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Nonvisual Legibility and the Coherence of Space: A New Theoretical Framework with Examples of Its Implementation in Empirical Research

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Abstract

The legibility and coherence of space are informative qualities as they facilitate the understanding and exploration of the environment. They also function as categories in architectural and urban design theory, as well as environmental psychology. The approaches of those disciplines, including their contemporary continuations, evolved from Lynch (1960) and are based solely on the visual qualities of the environment.

In this article, I argue that relying only on the visual scope of human-environment relations is insufficient for inferring the user's perception of the environment as *legible* and *coherent* and evaluating design solutions from the users' perspectives. The proposed revised theoretical framework combines architecture and urban design perspectives with environmental psychology and broadens concepts of legibility and coherence. The revised framework combines the visual scope of the legibility and coherence with other aspects of human-environment relations by referring them to multisensory perspective, social and spatial functioning, levels and characters of stimulation, and affective appraisal of the environment.

To show how we can address this broadened approach to legibility and coherence in empirical research, I present two examples of experimental research using bimodal research materials. They present how nonvisual qualities contribute to legibility and coherence and how they can be measured (tested) during the data-driven evidence-based design process. The first experiment investigates the relationship between the qualities of soundscapes and the social functioning of users. The second covers the tactile and haptic dimensions and their connections with blind and visually impaired users' spatial functioning.

Keywords

legibility, coherence, nonvisual perception, experiment, user-centred design

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Introduction

In order to meet the standards of the user-centred design paradigm (ISO 9241-210, 2010), a design needs to follow a precise understanding of users' perspective and the context in which they function. The design evaluation becomes focused on users' needs and abilities. The overriding goal of this article is to bring closer the focus on users' perspective as understood in environmental psychology research to architectural and urban design. The scope of this article is limited to a small fraction of a whole spectrum of human-environment relations; that is, the issue of legibility and coherence of space experienced via nonvisual perception. The non-visual perception's delimitation is in contradiction to the ocularcentrism. It also serves as a "special" constraint that lets us examine and verify the common patterns in research of human-environment relations by putting them in a broader context of the environment's multisensory experience.

The central thesis of this article states that it is insufficient to rely on visual information while evaluating the legibility and coherence of the environment as perceived by users. For more accurate verification of architectural and urban design, it is necessary to capture a broader context in which the environment is experienced as legible and coherent. The main research problem is identifying the nonvisual aspects of human-environment relations underlying our environmental preferences in the scope of legibility and coherence of space. Two examples of experiments show how to implement the proposed theoretical framework into empirical research that may serve as a tool for architectural and urban design evaluation.

Basic Concepts of Legibility and Coherence of Space

The legibility and coherence of space are investigated in both disciplines – architectural and urban design as well as environmental psychology (Kaplan & Kaplan, 1989), using the same basic definitions provided by Lynch (1960). They may serve as a common ground for these diametrically different fields and a starting point for the extended approach proposed in the framework. Moreover, Lynch's theory links the environment's perception with the context of human-environment relations, which follows the transactional paradigm of social science empirical research (Altman, 1992, p. 268; Altman & Rogoff, 1987). The transactional approach puts perception (among other psychological processes) in a broader context of people's functioning in the environment and their understanding of it.

Lynch (1960, p. 3) defines *legibility* as "a strictly visual quality" for which cities' parts can be recognised and organised into a coherent pattern. He further discusses the *coherence* of space as the relations between parts and the whole that serves legibility (Lynch, 1960), which gives rise to an impression of a "hanging together" (Kaplan & Kaplan, 1989, p. 54).

In environmental psychology, the continuation of Lynch's concept considers legibility and coherence not as objective features of the environment but rather as its qualities perceived by users. Whereas architectural and urban theory unfolds in two directions: the former takes legibility and coherence as objective measures of spatial organisation, and the latter, similarly to social science, investigates legibility and coherence of the environment as subjectively experienced.

The legibility and coherence treated as objective measures refer to space syntax analysis of spatial configurations and their social consequences (Hillier & Hanson, 1984; Dalton & Bafna, 2003; Hillier, 2007; Long, Baran, & Moore, 2007; Long, 2008; Koseoglu & Onder, 2011; Jiang, 2012; Schumacher, 2012; Mahdzar & Safari, 2014; Gohari, 2019), and to geometrical relations in structure and system configuration (Alexander et al., 1987; Alexander et al., 2002; Salingaros, 1998; Salingaros, 2000; Caliskan & Mashhoodi, 2017).

Subjectively experienced legibility and coherence are used to investigate users' spatial functioning (spatial orientation, wayfinding, navigation and mental maps) (Golledge & Stimson, 1997; Golledge, 1999). They are also the qualities indicated as significant in the Kaplans' environmental preferences theory (Kaplan, 1987; Kaplan & Kaplan, 1989) in the field of the environmental aesthetic (a discipline that investigates aesthetic of places as experienced by people in broad categories of attractiveness, i.e., Nasar, 1988; Porteous, 1996). Kaplan (1987) proposed a theoretical framework of environmental preferences that arise from two primary needs: understanding and exploring. He indicated four environmental qualities that influence our performance in realising these needs: coherence, legibility, mystery, and complexity.

Coherence gives us an immediate understanding, while complexity provokes quick exploration. These qualities refer to simple, easy to grasp information from the environment. Legibility is based on inferred information about the perceived environment. In particular, it allows the prediction of an environment's features, such as understanding its layout, deducing its structure, and predicting how we will orientate ourselves if we go beyond the scenery we can see (Kaplan, 1987). Legibility and coherence of space enhance our sense of independence by supporting our mobility and participation in social life (Metz, 2000; Mulligan, Carruthers, & Cahill, 2004).

Stamps (2004) provides a meta-analysis of 61 articles covering experimental studies following the "typical experimental protocols" given in Kaplan and Kaplan (1989, pp. 207–215). This procedure involves showing respondent static slides of various environments (coloured or in greyscale). Stamps (2004) concludes that it is impossible to predict people's environmental preferences relying on configurations and intensity of environment's qualities from Kaplan's environmental preferences model, because "[…] the correlations between preference and the information variables have not been reproducible" (Stamps, 2004, p. 10). The ranges of the correlations between respondents' preference and informative variables vary between different experiments to the extent that they do not allow to predict how legibility, coherence, mystery and complexity contribute to environmental preferences in a replicable pattern. Stamps (2004, p. 13) further suggests that "if the problem were measurement error, then a possible research strategy would be to try some other ways to measure the desired informational concepts."

Regarding Stamps's (2004) meta-analysis findings, I propose an extended theoretical framework and its empirical implementations that place legibility and coherence of the space in a broader context of other psychological concepts of human-environment relations and provide implications for user-centred design.

Extended Theoretical Framework and Revised Research Approach to Legibility and Coherence Concept

The definitions mentioned above of legibility and coherence have one assumption in common: they investigate qualities experienced by users that serve as predictors of user's environmental preferences, based solely on visual information. If research on people's environmental preferences should be helpful for design practitioners, they should address users' multisensory experience and psychological dimensions of human-environment relations underlying the experience of the environment as legible and coherent. This aim introduces four main elements of the proposed extended framework for research on legibility and coherence of space as perceived by users. These elements are:

1. The functional roles of legibility and coherence of space (spatial and social functioning).
2. The nonvisual perception of legibility and coherence.
3. Stimulation and affective reaction to the environment (based on circumplex model of affective appraisal of the environment (Russell, 1988))

as a background for research on the experience of places as legible and coherent.

4. A methodology enhancement that introduces the above theoretical concepts into the design evaluation process.

The first three elements lay the theoretical foundations that enable the legibility and coherence of the environment to be investigated in a reliable way. The fourth element introduces the use of the design artefacts as valid input in obtaining meaningful data for design evaluation. This is a stepping stone to develop a method easy to use by design practitioners in a professional setting to verify design solutions regarding the legibility and coherence of the environment.

Functional Roles of Legibility and Coherence

Legibility and coherence should be considered and investigated in the functional context. Places perceived as legible and coherent enhance our understanding and exploration activities. Therefore, legibility and coherence (intelligibility and imageability) are linked to our functioning in an environment. They address both spatial and social functioning that provide variables for evaluating the environment and its design.

Spatial functioning refers to the understanding of the spatial organisation, layout, and configuration of elements. It includes spatial orientation, wayfinding, and mental maps (e.g., see Golledge & Stimson, 1997; Golledge, 1999; Allen, 1999). Social functioning relies on our understanding of the social context of a place. It consists of our ability to read situations around us and participate in social interactions. Social functioning thus depends on:

1. Affordances – that is, artefacts and an environment's qualities that facilitate actions and participation in activities and interactions (Gibson 1979/1986), as well as a contemporary notion of indirect perception of affordances deduced from information extrapolated from mental representations and previous experiences with this type of object and environments (Baggs & Chemero, 2018).
2. Experienced ambience, defined as the impression evoked by a site's multisensory qualities, refers to comfort and social and environmental aesthetic characteristics. The experienced ambience is a sum of the experience of a place's distinct character that facilitates or suppresses certain activities (e.g., Chelkoff, 2008; Thomas, 2010; Thibaud, 2011; Böhme, 2017).

