the questionnaire design, type and application techniques, which can be used for the soundscape research, integrate psychological approaches, through a distinct focus on perception, emotion, interpretation, and experience (Berglund & Nilsson, 2006; Axelsson, Nilsson, & Berglund, 2010; Kang & Zhang, 2010; Hall et al., 2013). Several important studies on standardization of noise surveys serve as the backbone for many related research on noise annoyance (Guski, Felscher-Suhr, & Schuemer, 1999; Fields, De Jong, Gjestland, Flindell, Job, Kurra, Lercher, Vallet, Yano, Guski, Felscher-Suhr, & Schumer, 2001). Yet, there has not been a widely accepted gold standard on questionnaire design, which would be applicable to related soundscape studies. ISO/TS 15666:2003(E) document that entitles, 'assessment of noise annoyance by means of social and socio-acoustic surveys' is one of the most widely used technical specification for subjective acoustic evaluation. In addition, a recent standard on soundscape definition and conceptual framework is published (ISO, 2014). This ISO standard can be seen as the starting point for standardisation of soundscape factors and related evaluation criteria. In addition to such standards, a specially designed questionnaire format and evaluation methodology is crucial for any indoor soundscaping research that aims to integrate the data on contextual experience. There are several different approaches on soundscape evaluation in the literature but not a standardized mothod (Aletta, Kang, & Axelsson, 2016).

Subjective evaluation of the soundscape is the crucial part of any soundscape study. Especially for indoor soundscape studies factors related with soundscape perception and variable dependencies are not clearly studied or tested. The primary aim of this study is to design and validate a specially designed indoor soundscape questionnaire by testing the dependencies of psychological factors on space usage and demographical factors of the contextual experience. In order to fulfil this aim, an indoor soundscape questionnaire is designed and administered to users of enclosed library environments. The preliminary findings of this research have been presented as part of a PhD thesis (Dokmeci, 2013). The main research question of this study is, 'which demographical and space usage factors affect expectation, perception and reaction of users?' In addition, specific factorial relationships within contextual experience of indoor soundscaping is analysed to form a base for further related studies.

The research develops in three main phases. Firstly, the theoretical framework of indoor soundscaping and the contextual experience variable under this framework is presented in detail. In the second phase, indoor soundscape questionnaire that is developed through the contextual experience framework is explained. In the third phase, statistical analysis and results of the indoor soundscape questionnaire is discussed, in order to back feed the theoretical framework that is presented in the first phase.

2. Contextual experience factors: a theoretical framework

Previously the intricate relationship between contextual experience, built entity and sound environment variables of indoor soundscape framework has been presented in the literature by Dokmeci Yorukoglu and Kang (2016). This framework has been re-adapted and numerically re-structured to increase the comprehensibility of this study and methodological design. Therefore, contextual experience is considered as the key aspect in this study, which concentrates on the interactions between people and their environment. Under the contextual experience, three main factors are evaluated as; psychological, space usage, and demographical.

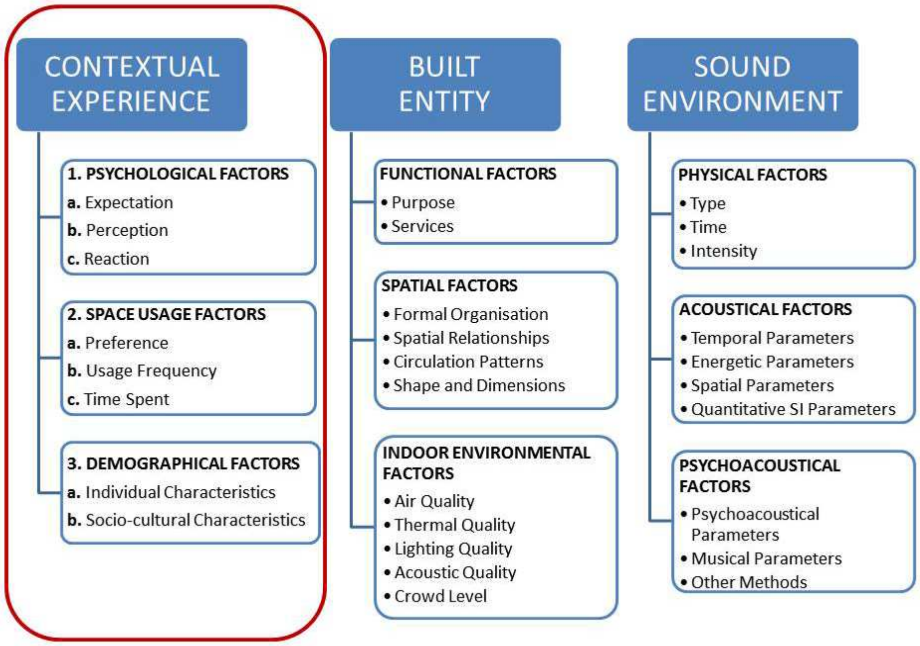


Figure 1. Variables of the indoor soundscape framework with a distinct focus on contextual experience (Dokmeci Yorukoglu & Kang, 2016).

2.1. Psychological factors

The process of perception starts with understanding expectation that is structured by knowledge, schemas and previous experiences (Axelrod, 1973; Tuan, 1977; Purcell, 1986). Several studies have previously discussed the concepts of competence and expectation but none has yet systematically incorporated them into consideration of human perception of the sonic environment (Truax, 2001; Bruce, Davies, & Adams, 2009). In order to undertake the subjective evaluation of a sonic environment and how it has been perceived, the analysis should start by understanding the expectation of the users who make contact with a physical environment. Hence, the previous knowledge of the users regarding the same space or spaces that deliver similar functions and usage should be questioned first in combination with their previous experiences regarding a space type and how they have formed their knowledge of that space (Bruce et al., 2014). Only then can the psychological state and the users' expectation of certain spaces be understood. In addition, it is important to know the expectation of users in a space as it directly effects their perception and thereby their reaction to the different aspects of a physical environment.

The basic process of knowing about or constructing reality involves the phase called experience, which is gathered by senses to form basic cognition of the lived environment (Tuan, 1977). The possible configurations lead to varied levels of perception and cognition of the experienced space and thereby affect the formation of schemas (Axelrod, 1973). The two most important sensations are sight and hearing, which carry the basic information gleaned from experiencing the space. However, "our perceptions are not only the result of a mechanical process of vision, but that they are filtered through our memory and intelligence" (Meiss, 1990, p. 25). Although visual data gained within a space is the most informative, auditory sensation also plays a major role in space perception. An individual is "subconsciously aware of the sources of noise, and from such awareness they construe auditory space" (Tuan, 1977, p.14). The impact of the sonic environment on individuals should not be underestimated. Whilst human space is mostly structured through vision, audition expands and enriches the visual space and helps users to enlarge their spatial awareness, as well as giving a sense of volume and of distance (Tuan, 1977).

As aforementioned above, in order to identify the psychological factors, understanding the process going on in a human mind is crucial for soundscape research. The overall process that starts with expectation and continues with perception concludes with an outcome (feeling, thought) or as a reaction (behaviour oriented action). This suggests that the 'mind flow' or the 'psychological process' could be used as a starting point to clarify the dominant aspects of the outcome (reaction). In terms of psychological mechanisms, the current research suggests a systematic framework applicable to the analysis of expectation, perception and reaction in soundscape studies. Findings based on detailed testing of the case study and melt down of literature findings supports the suggested scheme, as shown in Figure 2. Information on expectation, perception and reaction of users can be gathered by several different methods. The most commonly used methods include open, semi-structured or structured interviews, surveys or questionnaires that are designed for a specific research area.

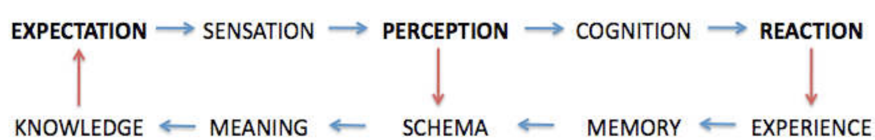


Figure 2. Diagram describing the psychological process and the concept of subjective evaluation from expectation to perception and reaction in indoor soundscapes (Dokmeci, 2013).

2.2. Space usage factors

In addition to psychological mechanisms, spatial usage is also very important for research that is related with human and his environment. Usage of a space is one of the most fundamental factors of social interactions. It is evident that without the social content, the physical space becomes an abstract realm (Hillier & Hanson, 1984). Therefore, in addition to psychological aspects, soundscape research should also consider space usage as one of the most crucial factor effecting contextual experience.

Space usage factors relate to the users and their integration with the space. As the users are sound sources and receivers at the same time, their attitude, behaviour and situation within the space are very important. Yet, the user and usage of a space are not the only important criteria to be addressed. This approach is also valid for indoor soundscape research involving spaces with similar architectural features but different functions or usage patterns.

Preference is the key concept in terms of space usage. If a space is not preferred it will not be used. Therefore analysis on liking the case space and preference tendencies should be evaluated as a starting point. Such preference characteristics are also linked to other aspects of space usage and psychological factors, as well as the sound environment perception factors in terms of contextual experience. It is also important to consider the usage and preference of a space from the architectural point of view and to designate whether 'the opportunities given to the user', and 'the level of experience or exposure' are controlled by the elements of a space. Bryan Lawson addresses a similar concept under the topic 'purposefulness and non-purposefulness behaviour' (2001). In his explanation, the human behaviour and its orientation around a space or an object is the key element, followed by needs, perception and appreciation. Through this point of view it can be argued that the opportunities and limitations in a space are highly related with perceptions and usage that lead to space preference. The concept of opportunities and limitations depends on two things, the designer and the user. The designer or the architect is the person who configures the elements within a space in a way that somehow determines the perception of the user. Any single change in the order, form or physical characteristics of the space would directly affect the perception, usage, and preference. On the other hand, the intended limitations control the perception and usage of the space, leading users to move and function accordingly. Although these user-designer or opportunity-limitation relationships are not the main focus of this research they affect the preference characteristics; hence, it is important to highlight their existence.

In addition to preference, it is important to consider the usage frequency. Many studies have indicated that conducting surveys at different times of the day and on different days of a week depending on the usage and function of an enclosure, leads to considerable SPL fluctuation, which also affects the physical acoustic characteristics of a space and the perception of that sonic environment (Chen & Kang, 2004; Dokmeci & Yilmazer, 2012). This factor is also tested, in another study concentrating on the subjective evaluation of users in a railway station. In this study, the acoustic comfort scores and usage preferences showed very significant correlations (Tardieu, Susini, Poisson, Lazareff, & McAdams, 2008). These previous findings all highlight the importance of usage frequency when conducting a soundscape study.

Time spent is the final factor that is integrated under space usage. This factor mainly entails the numeric amount of time that is spent in minutes or hours depending on the case. Previous studies have also considered time spent as an important factor in sound annoyance and acoustic comfort. They found that duration of stay and frequency of travel are usage trades that show different correlations. Acoustic comfort scores and duration of stay showed negative correlation; whereas frequency of travel positively correlated with the scores (Kang, Chung, & Ip, 2006). A similar study on time spent by users in the food court of a shopping mall showed a significant positive correlation between annoyance from other people's noise in the food court and longer time spent in the food court space (Dokmeci & Yilmazer, 2012). These findings demonstrate clearly that time spent is an important factor for consideration in soundscape studies as well, which affects user perception and experience.

2.3. Demographical factors

Demographic factors are the most important basic characteristics for classifying the sample population of a participant group. In this study, the demographic factors are considered separately as either individual characteristics or socio-cultural characteristics. The individual characteristics of the population sample group reflect basic information regarding the individual participants as human beings. The main focus is on physiological characteristics. The physiological characteristics mainly considered for the purpose of this study are those relating to gender and age. The socio-cultural characteristics mainly reflect the background and behavioral patterns of the participants of the sample group. According to the type of the research, integrated questions on the socio-cultural characteristics show great variance. The most common elements are questions on, education, cultural background and habitual characteristics, whilst questions on self-musicality and musical taste can also be considered.