Multisensory Instead of Visual Information

Research on legibility and coherence of space should address multisensory dimensions of experiencing the environment. In this article term, "multisensory" refers to considering the visual qualities of the environment, and these addressed to other senses through which we experience the environment, that is, aural, haptic, and olfactory.

The most straightforward way of thinking about legibility and coherence in architectural and urban design is via a spatial layout and visual information systems. Passini (1996, p. 326) wrote: "Wayfinding difficulties might be due to poor articulation of architectural features such as the indication of entrances, exits, horizontal paths, stairs, lifts and escalators, landmarks serving as anchor points and the circulation system. We feel that these architectural wayfinding cues are not only easy to convey but that they are essential features of architectural composition and should not require signage support. Signs indicating lifts or entrances are manifestations of architectural inadequacies." More evidence-based and data-driven decisions about spatial configuration and articulation would better serve wayfinding without additional signage systems. Instead of relying solely on these additional systems, the legibility and coherence of space address all senses engaged in the experience of the environment and can be precisely planned as the outcome of design decisions on architectural articulation and organisation.

A multisensory approach to legibility and coherence of space as experienced by users is elementary for a universal design paradigm (Preiser & Smith, 2011). The universal design emphasises that designed artefacts and places should be accessible and safe for everyone. This assumption includes the perspectives of various groups of users in the design process. These are the "extreme users" named after Tim Brown (2009, p. 44), who pointed out that we mostly confirm what is already known if we consider only the close to average cases. We instead need to look at users towards the edges of the Gaussian distribution curve – the extreme ones who live differently. For research on legibility and coherence of space, the extreme users will be those with perceptual disabilities, which orientate themselves, navigate and read social contexts using information from the environment differently than average in the population. One presented example of empirical research was conducted with blind and visually impaired participants (Kuryłowicz & Bogucka, 2011). This approach to selecting the research participants helps to verify theoretical assumptions about the legible and coherent environment and design solutions designed primarily for a visual experience.

Architectural articulation addresses not only our vision: using Lynch's (1960) classification, paths, landmarks, edges, districts, and nodes can also be experienced as nonvisual stimuli. For example, the curb separating a sidewalk from a street became Lynch's edge, while a street sign, stand or trash bin at the intersection can be considered a landmark. Changes in pavement textures and cross slopes signal different path sections, nodes, or even borders between districts. For persons who are blind or visually-impaired, soundscape (Schafer, 1977; Fiebig, Jordan & Moshona, 2020), smellscape (Henshaw, 2013;), and haptic and tactile (Shiff & Foulke, 1982) qualities are the primary sources used in spatial orientation and social functioning. Research comparing the abilities of blind and visually-impaired people to the abilities of those using vision show no differences as to mechanisms and the efficiency levels of spatial functioning . The only difference is the stimuli input, in that the blind and visually-impaired people navigate and orientate themselves and rely on different and a greater number of environmental clues (Golledge & Stimson, 1997, p. 510). For example, instead of seeing obstacles, they hear them through echolocation (Dolański, 1954), such as is the case for the walls, other barriers, and entrances. Such features reflect sounds, regulate airflow and provide nonvisual information about a spatial layout. The affordances are the sources of sounds and social stimulation which provide clues regarding the social contexts. The extreme users' empirical perspective also questions the fundamental and often implicit assumption that links affordances with the ecological approach to visual perception (Gibson, 1979/1986; Lynch, 1960). As empirical research has shown (e.g., Kuryłowicz & Bogucka, 2011; Bogucka, 2011; Bogucka, 2012; Bogucka, 2013; Bogucka, 2018), not solely visual information is responsible for identifying and using the affordances of the environments and objects.

Stimulation and Affective Reactions as a Background of Experiencing Legibility and Coherence

Legibility and coherence of space should be analysed in the context of experienced stimulation from the environment and the affective appraisal of it. The quality and comfort of spatial and social functioning stem from the types and levels of stimulation we experience in a given setting. Our understanding of the environment (in both the social and spatial dimension) depends, among other things, on our perceptual abilities. On the one hand, an environment's qualities contribute or not to its legibility and coherence, while on the other, this legibility and coherence is a result of our capabilities to process the stimuli.

At the elementary level, we in fact do not experience the legibility and coherence of a place. Instead, we experience the stimulation as our reaction to the environment. There are three primary kinds of stimulation: sensory, resulting from social interactions, and this caused by our movement (Wohlwill, 1974). The environment is a source of these three types of stimulation (directly and indirectly). We tend to look for optimal (meaning: desirable) levels of stimulation. There are individual differences in our preferences, but we can distinguish stable trends in how people react to specific stimulations from the environment. Therefore, it is possible to predict that some settings might be overstimulating, for instance, noisy or overcrowded. Based on Kaplan's Attention Restoration Theory (Kaplan, 1995), natural settings or elements thereof in the urban environment might regulate stimulation positively, while monotonous places (i.e. characterized by a low level of complexity) cause under-stimulation.

We can react to the environment with stimulation on a continuum from low to high. Russell (1980, 1988) adds a second – evaluative – dimension indicating if the stimulation is experienced positively or negatively. Declarative affective appraisal indicates that places with certain qualities can make us feel stressed, irritated, excited, or delighted; others might lower our level of stimulation (i.e. causing boredom and sleepiness) or in a positive way (making us relaxed and calm).

How are legibility and coherence connected with the levels and types of experienced stimulation and affective appraisal of the environment? Their role is best seen when we experience the psychological consequences of them being absent. An environment experienced as illegible and incoherent increases the stimulation level during spatial functioning by decreasing the sense of security (Koseoglu & Camas, 2016). Spatial orientation and wayfinding are complex tasks (primarily when performed without visual information). The Yerkes-Dodson law indicates that the best performance favours a moderate level of stimulation. Therefore, a higher level of stimulation (potentially caused by an illegible environment) impacts our effectiveness in complex tasks like spatial orientation and wayfinding (Yerkes & Dodson, 1908; Diamond et al., 2007). Overstimulation, the lack of coherent and legible patterns makes finding the clues about possible affordances difficult. It leads to "misaffordances" (Heft, 1997), causing environmental stress, frustration, annoyance, and helplessness (Evans & Cohen, 1987; Norman, 1988). On the contrary, legible and coherent environment enhance social interactions and social sustainability by making the environment accessible (Moulay, Ujang, & Said, 2017).

Linking perceived legibility and coherence to stimulation and multisensory experience makes environmental preferences a dynamic and situational concept (i.e. dependent on what we do in the environment) which is also context-dependent and specific (i.e. dependent on what is happening in a given environment and in a given time). Therefore, evaluation of a static picture (like in Kaplan's protocols) is insufficient to conclude about environmental preferences and perceived legibility and coherence of place. Our phenomenological lifeworld is multisensory; the same applies to the perception of legibility and coherence thereof. This extended concept of legibility and coherence accompanied by user-centred design requirements impose methodological changes in empirical research, starting from the research goal.

A New Research Goal – From Basic to Applied Research Measurements and Design Evaluation

The basic research procedure proposed by Kaplan and Kaplan (1989) served a research goal to identify the environmental preferences of the general population. The Kaplans asked what environmental qualities meet preferences of people (what people like or dislike). A review of early research provided by Kaplan (1987) answers this question to some extent: human beings prefer savannah-like environments as this type of scenery provides the right mix of four informative qualities (legibility, coherence, mystery, and complexity) . It does not mean, though, that every designed environment should resemble the savannah. We may try, however, to achieve a balance between informative variables that meet people perceptual capabilities.

As opposed to the basic research goal, the applied research goal is closely connected to the design task. The applied research approach involves changes in research procedures and research material selection. In basic research protocols, we have a set of images: representations of heterogeneous environments to the extent that they facilitate inquiry into general human preferences. In applied research protocols, instead of a diverse set of environment representations, we use research material that refers to various designs of the same place, which makes it possible to verify which design solutions are preferred the most by future or potential users. Employing applied research procedure and goals makes the already mentioned Kaplan's theory applicable in design practitioners' workflow.

Practical Implementation of the Applied Research Approach to Environmental Preferences

The proposed theoretical framework requires different research protocols from those used in basic research. If the empirical research goal should be valid for a design practitioner's workflow, it must accurately verify the design decisions that affect people's environmental preferences.

Summing up the first three theoretical framework elements, we need to address in empirical research the social and spatial functioning accompanied by multisensory experienced levels and characteristics of stimulation (manifested in affective appraisal) and the perceived qualities of affordances and ambience. An experiment is an empirical research method that helps establish the relations between independent variables and dependent ones. Here independent variables are the qualities of the environment and dependent – affective reactions to the environment, stimulation level, perceived comfort of affordances, performance in spatial functioning tasks. Two exemplary experiments presented in the following sections show how the proposed theoretical framework may be implemented in the research procedure to verify the design solutions from the users' perspective. The first example refers to the legibility and coherence of space inferred from nonvisual information in the context of social functioning. The second one addresses the spatial functioning scope of nonvisual legibility and coherence of the environment.