3. Designing the indoor soundscape questionnaire

The key part of designing an indoor soundscape questionnaire is to understand the acoustic environment, and how the users perceive it in an identified context within an enclosure. Through this approach, the research aims to design a specialised indoor soundscape questionnaire, which can assess specific properties of contextual experience. Therefore, investigating the baseline characteristics of listeners and their interference with their acoustic and spatial environment is primarily considered. In this study, the indoor soundscape questionnaire is designed in 6 different parts. These parts include the questions on;

1- Demographical information,
2- Space usage,
3- Expectation on acoustic and spatial factors (importance ratings),
4- Perception of sound sources (annoyance ratings),
5- Reaction to acoustic and spatial factors (quality ratings),
6- Reaction to sound sources (disturbance or preference ratings).

The first part is on the basic individual and socio-cultural characteristic information, including demographics of the users such as; age, gender and education level. Questions on the usage and time spent patterns, and space preference are included the second part of the questionnaire that concentrates on space usage.

Next part includes unipolar 5-point importance ratings and bipolar 5-point semantic differential analysis for the evaluation of 14 different factors on, indoor environmental comfort (acoustics, air quality, humidity, temperature, light), acoustics (sound level, sound types, sound intelligibility, reverberation level, noise from other spaces, locating by sound), and architecture (way finding, spaciousness, level of crowd). The importance scores indicated the expectation of the users regarding the predefined factors as shown in Table 1 and similarly the quality scores indicated the reaction for the same factors as presented in Table 2. These factors are grouped under indoor environmental, spatial and acoustical quality assessment characteristics and can be applicable to other indoor spaces.

Table 1. Importance ratings for the 14 factors that are used in the indoor soundscaping questionnaire to evaluate expectation.

Factors		Ratings on importance				
		Rate from (1) not important to (5) very important				
1	Level of indoor air quality	1	2	3	4	5
2	Level of indoor humidity	1	2	3	4	5
3	Level of thermal comfort	1	2	3	4	5
4	Brightness of lighting	1	2	3	4	5
5	Level of sounds (loudness)	1	2	3	4	5
6	Level of acoustic comfort	1	2	3	4	5
7	Different types of sounds	1	2	3	4	5
8	Intelligibility of sounds (definition)	1	2	3	4	5
9	Level of reverberation (echo)	1	2	3	4	5
10	Ability to locate via sounds	1	2	3	4	5
11	Way-finding (ability to find your way around)	1	2	3	4	5
12	Level of crowd (users' density in the space)	1	2	3	4	5
13	Level of spaciousness	1	2	3	4	5
14	Noise from neighbouring spaces	1	2	3	4	5

Table 2. Quality ratings for the 14 factors that are used in the indoor soundscaping questionnaire to evaluate reaction.

Factors		Ratings on quality				
1	Level of indoor air quality	Rate from (1) very bad to (5) very good				
		1	2	3	4	5
2	Level of indoor humidity	Rate from (1) very good to (5) very humid				
		1	2	3	4	5
3	Level of thermal comfort	Rate from (1) very uncomfortable to (5) very comfortable				
		1	2	3	4	5
4	Brightness of lighting	Rate from (1) very dull to (5) very bright				
		1	2	3	4	5
5	Level of sounds	Rate from (1) very loud to (5) very quiet				
		1	2	3	4	5
6	Level of acoustic comfort	Rate from (1) very uncomfortable to (5) very comfortable				
		1	2	3	4	5
7	Diversity of different sounds	Rate from (1) very similar to (5) very diverse				
		1	2	3	4	5
8	Intelligibility of sounds (definition)	Rate from (1) very blurred to (5) very defined				
		1	2	3	4	5
9	Level of reverberation	Rate from (1) very echoey to (5) very absorbed				
		1	2	3	4	5
10	Ability to locate via sounds	Rate from (1) very hard to (5) very easy				
		1	2	3	4	5
11	Way-finding (ability to find your way around)	Rate from (1) very hard to (5) very easy				
		1	2	3	4	5
12	Level of crowd (users' density in the space)	Rate from (1) very crowded to (5) very empty				
		1	2	3	4	5
13	Level of spaciousness	Rate from (1) very spacious to (5) very enclosed				
		1	2	3	4	5
14	Noise from neighbouring spaces	Rate from (1) very audible to (5) very inaudible				
		1	2	3	4	5

The last part comprises questions on sound sources in the case space. The 19 different sound sources identified by the initial pilot studies are included in the questionnaire for the evaluation by 2 different question formats and answer formats. The first question format is on the annoyance from these defined sound sources that will indicate perception of the sound sources in the case soundscapes as shown in Table 3. The answer format of the annoyance rating is designed as unipolar 5-point scale ranging from not at all annoying to extremely annoying. The second question set is on the disturbance or preference of the defined sound sources designed with a bipolar semantic differential rating that will indicate the reaction to these sound sources as presented in Table 4.

It is evident that varied functions, activities and usage of a space lead to the differentiated sonic conditions. In the literature, it is found that, soundscape characteristics in terms of the compositions of the sound sources differed according to the main functions of the places in urban contexts (Hong & Jeon, 2015). Thereby, similar variances are expected for indoor sound environments as well and the sound sources included in this questionnaire should be adapted accordingly for detailed and corresponding evaluations. The sound sources in Tables 3 and 4 are surveyed and identified by initial pilot studies and then included in the final questionnaire to be evaluated by the participants. This method can be used for the selection of the specific sound sources for evaluating other indoor spaces.

Table 3. Question on the evaluation of 19 sound sources from not at all annoying to extremely annoying, indicating sound source perception.

	Sound sources	Rate from (1) not at all annoying to (5) extremely annoying					
1	Speech	1	2	3	4	5	N/A
2	Laughter	1	2	3	4	5	N/A
3	Whispering	1	2	3	4	5	N/A
4	Walking/footsteps	1	2	3	4	5	N/A
5	Doors slamming	1	2	3	4	5	N/A
6	Automated doors	1	2	3	4	5	N/A
7	Computer fan	1	2	3	4	5	N/A
8	Computer keyboard	1	2	3	4	5	N/A
9	Page turning	1	2	3	4	5	N/A
10	Printers/copiers	1	2	3	4	5	N/A
11	Book trolleys	1	2	3	4	5	N/A
12	Mobile phones	1	2	3	4	5	N/A
13	Mechanical fan/AC	1	2	3	4	5	N/A
14	Cash register	1	2	3	4	5	N/A
15	Elevator	1	2	3	4	5	N/A
16	Personal music player	1	2	3	4	5	N/A
17	Traffic noise	1	2	3	4	5	N/A
18	Construction noise	1	2	3	4	5	N/A
19	Overall noise	1	2	3	4	5	N/A

Table 4. Question on the evaluation of 19 defined sound sources from very disturbing to very preferable indicating the reaction to these sound sources.

	Sound sources	Rate from (1) very disturbing to (5) very preferable					
1	Speech	1	2	3	4	5	N/A
2	Laughter	1	2	3	4	5	N/A
3	Whispering	1	2	3	4	5	N/A
4	Walking/footsteps	1	2	3	4	5	N/A
5	Doors slamming	1	2	3	4	5	N/A
6	Automated doors	1	2	3	4	5	N/A
7	Computer fan	1	2	3	4	5	N/A
8	Computer keyboard	1	2	3	4	5	N/A
9	Page turning	1	2	3	4	5	N/A
10	Printers/copiers	1	2	3	4	5	N/A
11	Book trolleys	1	2	3	4	5	N/A
12	Mobile phones	1	2	3	4	5	N/A
13	Mechanical fan/AC	1	2	3	4	5	N/A
14	Cash register	1	2	3	4	5	N/A
15	Elevator	1	2	3	4	5	N/A
16	Personal music player	1	2	3	4	5	N/A
17	Traffic noise	1	2	3	4	5	N/A
18	Construction noise	1	2	3	4	5	N/A
19	Overall noise	1	2	3	4	5	N/A

A simple random sample of the 270 participants and their responses is presented for the findings of this study. The questionnaires are administered to 139 females and 131 males in the foyer areas of the three main university libraries in Sheffield, which are, St. George's Library, Western Bank Library and Information Commons. Among all questionnaire participants, 174 participants are undergraduate students, 88 are master's students, and 8 are PhD students. Pearson's Chi-Square tests of goodness of fit is used to explore the relations between ordinal and nominal variables to assess whether or not the observed frequency distribution differs from the theoretical distribution. Chi-square statistic tests do not give any information about the strength of the relationship, but identify substantial relationships between the variables investigated, if any exist. The important value is the significance level (p) as it designates whether the relationship is significant or not. If the p is equal or less than 0.05 ($p \leq 0.05$), this means a significant relationship exists. This test is used across descriptive nominal questions on demographical and space usage factors and four groups of ordinal questions on psychological factors (ratings on factorial importance, factorial quality, sound source annoyance, and sound source disturbance or preference) as shown in Figure 3.

The scaling format from the ISO/TS 15666:2003 document was adapted mainly for the purpose of achieving criterion related validity for the current study. Internal reliability scores were calculated for all ranked question groups. For the questions on factorial importance (Table 1) the Cronbach's α value is 0.82. For the questions on factorial quality (Table 2) the Cronbach's α value is 0.72. As the values of both question groups are above 0.7, they were found to have high internal reliability scores.

Effects of space usage factors that are time spent usage frequency and space preference in addition to demographical factors, which are education level and gender on expectation, perception and reaction, are statistically tested for this study. In order to understand the specific relationships and correlations among these factors, findings are derived by intra-statistical analysis. Furthermore, these factors are grouped as independent and dependent variables as shown in Table 5, in order to design the statistical tests and combinational correlations.

Table 5. Independent and dependent variables that are statistically tested in this study.

Independent variables		Dependent variables
Demographical factors	Space usage factors	Psychological factors
Gender	Preference	Expectation
Education level	Usage frequency	Perception
	Time spent	Reaction

4. Analysis on contextual experience factors

4.1. Demographical factors affecting expectation

In Figure 3, the statistical findings between demographical factors and expectation are summarised. In this study expectation is evaluated as the importance given to the factors that are included in the indoor soundscaping questionnaire. This approach is built upon the soundscape expectation model that is proposed by Bruce and Davies (2014), which presents specific behaviour patterns starting from previously learnt experience. Therefore, importance given to certain factors in a specific context is the main consideration of this study regarding expectation analysis.

Correlations between gender and expectation indicate that female users give more importance to thermal comfort ($\chi 2$ (4, n = 270) = 12.839, $p < 0.05$) and loudness ($\chi 2$ (4, n = 270) = 10.694, $p < 0.05$) whereas; male users give more importance to acoustic comfort ($\chi 2$ (4, n = 270) = 10.211, $p < 0.05$) when compared to female users as presented in Figure 4. In addition, users with Master's degree give more importance to ability to locate via sounds ($\chi 2$ (8, n = 270) = 17.582, p

< 0.05) when compared to users with undergraduate degree. On the other hand, users with undergraduate and Master's degree give more importance to intelligibility of sounds.