Experiment 1

The first experiment (Bogucka, 2013) is an example of ways to measure the influence of soundscape on the perceived social functionality of an environment.[1] The research question was: What is the role that soundscape plays in users' perception of ambience, social functionality of place, and in their perception of the built environment's affective qualities?

The research goals include:

- The identification of the role and significance of sound information in the perception of ambience.
- The investigation of a method to verify the soundscape influence on functionality and ambience perception at the design stage.

Method

Experiment Design

In a two-way analysis of variance, three different soundscapes (S0: silence – the control condition, S1: traffic sounds, S2: people activity sounds) were crossed with two public space schematic urban plans (P1 – dominated by infrastructure for cars, P2 – dominated by infrastructure for pedestrians). The additional one-way factorial analysis (two soundscapes (S1, S2) presented without schema of the places) was conducted to identify the differences between soundscapes' perception in two dimensions: (1) audibility of various sounds (people activity, traffic and nature), (2) the characteristics of soundscapes based on the semantic differential scale.

Research Materials

Places' Schemas

Two samples of public spaces as schemas were based on layouts of urban squares in Warsaw, Poland. The presented places' orientation was

[1] R language (R Core Team, 2013) was used for statistical analysis.

changed not to make them as easy to recognise as existing sites. The ratio of the area occupied by the streets to the sidewalk differentiates these public spaces. Place 1 has more road infrastructure than place 2 compared to the sidewalks (see Figure 1).

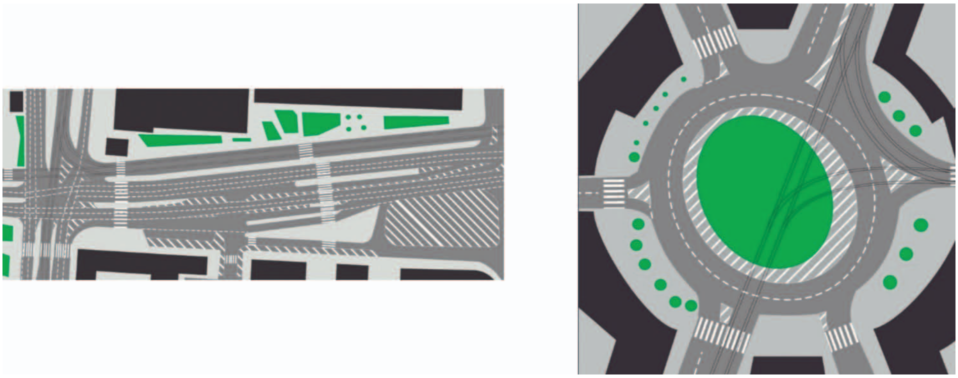

Figure 1

The schematic plans of the two sites used in experiment (Place 1 – left, Place 2 – right)

Samples of Soundscapes

The audio samples were recorded in two public spaces in Warsaw (different from those on schematic plans) using binaural microphones. The soundscapes used in the study were 70 seconds long each. Due to the unbalanced samples of respondents (consisting of various numbers), soundscapes were compared using a non-parametric Kruskal-Wallis rank-sum test in experimental condition without place representation. The number of respondents (subjects) who took part in the experiment amounted to 103.

The rank-sum test results show that soundscape 1 is significantly more dominated by traffic sounds, while soundscape 2 is dominated by people sounds. Nature sounds were heard at the same low level in both soundscapes (Table 1). Only one characteristic differentiates the studied soundscapes significantly: soundscape 2 (S2) appeared more compelling than soundscape 1 (S1). Trends show that soundscape 1 (S1) might be slightly more unpleasant and more homogeneous (Table 2).

Table 1

Differences between soundscapes based on intensity of sounds from different sources

Sound sources	Soundscape	*N*	*M*	*Median*	*SD*	Kruskal-Wallis rank-sum test		
						χ^2	*df*	*p*
People activity	S1	57	2.8	3	1.0	41.6	1	**<0.001**
	S2	46	4.2	4	0.9		1	
Traffic	S1	57	4.4	5	1.0	6.2	1	0.01
	S2	46	4.0	4	1.1		1	
Nature	S1	57	1.8	2	1.1	1.5	1	0.22
	S2	46	1.5	1	0.7		1	

Table 2

Differences between soundscape characteristics

Sound attribute	Soundscape	*N*	*M*	*Median*	*SD*	Kruskal-Wallis rank-sum test		
						χ^2	*df*	*p*
interesting – boring	S1	57	7.3	8	2.51	13.39	1	**<0.001**
	S2	46	5.3	5	2.45		1	
various – homogenous	S1	57	6.1	6	2.80	3.40	1	0.065
	S2	46	5.1	5	2.73		1	
unpleasant – pleasant	S1	57	3.3	3	2.23	3.01	1	0.08
	S2	46	3.8	4	2.05		1	
absorbing – unabsorbing	S1	57	5.4	5	2.63	2.26	1	0.13
	S2	46	4.6	4.5	2.57		1	
disturbing – non- disturbing	S1	57	3.7	3	2.91	0.01	1	0.91
	S2	46	3.6	3	2.64		1	
predictable – unpredictable	S1	57	3.8	3	2.37	1.69	1	0.19
	S2	46	4.6	3	2.86		1	
discordant – harmonious	S1	57	3.3	3	0.20	0.11	1	0.74
	S2	46	3.5	3	2.30		1	
loud – quiet	S1	57	2.8	2	2.51	0.00	1	0.94
	S2	46	2.5	2	1.77		1	
Cronbach's α = 0.69								

Dependent Variables

Soundscapes' Comparison

As shown above, the differences between soundscapes relate to two dimensions:

1. The identification of the level of sounds of people, traffic, and nature that was heard.
2. The semantic differential concerning sound characteristics.

The sounds of people, traffic, and nature were evaluated on a 1–5 scale, where 1 – not heard, 5 – completely dominates. The sounds' characteristics were rated on a semantic differential scale of 1 to 10 using the following pairs of adjectives:

- unpleasant – pleasant,
- various – homogeneous,
- absorbing – unabsorbing,
- disturbing – non-disturbing,
- predictable – unpredictable,
- discordant – harmonious,
- loud – quiet.

Another pair of opposite adjectives, namely: interesting – boring was used to evaluate the characteristic of soundscapes.

Public Spaces' Evaluation

The evaluation of public spaces was based on the following three dimensions:

1. Perceived affordances relating to social functioning and their quality.
2. Place characteristics concerning the ambience of places.
3. Perceived affective quality of the environment.

Social Functionality (Affordances) Scale

The items in this scale evaluate perceived affordances and their qualities. Using a 5-stage scale (from "definitely does not fit" to "definitely fits"), participants evaluated an adequacy of a given place for specific activities grouped into three categories: physical activities, meetings, and mental activities (Table 3).

Table 3

Factor analysis of social functionality scale. Principal axis factoring with varimax rotation

Activities in public spaces	I	II	III	IV
Reading	0.387	0.191	**0.764**	
Spending time in front of the restaurant, cafe (Is there a place suitable for restaurant's tables?)	**0.585**	0.407	0.417	0.140

Table 3 continued

Activities in public spaces	I	II	III	IV
Using laptop, tablet	0.261	0.250	**0.653**	0.200
Scheduling a meeting in characteristic place	0.241	0.405	0.138	**0.431**
walking (or: walking a dog)	**0.692**	0.309	0.260	
meeting with large group of people	0.367	**0.785**	0.271	0.118
meeting with small group of people	0.503	**0.603**	0.324	
spending time with children	**0.754**	0.301	0.251	–0.121
walking through a place without stopping	–0.138			**0.454**
observing the surroundings	0.204	0.203	0.200	**0.667**
sitting on a bench	**0.623**	0.220	0.295	0.377
sports activities	**0.700**	0.180	0.227	
SS loadings	2.993	1.718	1.691	1.079
Proportion Var	0.249	0.143	0.141	0.090
Cumulative Var	0.249	0.393	0.533	0.623
Cronbach's α = 0.89				

The factor analysis with varimax rotation shows four factors that emerged from the questionnaire: physical activities, meetings, mental activities, and being a passive observer. The first factor accounts for 25% of explained variance, the second and third factors account for 14% of explained variance. The fourth factor – being a passive observer – for 9% of explained variance (Table 3).

Ambience Characteristics Scale

The ambience characteristics of places were examined using the semantic differential of 14 items. The respondents answered on the scale from 1 to 10.

The factor analysis with varimax rotation (Table 4) refers to five factors described by the following pairs of adjectives: 1) friendly – unfriendly, 2) constant – variable, 3) comfortable – uncomfortable, 4) inflexible – flexible, 5) varied – homogeneous. The first factor accounts for 24% of explained variance. The second and third factors both account for 13% of explained variance. The fourth factor for 6% and the fifth for 4% of explained variance.