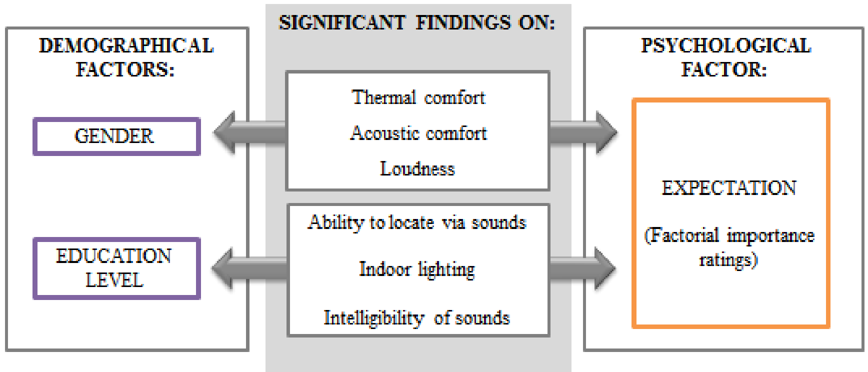
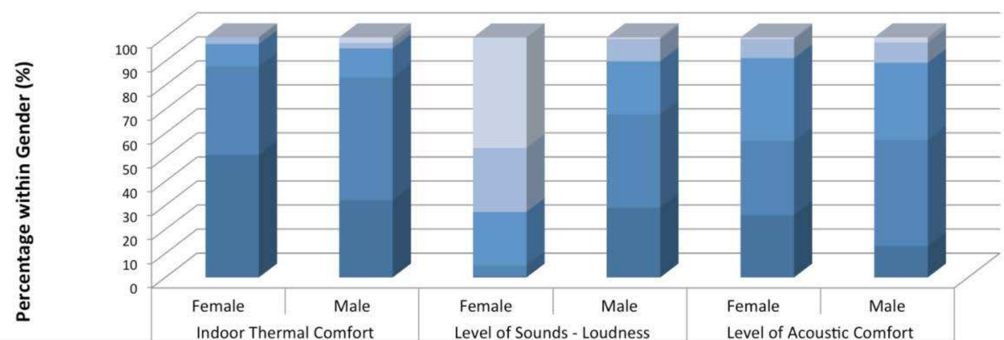


Figure 3. Statistically significant relationships between demographical factors and expectation evaluated by factorial importance ratings.



	Indoor Thermal Comfort		Level of Sounds - Loudness		Level of Acoustic Comfort	
	Female	Male	Female	Male	Female	Male
% Not Important	0	2.3	46	0.8	0.7	2.3
% Slightly Important	2.9	2.3	26.6	9.2	7.9	8.4
% Moderately important	9.4	12.2	22.3	22.1	34.5	32.1
% Important	36.7	51.1	4.3	38.9	30.9	44.3
% Very Important	51.1	32.1	0.7	29	25.9	13

Figure 4. Expectation ratings by percentages on factorial importance showing gender variations (Dokmeci, 2013).

4.2. Space usage factors affecting expectation

Regarding the correlations between space usage factors and sound source expectation, findings show that users who prefer the case library give more importance to noise from neighbouring spaces ($\chi2$ (4, n = 270) = 11.068, $p < 0.05$). Furthermore, a significant relation was identified between time spent in hours and the importance attached to level of different types of sounds ($\chi2$ (4, n = 270) = 13.195, $p < 0.05$). The majority of all participants who spent more than 1 hour in the library found the factor to be at least moderately important. Among these participants, the group who spent six to eight hours in the library constituted the highest percentage. This finding indicates that importance given to sound level of different sources becomes more important when the time users spend increases leading to a varying expectation compared to other users who spend less time. Both of these findings are summarised as a scheme in Figure 5.

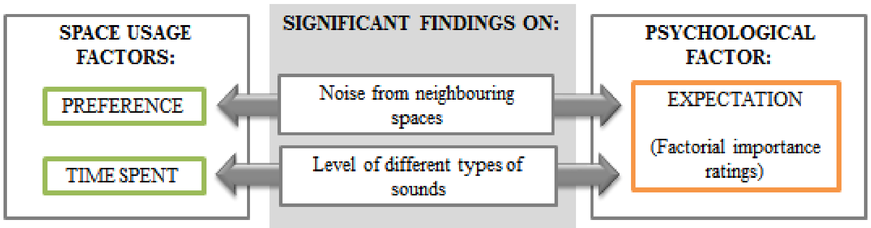
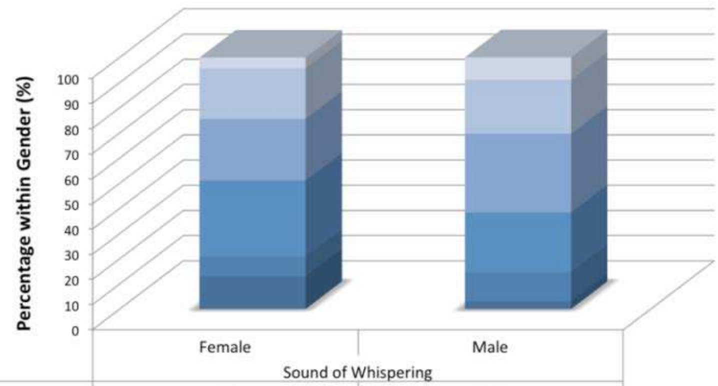


Figure 5. Statistically significant relationships between space usage factors and expectation evaluated by factorial importance ratings.

4.3. Demographical factors affecting perception

A significant relationship between gender and annoyance from the sound of whispering ($\chi 2$ (5, n = 270) = 13.610, $p < 0.05$) was identified. The results presented in Figure 6, highlighted that comparatively more female participants than males were moderately and extremely annoyed by the sound of whispering. Some variations are found regarding the education level as well. There was a significant correlation between education and perception of book trolley sound source annoyance ($\chi 2$ (10, n = 270) = 19.322, $p < 0.05$). The results showed that the majority of the participants with an undergraduate and PhD degree were not at all annoyed by the book trolley sound, whereas the majority of participants with a master's degree were slightly or moderately annoyed. The reason for this variation could be depending on other factors such as time spent or activity in the case library. Further detailed analysis can be done to understand such variations. In Figure 7, the summary of the findings is presented.



	Female	Male
N/A	4.3	9.2
Not at All Annoying	20.1	21.4
Slightly Annoying	24.5	31.3
Moderately Annoying	30.2	23.7
Very Annoying	7.9	11.5
Extremely Annoying	12.9	3.1

Perception of Annoyance from Sounds by Gender

Figure 6. Perception ratings by percentages on annoyance from sound of whispering showing gender variations (Dokmeci, 2013).

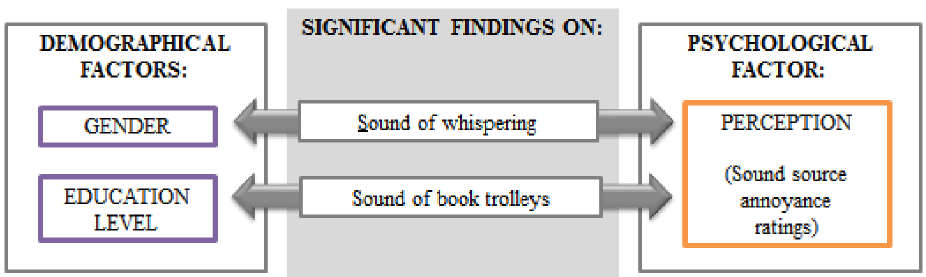


Figure 7. Statistically significant relationships between demographical factors and perception evaluated by sound source annoyance ratings.

4.4. Space usage factors affecting perception

The statistical tests revealed several significant relations between preference and perception of sound source annoyance as shown in Figure 8. Preferring other spaces and perception of annoyance from sound of mechanical fans was significantly related ($\chi 2$ (5, n = 270) = 16.647, p = 0.005). Majority of the case space users who have preferred the case space to other libraries were not at all, slightly or moderately annoyed from the sound of mechanical fans. In addition, time spent (in hours) and perception of whispering sound is tested. A significant relation was identified between time spent and perception of annoyance from the sound of whispering ($\chi 2$ (20, n = 270) = 31.658, $p < 0.05$). This finding indicates that, the longer time participants spend in the case library their perception of annoyance increase from the sound of whispering that is also noted as one of the most dominating sound sources in a library setting.

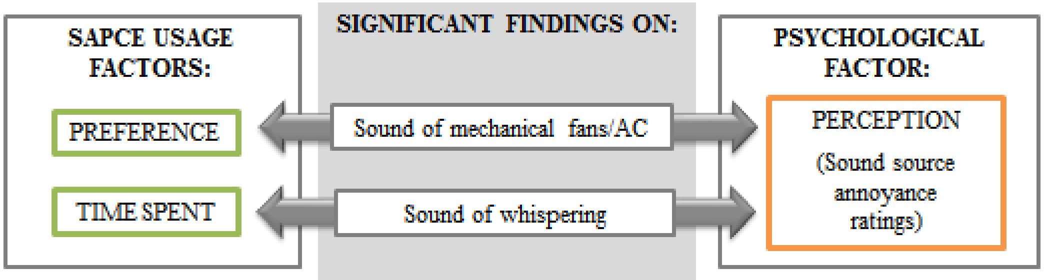


Figure 8. Statistically significant relationships between space usage factors and perception evaluated by sound source annoyance ratings.

4.5. Demographical factors affecting reaction

Participants were classified by their gender (male or female) and by their reactions to factorial quality (negatively connoted to positively connoted semantic pairs). As presented in Figure 9, findings show that, a significant correlation was identified between gender and reaction to factorial quality for the perceived reverberation ($\chi 2$ (4, n = 270) = 11.513, $p < 0.05$). The majority of female participants ranked the space as moderately echoey, whereas the majority of males ranked the perceived reverberation as being absorbed.

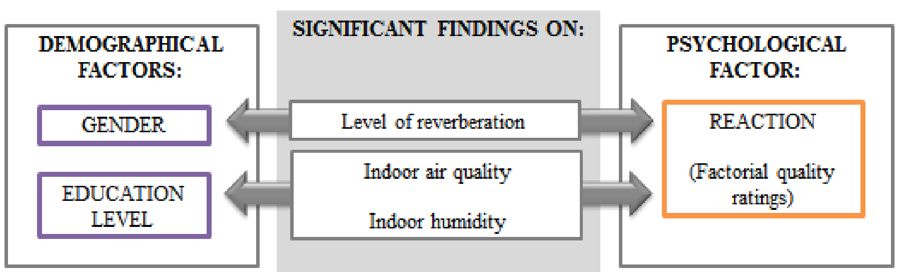


Figure 9. Statistically significant relationships between demographical factors and reaction evaluated by factorial quality ratings.

Furthermore, important significant relationships were identified between education and reaction to the factorial assessment of indoor air condition ($\chi 2$ (8, n = 270) = 16.425, $p < 0.05$), and reaction to the factorial assessment of indoor humidity ($\chi 2$ (8, n = 270) = 15.638, $p < 0.05$). The majority of participants with undergraduate and Master's degree rated the factorial quality of indoor air as good. On the other hand, the majority of the participants with undergraduate level rated the factorial quality of indoor humidity to be moderate, whereas the majority of participants with Master's and PhD degree rated the quality as humid, indicating higher level of awareness for the level of humidity.

In addition to factorial quality evaluations, participants' reactions to sound sources are also analysed. For these analyses, participants were classified by their gender and by their reactions in terms of disturbance from or preference of sound. The findings are summarized in Figure 10.

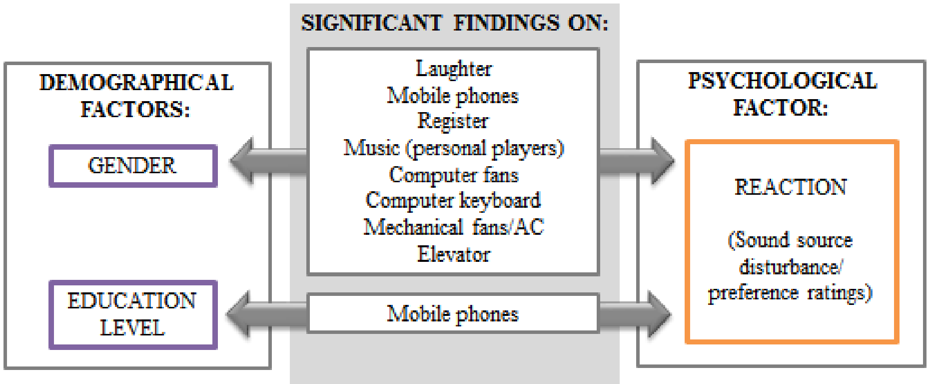


Figure 10. Statistically significant relationships between demographical factors and reaction evaluated by sound source disturbance/preference ratings.