Table 4

Factor analysis of ambience characteristics scale. Principal axis factoring with varimax rotation

Ambience characteristics	I	II	III	IV	V
intimate – open	0.171		**0.508**		
warm – cold	**0.603**		0.322	–0.201	
friendly – unfriendly	**0.802**	0.102	0.412	–0.124	
inviting – unappealing	**0.786**	0.108	0.394	–0.135	
happy – sad	**0.717**		0.181	–0.230	0.299
familiar – unfamiliar	**0.672**	0.121	0.199		0.253
sophisticated – common	0.296		**0.621**	–0.123	0.293
comfortable – uncomfortable	0.515	0.119	**0.648**	–0.141	
ordered – chaotic	0.227	0.476	0.462		0.183
predictable – unpredictable	0.118	**0.819**			
simple – complicated	0.109	**0.635**	0.180		
constant – variable	–0.183	**0.598**	0.101	0.393	–0.195
inflexible – flexible	–0.364	0.302	–0.112	**0.733**	–0.134
diverse – homogeneous	0.346	–0.264		–0.197	**0.470**
SS loadings	3.335	1.882	1.835	0.909	0.576
Proportion Var	0.238	0.134	0.131	0.065	0.041
Cumulative Var	0.238	0.373	0.504	0.569	0.610
Cronbach's α = 0.79					

The Affective Quality of Environment Scale

The scale of the affective quality of the environment follows Russell and Pratt's (1980) circumplex model of affect (Figure 2). The affective qualities of places were measured on the 16-items scale (from 1 – "definitely not" to 5 – "definitely yes"). The items were grouped into four factors on two bipolar dimensions: a level of stimulation (arousal – sleepiness) and its sign (pleasant – displeasing). The 16 adjectives were based on the Polish adaptation of Russell's model (Russell, Lewicka, & Niit, 1989) and Russell, Ward and Pratt's (1981) factor analysis of affective quality attributed to the environment.

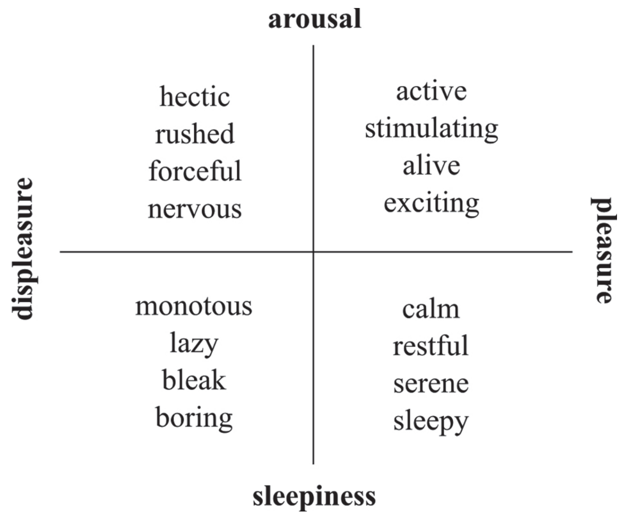

Figure 2

Affective quality of environment scale based on Russell and Pratt (1980) circumplex model of affect and Russell, Ward and Pratt (1981)

Procedure

The study was a computer-assisted web interview. Research material in every experiment condition was presented as a film with a static plan presentation and with or without the soundscape soundtrack. Each film was 70 seconds long. Research material was presented randomly to the participants. After the presentation of a public space, participants filled out the questionnaire about the soundscape characteristics and the place features.

Results

Participants

Seventy-four subjects living in Poland took part in this experiment: 179 (65%) females and 95 (35%) males in the18–63 years age group. Most of them (65%) lived in big cities (with population of over 500,000 inhabitant), 31% in smaller cities (from 20,000 to 500,000 inhabitants), while 4% lived in villages. 68% hold a university-level education, 17% declared unfinished university-level education, 12% declared high school level-education, and 3% have primary school-level education.

How Does the Types of Soundscape and Place Influence Perception of Affordances' Quality?

Physical Activities

A two-way ANOVA shows the significant place effect ($F(1, 268) = 6.704$, $p = 0.01$) on the perceived quality of physical activities (Figure 3). Place 2 was rated as more suitable for physical activities than place 1 when presented without any soundscape.

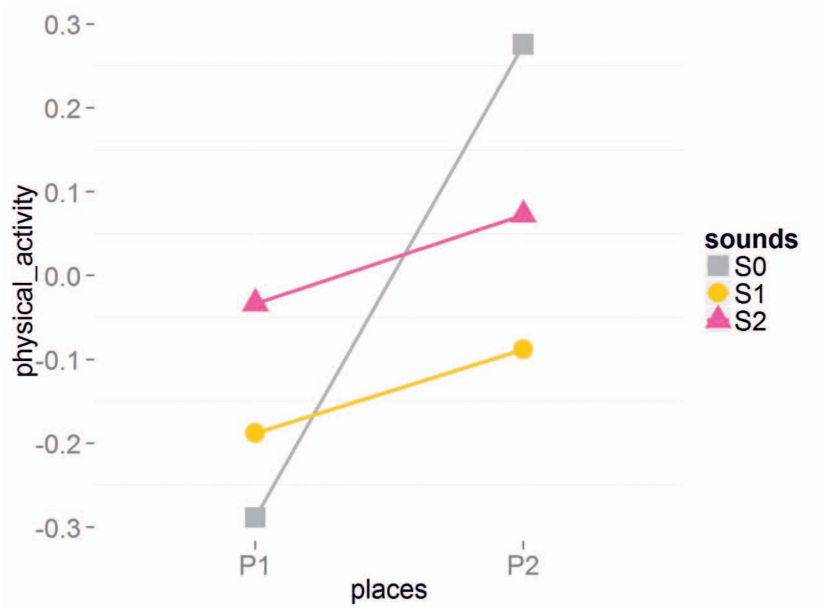

Figure 3

Mean places' suitability for physical activity as a function of the place and the soundscape

Mental Activities

Significant place effect ($F(1, 268) = 4.361$, $p = 0.04$) also influenced the perception of the places as suitable for mental activity. A significant interaction between the place and the soundscape effects ($F(2, 268) = 3.101$, $p = 0.05$) shows that the car soundscape increases the ratings of car place as suitable for mental activities and lowers the ratings of people place in this factor (Figure 4).

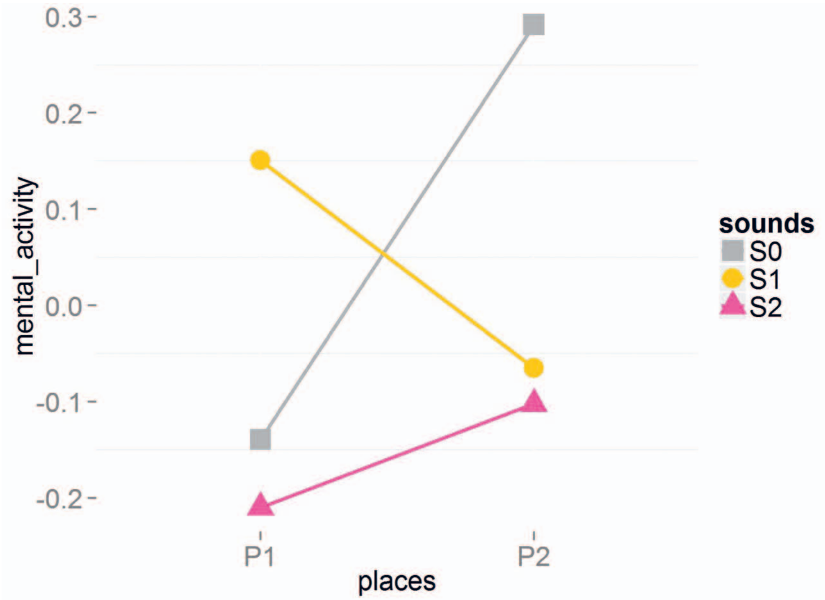

Figure 4

Mean places' suitability for mental individual activities as a function of the place and the soundscape

Meetings

There is a significant sound effect (F(2, 268) = 8.252, $p < 0.001$) on the evaluation of the places as suitable for meetings (Figure 5). The Tukey multiple comparisons of means show differences between S0, S1 and S1, S2 ($p < 0.05$ in both pairs) (Table 5). Adding two different soundscapes to the presentation of place 1 (car place) changed its evaluation from good for meetings with people soundscape (S2) to worse with car soundscape (S1).

Table 5

Tukey post hoc tests for soundscape effects on perceived quality of affordances referring to meetings

Comparison	Estimator	Lower	Upper	Statistic	P
S0, S1	0.366	0.270	0.474	–2.883	**0.011**
S0, S2	0.482	0.377	0.589	–0.385	0.930
S1, S2	0.619	0.525	0.706	2.940	0.008

There is also a significant interaction of the place and sound effects (F(2, 268) = 5.583, $p = 0.004$) on the place ratings concerning meetings (Figure 5). Soundscapes changed places ratings differently for each place. In the car place case (P1), people-soundscape (S2) elevate the ratings, causing the place to look more suitable for meetings. In contrast, both soundscapes slightly lowered the car place (P2) ratings compared to the experimental control condition (without soundscapes).