Gender was found to be significantly related with reaction to sound source disturbance/preference. The significant relations were identified by the assessment of the reactions to eight different types of sound sources, which are laughter ($\chi2$ (5, n = 270) = 13.267, $p < 0.05$), computer fan sound ($\chi2$ (5, n = 270) = 11.303, $p < 0.05$), computer keyboard sound ($\chi2$ (5, n = 270) = 11.637, $p < 0.05$), mobile phone sound ($\chi2$ (5, n = 270) = 11.524, $p < 0.05$), mechanical fan/AC sound ($\chi2$ (5, n = 270) = 20.905, $p = 0.001$), register sound ($\chi2$ (4, n = 270) = 18.091, $p = 0.001$), elevator sound ($\chi2$ (4, n = 270) = 10.666, $p < 0.05$), and music sound from a personal player ($\chi2$ (4, n = 270) = 11.964, $p < 0.05$). In Figure 11, all the percentages regarding this significant correlation is presented for each sound source. The highest percentage indicates the variance for the statistical significance within the tested variables. In a similar study on library soundscapes and specific sound source distraction analysis, phone conversation (78%), talking (62%), and intense discussion (68%) are found to be the most distracting sound sources among others in a library contexts (Ikhwanuddin, Sarwono, Sudarsono, & Utami, 2017). In addition, findings of this study on higher preference ratings of music sound by male participant's supports the same finding that has been presented by Liu and Kang (2016). Therefore, it is evident that gender differences have major effects on sound source evaluation.

The reaction towards disturbance by mobile phone sound was found to relate significantly to education ($\chi2$ (10, n = 270) = 19.405, $p < 0.05$) as well. The majority of the undergraduates were very disturbed by the sound. On the other hand, participants with Master's and PhD degree were extremely disturbed by the mobile phone sound in the case library spaces showing an increased level of disturbance when compared to undergraduate participants. This finding highlights that the level of disturbance regarding mobile phone sound in library spaces increases with the higher level of education.

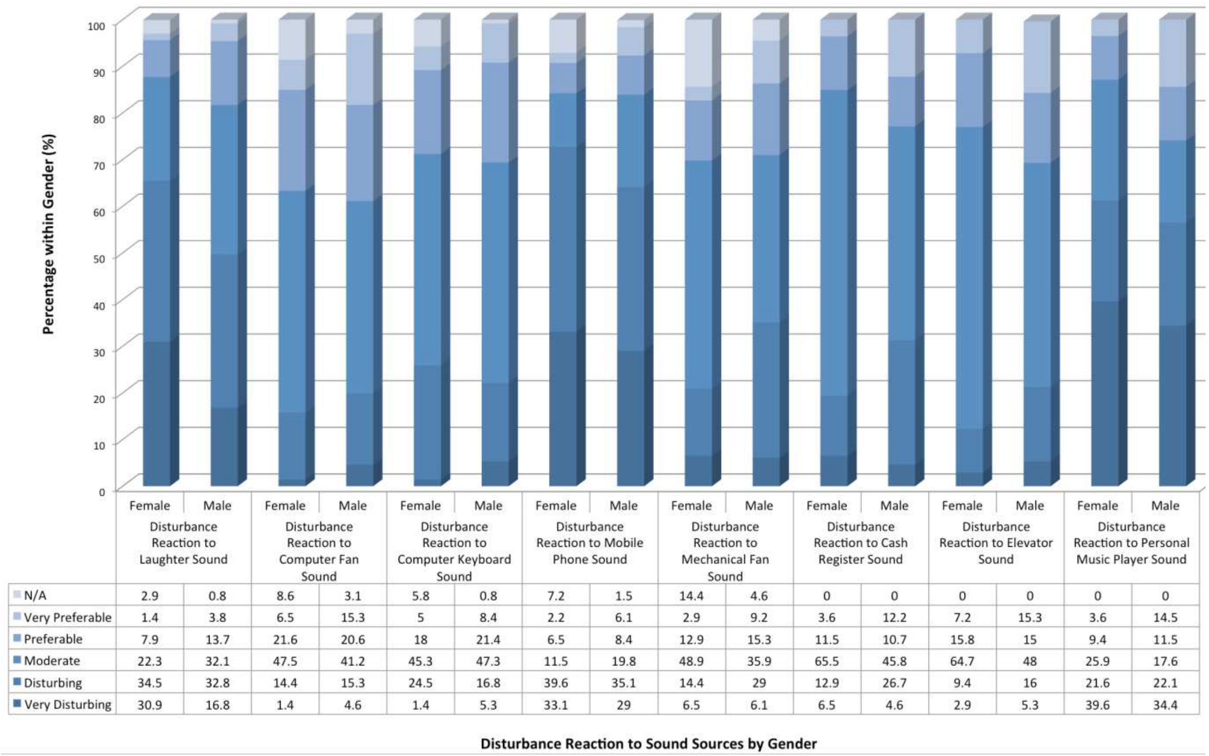


Figure 11. Reaction ratings by percentages on sound source disturbance or preference showing gender variations (Dokmeci, 2013).

4.6. Space usage factors affecting reaction

Several significant relations were identified between space usage factors and reaction to factorial quality as presented in Figure 12. Significant relations were identified between preferring other spaces and reaction to factorial quality of loudness ($\chi 2$ (4, n = 270) = 39.334, p = 0.001). The majority of the participants, who preferred other libraries, rated perceived loudness of the case library as moderate. Similar to perceived loudness, the majority of the participants who preferred other spaces ($\chi 2$ (4, n = 270) = 25.375, p = 0.001) rated the perceived acoustic comfort as moderate. Two basic factors of the soundscape evaluation, which are loudness and acoustic comfort, are significantly correlated with the space usage factors indicating direct effects on reaction ratings of the users especially for the preference of library spaces. This finding is interesting as another related study have reported that discomfort-comfort ratings do not influence the soundscape perception (Ikhwanuddin, Sarwono, Sudarsono, & Utami, 2017).