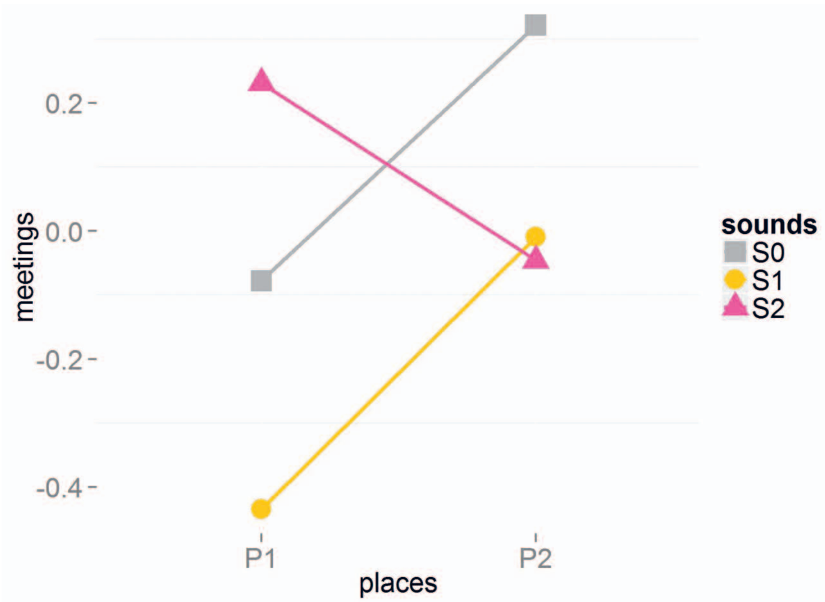

Figure 5

Means of places' suitability for meetings as a function of the place and the soundscape

Passive Observation

There were no significant effects of the places and the soundscapes on evaluating places on the fourth factor – being a passive observer.

Quality of Affordances Summary

The two-way analysis of variance shows that the ratings of the places presented without soundscape (S0) are more polarised than those with soundscapes. The people place (P2) is better for physical activities and mental activities than the car place (P1). Both soundscapes lower the ratings of the people place (P2) (significantly only in the meetings' affordances). The people soundscape (S2) improves the ratings of meetings' affordances in the car place (P1) in comparison to the car soundscape (S1) significantly. In summary, the people soundscape (S2) makes places unsuitable for mental activities, while the car soundscape (S1) does not. Although car soundscape is not disturbing mental activities, car place (P1) with car soundscape (S1) lower the quality of meetings' affordances.

How do Soundscapes and Place Types Influence the Perception of the Place Ambience's Features?

Friendly – Unfriendly Continuum

The two-way ANOVA shows significant place effect ($F(1, 268) = 20.353$, $p < 0.0001$) (Figure 6). The car place (P1) was always rated as more unfriendly. The interaction between the soundscape and place effects is also significant ($F(2, 268) = 5.4$, $p = 0.005$). The soundscape effects varied between places. In the car place (P1) case, the soundscapes lower the unfriendly impression. The soundscape's effect is also significant ($F(2, 268) = 13.457$, $p < 0.0001$). The post hoc Tukey test shows significant differences in S0, S2 and S1, S2 pairs (Table 6). People soundscape (S2) makes both places friendlier.

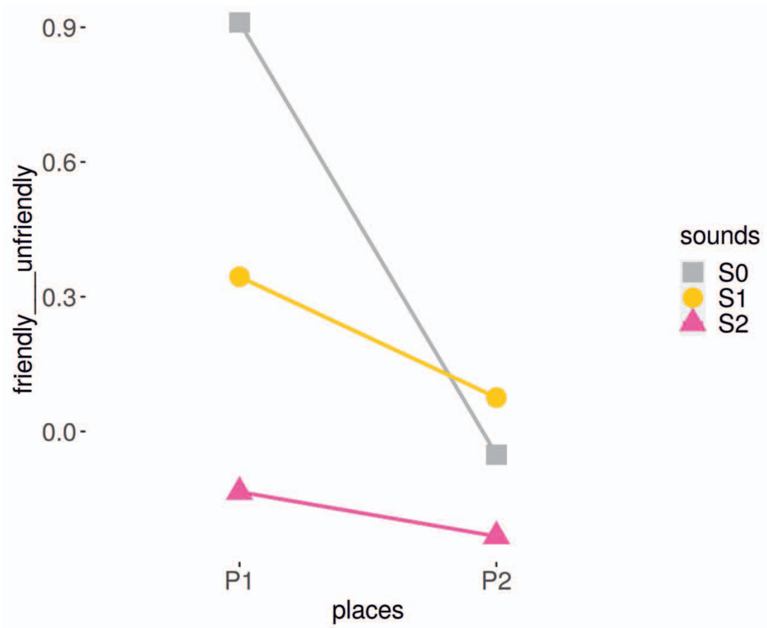

Figure 6

Means on friendly – unfriendly continuum as a function of the place and the soundscape

Table 6

Tukey post hoc tests for soundscape effects on perception of a place's ambience on friendly – unfriendly continuum

Comparison	Estimator	Lower	Upper	Statistic	p
S0, S1	0.454	0.347	0.566	–0.950	0.611
S0, S2	0.361	0.264	0.471	–2.923	**0.009**
S1, S2	0.376	0.290	0.470	–3.063	**0.005**

Comfort – Discomfort Continuum

The two-way ANOVA shows significant place effect ($F(1, 268) = 7.38$, $p = 0.007$) influencing the perception of places' ambience. The car place (P1) is perceived as more uncomfortable than the people place (P2) when presented without any soundscapes (Figure 7).

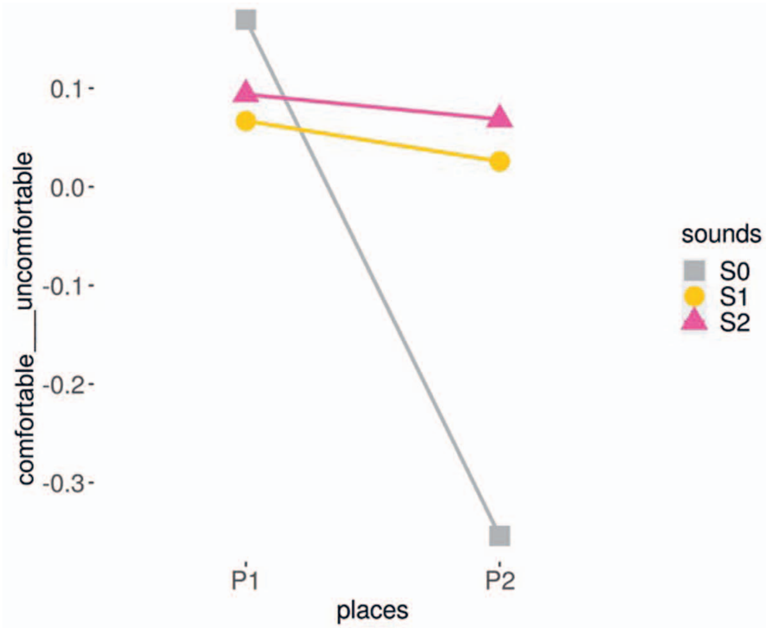

Figure 7

Means on comfortable – uncomfortable continuum as a function of the place and the soundscape

Constant – Variable Continuum

There is a significant place effect ($F(1, 268) = 10.367$, $p = 0.001$) on perception of places as more constantly or variable (Figure 8). The car place (P1) was more variable than the people place (P2). There is also a significant soundscape effect ($F(2, 268) = 6.58$, $p = 0.002$). Significant differences were between S0, S2, and S1, S2 pairs (Table 7). The people soundscape (S2) moves ratings of both places toward more variables than the car soundscape (S1). In the people place (P2) case, every soundscape moves ratings of ambience toward a more variable characteristic, while in the car place (P1) case, soundscapes change ratings to more constantly characteristic. The interaction effect of the place and the soundscape factors is significant ($F(2, 268) = 4.799$, $p = 0.009$).

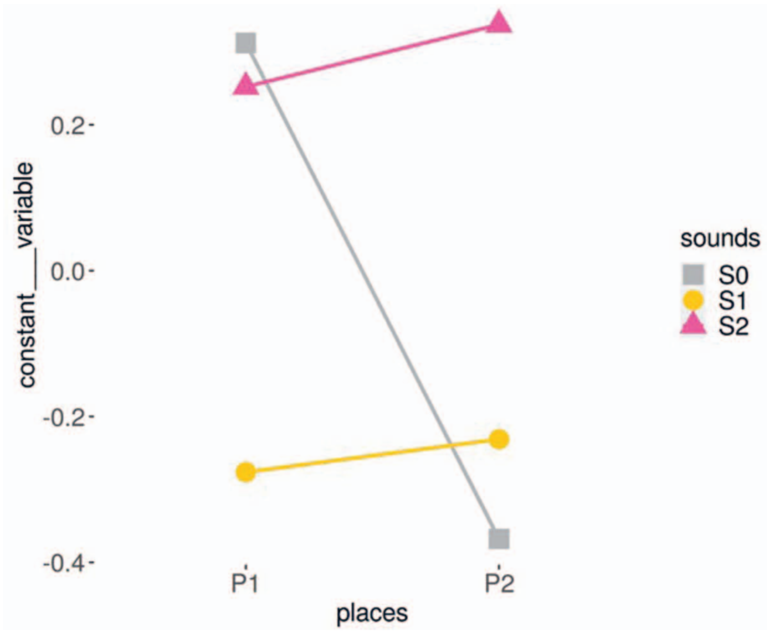

Figure 8

Means on constant – variable continuum as a function of the place and the soundscape

Table 7

Tukey post hoc tests for sound effects on perception of a place's ambience on constant – variable continuum

Comparison	Estimator	Lower	Upper	Statistic	p
S0, S1	0.455	0.351	0.563	–0.983	0.598
S0, S2	0.640	0.530	0.737	2.967	**0.008**
S1, S2	0.687	0.593	0.767	4.522	**>0.001**

Inflexible – Flexible Continuum

The significant soundscape effect (F(2,268) = 5,005, p=0,007) was shown in places' evaluation on inflexible – flexible continuum (Figure 9). The Tukey test (Table 8) indicates significant differences between S0, S2 and S1, S2 pairs. The people soundscape (S2) moves both places ratings toward more flexibility in comparison to the silence experiment condition (S0) and the car soundscape (S1).

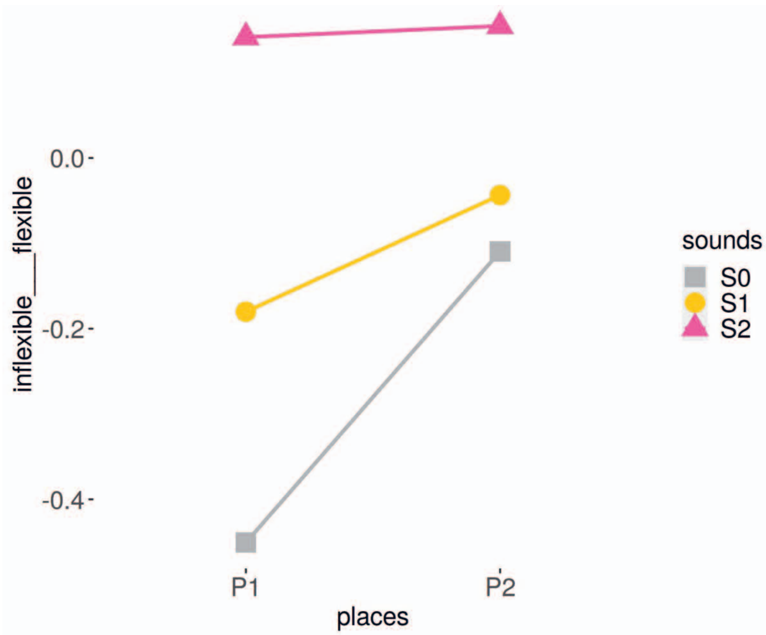

Figure 9
Means on inflexible – flexible continuum as a function of the place and the soundscape

Table 8
Tukey post hoc tests for sound effects on perception of a place's ambience on inflexible – flexible continuum

Comparison	Estimator	Lower	Upper	Statistic	P
S0, S1	0.554	0.445	0.658	1.154	0.484
S0, S2	0.636	0.529	0.731	2.959	**0.007**
S1, S2	0.598	0.503	0.686	2.408	**0.042**

Varied – Homogeneous Continuum

There were no significant effects of places and soundscapes on the evaluation of place concerning the fifth factor: varied – homogeneous dimension.

Summary of Ambience Characteristics

The soundscape with people sounds prevailing makes both places more friendly. More diverse and interesting soundscape (people soundscape, see Table 2) translates into the both places scoring higher on flexible and variable dimensions. The inflexible – flexible continuum of places evaluation was determined only by the information delivered by soundscapes.

How do Soundscapes and Place Types Influence the Perception of the Environment's Affective Qualities?

A two-way analysis of variance was conducted for four factors from Russell et al.'s (1980) circumplex model of affect (Table 9, Figure 10). The two-way ANOVA indicates significant place effects in (a) arousal – displeasure and (d) sleepiness – pleasure continua. The car place (P1) tends to be perceived as more arousal-displeasure (e.g., tense) and less sleepiness-pleasure than the people place (P2).

Table 9

Two-way ANOVA of environment's affective qualities

Source of variance	Dependent variable	ANOVA		
		df	*F*	*p*
Place	arousal pleasure	1	0.7216	0.3964
Soundscape		2	3.8621	**0.0222**
Place x soundscape		2	0.3149	0.7301
Place	arousal displeasure	1	11.0104	**0.0010**
Soundscape		2	0.8756	0.4177
Place x soundscape		2	3.4525	**0.0331**
Place	sleepiness pleasure	1	16.9887	**>0.0001**
Soundscape		2	3.8199	**0.0231**
Place x soundscape		2	7.7092	**0.0006**
Place	sleepiness displeasure	1	0.9937	0.3197
Soundscape		2	4.7295	**0.0096**
Place x soundscape		2	0.0493	0.9519

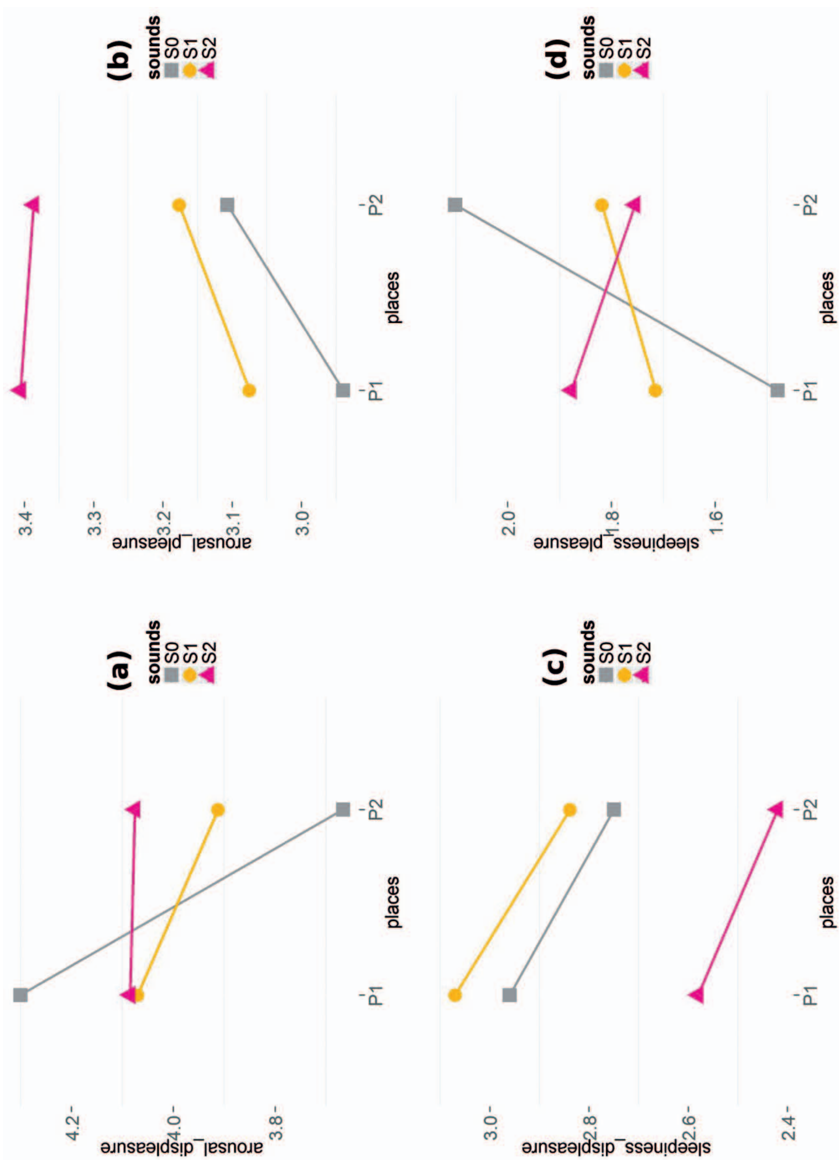

Figure 10

Means of places' affective qualities: (a) arousal displeasure, (b) arousal pleasure, (c) sleepiness displeasure, (d) sleepiness pleasure as a function of the place and the soundscape

The Tukey tests show significant differences in sound effect in (b) arousal – pleasure continuum, in pairs: S0, S2, and S1, S2; in (c) sleepiness – displeasure continuum, in pairs: S0, S2, and S1, S2. The Tukey test also shows no differences between particular soundscapes in (d) sleepiness – pleasure continuum (Table 10). Significant interaction's effects are noticed in (a) arousal – displeasure and (d) sleepiness – pleasure continua. In both cases, the soundscapes equalise the affective evaluation compared to the silence condition (S0). The soundscapes lower the positive (sleepiness – pleasure) rates of the people place (P2) and increase the negative ones (arousal – displeasure).