Thereby, it can be discussed that, wording the scales as acoustic comfort might lead to a better understanding of the designated comfort ratings regarding the specific perceptual attribute.

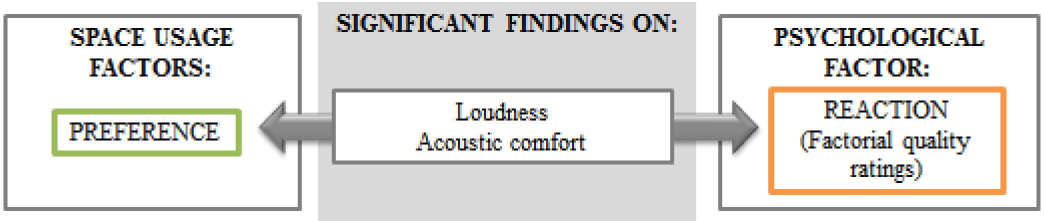


Figure 12. Statistically significant relationships between preference and reaction evaluated by factorial quality ratings.

As another part of the chi-square analysis, the effects sound source perception on space usage is tested. As shown in Figure 13, significant relationships were identified between preferring other spaces and disturbance reaction to sounds of walking/footsteps ($\chi 2$ (4, n = 270) = 17.104, $p < 0.005$) and sound of outside construction ($\chi 2$ (4, n = 270) = 14.917, $p = 0.005$). The majority of people who preferred other library spaces rated the disturbance from the sound of walking/footsteps and the sound of outside construction of the case library as moderately disturbing.

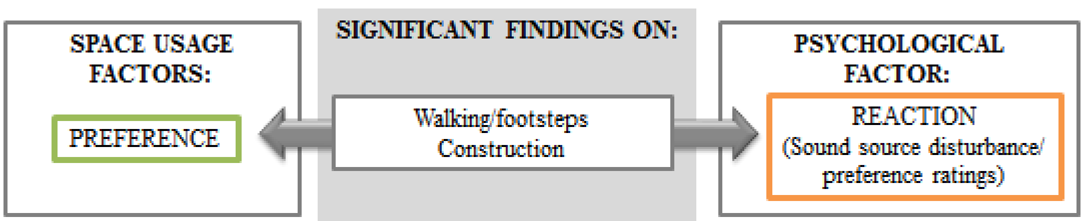


Figure 13. Statistically significant relationships between preference and reaction evaluated by sound source disturbance/preference ratings.

5. Conclusion

In this study variable dependencies have been tested considering three main factors under contextual experience, which are demographical, space usage and psychological factors. The statistical results of Chi Square test of goodness of fit are presented in detail considering all combinations of the aforementioned factors. The results show that demographical factors such as gender and education level and space usage factors such as preference, usage frequency and time spent all affects the psychological factors tested in this study, which are identified as expectation, perception and reaction. In order to conduct a detailed analysis on the variables of contextual experience, firstly indoor soundscaping questionnaire is designed and validated.

It is concluded that, gender and education level effects expectation of acoustic factors, which are acoustic comfort, loudness, intelligibility of sounds and sound oriented way-finding, and other environmental factors such as thermal comfort and lighting level. In addition, expectation is affected by preference of the case space and time spent in the case space especially for factors related to noise from neighbouring spaces and level of different types of sounds in the case space.

Perception found to be affected by gender and education level variances, especially for sound of whispering and sound of book trolleys. Both of these sound sources are specifically within the context of a library sound environment and therefore, it is concluded that such individual sound source evaluation for indoor soundscape analysis directly leads to specific and meaningful results. Similarly, preference and time spent in a library setting is found as directly related with the perception of mechanical fan sounds and whispering. Users who spend longer time in the library are more annoyed from sound of whispering, which act as one of the most dominant sound source in a library setting.

Reaction analysis indicated important relations regarding gender. Results highlight that females are more sensitive to highly reverberant environments. Furthermore, female users also rated sound of laughter, mobile phones, register, and music from personal players in the case space to be more disturbing, whereas male users rated sound of computer fans, computer keyboard, mechanical fans/AC, and elevator in the case space to be more disturbing. With such findings the clear variations regarding gender on sound source disturbance is identified. Furthermore, results indicate that higher education level may lead to higher awareness or sensitivity for humidity levels and mobile phone sound.

In addition to demographical findings, space usage and reaction also shows significant relations. Users who prefer other libraries rated case library as moderately loud and rated acoustic comfort as moderate. These findings can be discussed as, loud overall sound environments and moderate acoustic comfort may lead to the preference of other library spaces when compared to the case library. Furthermore, users who prefer other libraries rated sound of walking/footsteps and construction moderately disturbing in the case library indicating that such sound sources definitely plays an important role for preference.

It is concluded that, detailed analysis through specially designed questionnaires may reveal important insights for indoor soundscape experience of the users. Similar studies in different case spaces would be beneficial to link the findings of the validated indoor soundscaping questionnaire that is presented with this case study, which is specifically for library soundscapes. Further studies could adapt this validated questionnaire through revisions of the sound sources that are specifically identified for the purpose of library sound environments in this study. The methods and results presented in this study may act as a starting point to understand indoor sound environments from the contextual experience perspective. In addition, it should be noted that, findings presented in this study are based on psychological factors and such variables heavily depend on cultural and contextual variations. Thereby, cross-cultural studies could bring detailed insights regarding studies on contextual experience. Increased awareness for the study of indoor soundscapes will lead to the development of specific soundscape design guidelines for an enhanced indoor sound environment and user experience in different indoor spaces with varying cultural context.

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