Table 10

Post hoc Tukey tests for Russell et al.'s (1980) circumplex model of affect

Dimension	Comparison	Estimator	Lower	Upper	Statistic	P
arousal pleasure	S0, S1	0.519	0.414	0.623	0.423	0.913
	S0, S2	0.626	0.520	0.720	2.781	**0.014**
	S1, S2	0.607	0.512	0.694	2.642	**0.022**
sleepiness displeasure	S0, S1	0.541	0.431	0.647	0.868	0.667
	S0, S2	0.390	0.293	0.496	–2.436	**0.039**
	S1, S2	0.341	0.259	0.434	–3.911	**0.0002**
sleepiness pleasure	S0, S1	0.459	0.353	0.568	–0.879	0.653
	S0, S2	0.474	0.368	0.582	–0.563	0.843
	S1, S2	0.510	0.418	0.602	0.258	0.968

Rates of both places with people soundscape (S2) were the highest on the arousal – pleasure continuum (e.g. exciting) and the lowest on the sleepiness – displeasure one (e.g., boring). In the silence condition (S0), both places were rated significantly different on the sleepiness – pleasure (e.g., relaxing) and the arousal – displeasure (e.g. tense) continua. Adding soundscape equalised the places' rates.

Discussion

In this experiment, the design outcomes (two schematic plans of public places) stayed unchanged while their ratings varied under the diverse soundscape conditions. The soundscapes contribute significantly to the changes in the perception of type and stimulation level of the surroundings presented as a schematic plan. The associations people have in relation to social functionality and the ambience of public space are subject to change when information relating to sound is added.

The sounds in the built environment can bring a considerable amount of information about what is happening (Rodaway, 1994). Besides information, the sounds from the environment are essential sources of certain levels and kinds of stimulation. For example, places designed with the dominance of traffic infrastructure are "the worst-case scenario" for meetings with other people and are experienced not only visually as car places but also aurally. This negative experience of the car-dominated places decreases when it is possible to hear the people soundscape. The soundscape components (like people activities, cars, nature) add information about possible social functionality. Its intensity and diversity might be sources of information about the quality of these affordances based on places' ambience and the experienced affective reactions to the environment.

The soundscape as an emotionally engaging feature of an environment (Fiebig, Jordan, & Moshona, 2020) might be a significant factor in modulating participants' ratings about social functionality and ambience in presented places. That explains why places' adequacy for various activities changes under different sound conditions. Therefore, considering the acoustic dimension of designed or evaluated space contributes significantly to predictions about the final effect of the design process perceived from the users' perspective.

These results lead to practical implications. First, it is worth planning the acoustic features (not only a noise level) parallel to the visual attributes during the design process as the factor influencing the end users' experience. Following that, it is crucial while planning and designing to consider the level and character of the stimulation planned to achieve and then translate it into physical and acoustical features of the designed environment.

Experiment 2

In the second experiment, the research goal was to verify the urban environment's legibility at the concept design stage from a blind person's perspective (Kuryłowicz & Bogucka, 2011). We used tactile maps of four students' urban designs to check which were easier to learn and more legible for blind users. The structured interviews accompanied the experiment method. The main research question was whether it was possible to verify the designed place's legibility based on nonvisual cues about spatial qualities. How can we use tactile maps in the urban and architectural design process? How can we verify the design outcomes using tactile maps (e.g. legibility of the built environment configuration for blind users)?

The research goal was to verify which of the urban design projects prepared by students were easy to learn, and thus, more legible. It had been anticipated that the complexity of the spatial system of presented projects would alter the ease of learning a given site from a tactile map. It had been assumed that blind persons will be able to indicate, using tactile maps, potential problems concerning spatial orientation.

Method

The research consisted of triangulating the two research methods: experiment and structured interview supported by mapping technique. The experiment was designed as a one-way ANOVA with repeated measures. The order of the presented site's plans was randomised between subjects. Interviews provided qualitative data on the evaluation of design projects and the usefulness of tactile maps of presented spaces. Evaluation of the place's legibility was mapped on schematic tactile maps of design projects.

Research Materials

We used urban designs devised by four students of architecture. Their task was to transform and redesign the Pichelsberg Tip (Olympic Park close to Berlin, Germany) into an attractive, functional, and fully accessible compound for sports and stage events alike. Urban plans were presented to participants as schematic and simplified tactile maps (mobility maps according to James's (1982) classification). The maps were prepared in Braille printing technique.

Dependent Variables

There were five dependent variables in the experimental phase of the study:
1. Time spent on getting familiar with the map.
2. Time needed to find the preferred route from place A to B (from the train station to the amphitheatre).
3. Time of indicating the chosen path from A to B.
4. Number of the attempts to show the path (amount of change in chosen initially route).
5. Number of errors in following the chosen path.

The structured interview's questions that followed the experiment phase regarded the most accessible paths and the most difficult places on the site plans.

Procedure

The study was carried out in three phases:
1. Learning (dependent variable no. 1).
2. Analysing (dependent variables no. 2–5).
3. Evaluating (structured interview).

In the evaluation phase, the participants were asked to show the most accessible paths and potentially most confusing places (where they might have got lost or experienced difficulties in spatial orientation) and explain their choices.

Results

Participants

Twelve blind and visually impaired participants (six females and six males) aged 32–74 took part in the experiment. Ten of them were gainfully employed; nine hold a higher-education degree. Seven people were blind from birth; three had lost sight during childhood. Two respondents were visually impaired: one had lost sight at the age 15, whereas another already in adulthood – two years prior to the experiment. All respondents declared they go out from home every day and use a white cane. Five persons declared the use of a guide. Eleven respondents use public transportation. All of them read Braille and had previous experience with tactile graphics.

Experimental Phase: The Impact of the Differences in the Urban Plan's Features on the Level of Performance in Tasks Involving Maps

One-way ANOVA with repeated measures showed no significant differences between four urban plans on all five dependent variables (Table 11).

Table 11

One-way ANOVA with repeated measures of dependent variables on four urban plans

Dependent variables	Plan A N = 12		Plan B N = 12		Plan C N = 12		Plan D N = 12		ANOVA		
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*df*	*F*	*p*
1. Time spent on getting familiar with the map	117.58	69.02	98.08	47.18	119.50	74.87	92.33	38.02	3. 33	1.25	>.05
2. Time of looking for a preferred route from place A to B (from the train station to the amphitheatre)	39.67	27.84	30.83	19.45	51.50	52.96	51.50	43.73	3. 33	0.83	>.05
3. Time of showing the chosen path from A to B	26.58	25.48	22.50	14.63	12.25	14.47	24.42	30.45	3. 33	1.05	>.05
4. Number of the attempts to show the path (amount of change in chosen initially route)	1.83	0.83	1.42	0.67	1.67	0.78	1.67	0.89	3. 33	0.79	>.05
5. Number of errors in the following chosen way	1.17	1.70	1.08	1.68	0.17	0.39	1.00	0.95	3. 33	1.67	>.05

Spatial and Qualitative Evaluation of Urban Designs Legibility

Structured interviews followed tasks on maps. First, respondents were asked to indicate which map was the easiest and which one the most difficult in terms of learning and analysing tasks. Indicated as the easiest were plans B and D. Plan C was the most frequently indicated as the most difficult to learn (Figure 11).

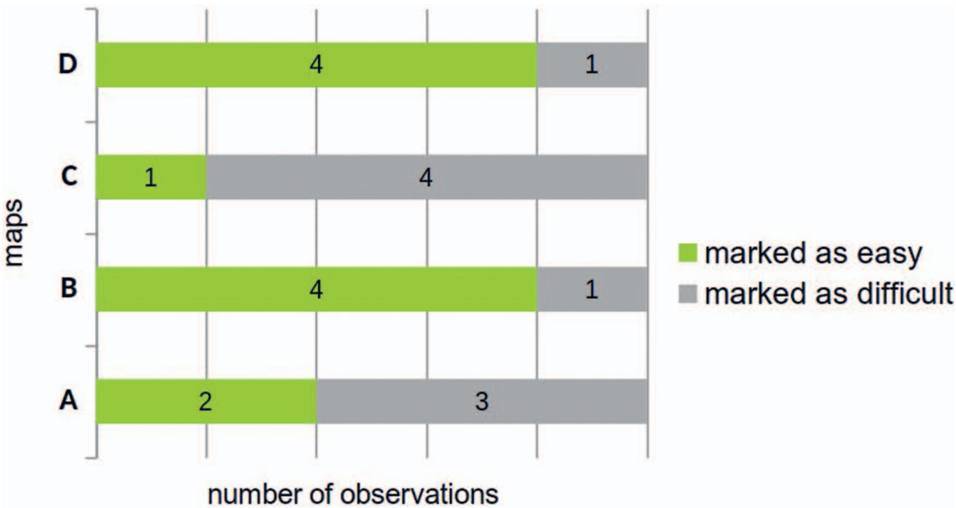

Figure 11

Quantity of general rates of tactile maps declared as easy and difficult by the respondents

Then, the respondents were asked to explain why they choose specific paths, what was especially legible or illegible on the urban plan, which places were potentially illegible and why.

The difficult places. According to the participants' indications, the illegible places on urban designs in question (Figure 12) were:

- intersections of more than two roads,
- intersections of/between non-perpendicular streets,
- the paths that are in an arc shape,
- wide-open spaces without any orientation point(s).

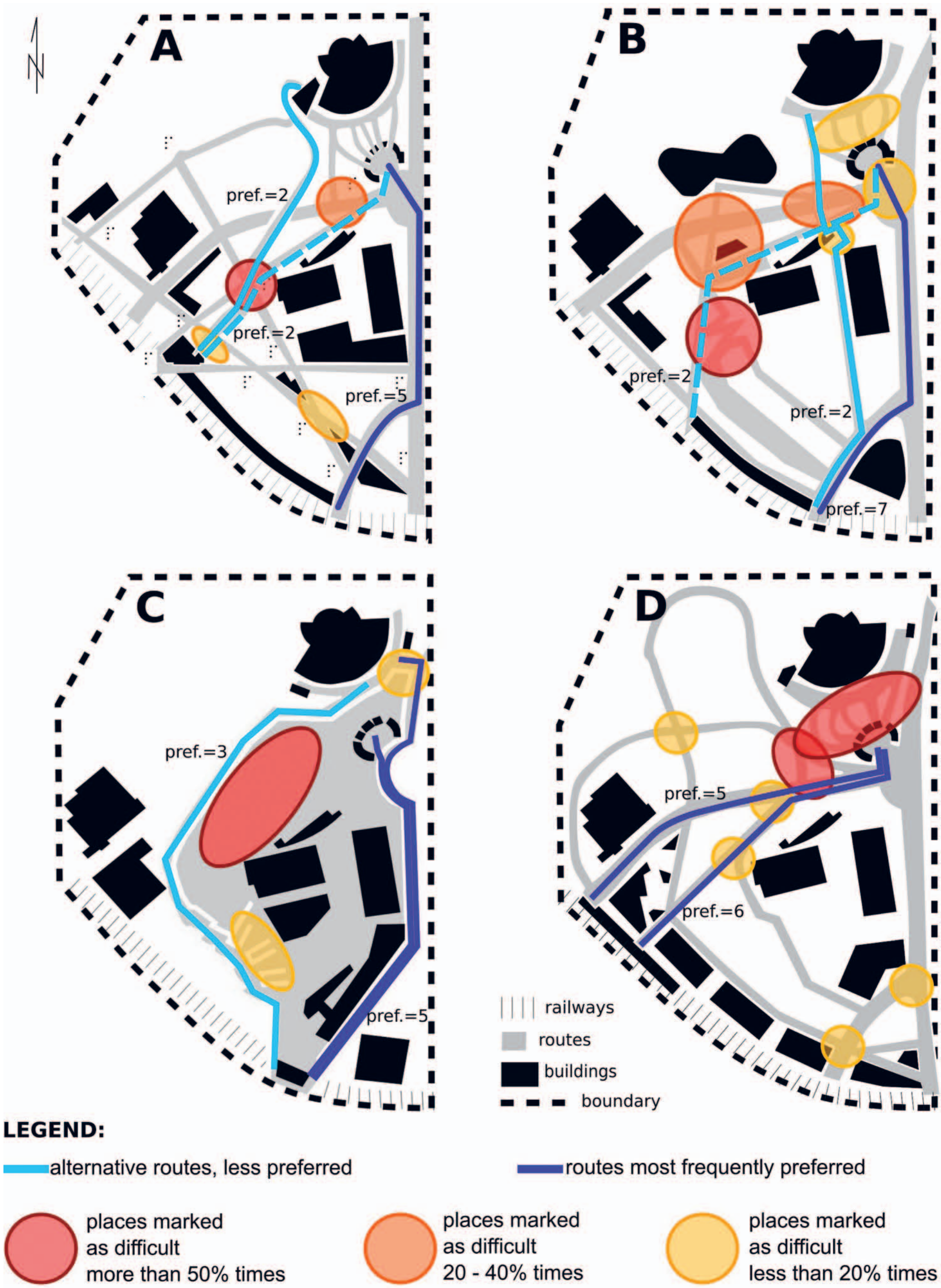

Figure 12

Maps with preferred routes and difficult places indicated by the respondents (N = 12)

The mentioned difficulties in relation to spatial orientation and illegible places affect how respondents perceived the ease of following the paths that ran across these places.

The preferred paths. Respondents indicated routes from the train station to the amphitheatre that were possible to follow and the one that they would have preferred to take.

On the most accessible map (plan B), respondents remarked that there were paths crossing at the right or the near-right angle. Opposite to these solutions was plan C with no intersections at all. However, this design was not perceived as legible enough for spatial orientation and wayfinding because of the wide-open space along the designed route (on the west side of the site plan). The preferred route was the one already existing on the site and not allowed to change in the design (along the eastern border of the map). The designed additional buildings even increased its legibility along the way and serve as orientation points.

Interestingly this route, existing on the site and not allowed to change in the design, appeared as the most legible on every design. It was indicated most frequently as the preferred one (Figure 12, indicated by the purple lines on maps).

Discussion

The experiment consisted of triangulating two research methods: a one-way experiment scheme with repeated measures and structured interviews accompanied by a mapping research technique. Although the experiment results did not significantly indicate which design solutions were more legible for blind and visually impaired people, the experiment served two roles.

First, it showed the tendencies confirmed in qualitative data. For example, the average time of looking for a preferred route and the number of attempts to show the path was slightly lower in design B. These trends align with the qualitative data showing that design B was perceived as the easiest in general. However, the experiment results as to dependent variables for map C could lead to the conclusions opposite to those yielded by in structured interviews. Referring to dependent variables: 3) time of indicating the chosen path from a train station to amphitheatre and 5) the number of errors in following the chosen path, the map C would appear as legible and easy for blind and visually impaired people, which is in opposition to the results of structured interviews. This difference in results may stem from a different context in which respondents analysed the designs. In the experiment phase, the task was to get familiar with a given design and simply show the path. Time to familiarize oneself with paths may have been shorter if there had been fewer elements and intersections of the paths.

On the other hand, the structured interviews directed the participants' attention and imagination towards how it would have been to walk and orientate oneself in given places. The interviews shifted their attention from the legibility and ease of the design (the drawing) to the legibility of a place represented by the map. Simultaneously, plan C was simpler and more accessible as a graphic and the most difficult as a place in which they were supposed to orientate themselves and navigate through. Given the obtained results, it is crucial to focus the respondents' attention, imagination, and memory on their spatial functioning rather than on the qualities of graphical representations of the environment.

The second role of the experiment was more of a procedural one. Strict and precise instructions directed at every respondent helped to control the process of familiarisation with the research materials. Giving each respondent the same precise tasks enables us to presume that they study every design with the same or similar attention. When planning design evaluation involving users, it is worthwhile to account for a precise and repetitive procedure of familiarisation with the design (as shown in the tasks concerning dependent variables) to keep a similar level of attention and focus among research participants.

The structured interviews supplemented by the mapping technique showed several issues of illegibility in evaluated designs. They were evident for the blind and visually-impaired respondents but not for the designers (students that had prepared the designs). This experiment using the students' task leave us with the main conclusion: "knowing is *not* half the battle." Santos and Gendler (2014) used this negation of a statement from the TV cartoon *G. I. Joe* to show the power of cognitive biases. In our case, the students were equipped with theoretical knowledge on blind and visually impaired people's spatial orientation. The experiment's results showed that knowing the theory about users' perception of space is not enough to prevent the design from the mistakes.

Conclusions

The article presents an approach to research legibility and coherence of space, referring these qualities to nonvisual experience. Legibility and coherence of space as qualities perceived by users are considered herein broader context than solely visual qualities that serve spatial orientation. The context of social and spatial functioning, experienced stimulation and affective appraisal of the environment serve as a theoretical basis for a comprehensive research approach to legibility and coherence, including more than one stimulus modality. Described experiments use bimodal research material to show how the nonvisual information from the environment influences legibility and coherence.

The proposed research approach (in both its methodological and theoretical scope) was motivated by the primary goal of bringing the environmental psychology research and architectural and urban design practice closer, so the findings from empirical research might serve as evaluation tools during the design process.

The directions of future research in this field seem to unfold in two ways. First, in the basic research domain, it should investigate the city's (and interior space's) image elements (analogous to Lynch's (1960) five elements) that sum up to the nonvisual dimension of legibility and coherence. The legibility and coherence concept and Gibson's affordances, and most contemporary continuations thereof refer to visual perception. Although, as shown in experimental examples, other modalities of stimuli play a role in spatial and social functioning. It would be also worthwhile to conduct empirical research using protocols that allow measuring the role of more than bimodal environmental stimuli on experiencing legibility and coherence of space.

The second path is a further development of measurement techniques that effectively introduce empirical research from the field of environmental psychology into evidence-based design procedures and verify design solutions from users' perspective. This shift to applied research introduces new challenges for researchers and design practitioners. On the one hand, research procedures need to be adjusted to design questions and the dynamic design process. On the other, from design practitioners' perspective, translating design questions into research questions requires a more thoughtful and precise link between the design solutions and users' experience. These are challenges worth taken when aiming to achieve the built environment of high quality of life.

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