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Drawing the city with the ears. Urban spaces comprehension and design through auditory perception

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Abstract

This work started from one questions: Do architects use their ears while drawing a public urban space? In other words, are we aware of how an urban space sounds, as we are aware of how it looks like?
By means of sounds recorded at night in different urban spaces and a three-session listening test, this work investigated urban shapes recognition through the perception of reverberance and the listeners' characteristics that work as factors of influence. A translations trough drawings of the sound perceived showed that is not always possible to represent a unique way to translate a sound into graphic signs.

Keywords: **soundscape; urban spaces; auditory perception**

1. Introduction

The combination of visual and non-visual information is crucial for people to understand the surrounding environment and to correctly localize themselves. Although for normal sighted people sight plays the main role into this process, important information comes from other senses. In the second part of XX century, starting from Kevin

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Lynch studies in the Fifties [1], urban planning began to move from an “only-visual” point of view to a more holistic approach that takes in account also other form of perception and of interaction between people and the environment.

Of particular interest for the purpose of this study were the researches carried out by Murray Schafer [2], who worked on the auditory perception and first introduced the concept of “Soundscape”. His experimental “Soundwalks” method was crucial for the conception of this work. Schafer, however, focused on sounds belonging to the environment which had a precise informative content (i.e. traffic noise, people chatting, etc). These sounds can be referred as “functional sounds”, i.e. sounds that give information on what is contained in a certain urban space. This research, on the opposite, aims to investigate on the shape and materials of the container rather than on its contents, and on how the shape and the materials modify the sound perception; this can be done by means of a sound emitted by the listener itself, using the echolocation, that is, as described by Schwitzgebel e Gordon [3], “the ability to detect properties of silent objects by attending to sounds reflected from them” or, as further specified by the same authors [3], “the ability to detect the reflective and reverberant characteristics of an object or an environment using sound generated in the area”.

This work can therefore be considered as a sort of follow up of previous experiments done on echolocation with normal sighted and blind people, whereas the study area has changed from objects material and shape [4] [5] [6], or indoor space [7] [8] detection, to enquiry on urban space shape and dimension. It is a preliminary study in this field that can be deepen with more rigorous measurements and with an enlarged sample of tested people, starting from its promising results.

2. The experiment

2.1. Test stimuli

A three-sessions test was developed, in order to have a set of recordings that included a variety of urban spaces of different typologies and shapes, with different reverberation times. Each session included selected parts of three long “soundwalks” recorded in San Salvario neighborhood in Turin (along via Madama Cristina, via Baretti and corso Marconi). The set of recording tools consisted in a pair of Roland CS-10EM binaural headphones and a Roland R09 DAT.

A “clapper”, a pair of wooden boards hinged together generating impulsive signals, was used as sound source. The operator, who wore shoes with soft sole (i.e. ‘sneakers’) in order to limit the noise generated by his own steps, played the clapper during the walk, at about 2 seconds intervals, and recorded the sound through the binaural earphones while walking. Impulsive sounds were recorded at night, as no other sound sources had to be present. The city at night is deprived of its characteristic soundscape and reduced to pure three-dimensional space where it is possible to catch the effect of the shape of the space on the recorded sound.

2.2. Test submission

Recordings were presented to some testers through a pair of Sony MDR-EX10BK in-ear headphones in a quiet, “neutral” indoor environment. Contrary to “typical” soundwalks, where the subjects listen to the full soundscape along the inquired space, the auditory stimulus in this test was therefore free from other sounds that could have influenced the space perception. Moreover, as subjects did not walk through such spaces, their answer could not be influenced by haptic stimulus or other sensorial stimulus. The group of subjects was composed by 32 university students of architecture, 12 architects and 28 people who don’t deal with architecture. These selection was made in order to understand whether an urban design background at different levels could imply a better distinguishing among sounds generated by different shapes. The full sample varied also in age and musical education. In particular, test results were analyzed separately for under 30, 30-50, over 50 years old people and people with no musical training, with 1 to 5 years of musical training and over 5 years of musical training.

The same test was then submitted to a small sample of 14 blind and partially-sighted people, aiming to investigate how previous experiences in spaced detection through self-emitted sounds and partially or totally missing visual information could have influenced subjects' performance. The sample was composed by 7 born blind people, 4 born partially-sighted people and 3 late blind people.

2.3. Test structure

Part 1 of the test dealt with different typologies of urban spaces, presenting the tester 6 seconds recordings in squares and streets of different sizes. In this part subjects were asked to correctly match a set of 3 sounds with a set of 3 urban spaces. Part 2 focused on the transition from one space typology to another, presenting the testers 10 seconds recordings, corresponding to walking passages through different space typology (e.g from a street to a square). In this part, two kinds of sound-space matching were proposed: the first type (matching 2A and 2B) presents a set of three sounds together with a set of four possible space variations, while the second type (matching 2C and 2D) is a two-alternative forced choice where subjects listen to only one sound at a time and are requested to match it to one of the two possible space variations. Fig. 1 shows a sample of the questions presented to the testers in both parts.

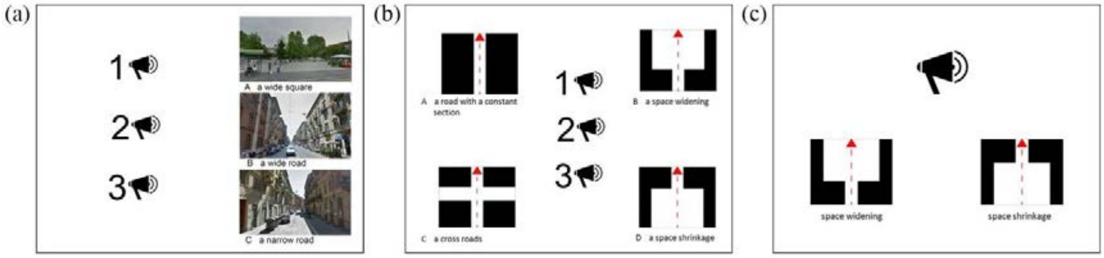

Fig. 1. (a) example of question in Part 1; (b),(c) examples of questions in Part 2

These first two sessions acted as preliminary sessions for the third one (Part 3), where people were asked to listen to a complete soundwalk and to redraw the space where such soundwalk was registered.

The three parts of the test were preceded by a training phase where people had to order 6 impulsive sounds with respect to their perceived reverberance. Also the cases of two extreme situations were produced, in which the sounds were recorded in six different urban spaces and in a semi-anechoic and reverberant chambers. The aim was to give clear acoustic references about the sound produced by the source in case of very low and very high reverberation.

3. **Results**

3.1. Part 1 and 2

Results of the preliminary training phase showed that subjects were able to correctly perceive variations in reverberation, placing the large squares over the higher grades of the scale, corresponding to greater reverberation, and the narrow streets in correspondence to the lowest grades.

Table 1 shows the percentages of answers corresponding to the different urban space-sound matching related to Part 1. The small square was recognized by 50% of subjects, while the other two squares turned out to be less recognizable (they were confused in about 40% of cases, both for wide square and covered square). In the case of streets the percentage of correct answers did not reach 30% in any case. In the case of mixing between streets and the wide square, the square was correctly identified in 75% of cases.

Table 2 shows the percentages of answers corresponding to the different walking transitions from one space typology to another, related to Part 2. More than 50% of subjects correctly recognized the absence of space variations, while the performances decreased in the recognitions of transition between different spaces, especially in matching 2c and 2d, where the percentage of correct answer was not significantly higher than the threshold of 50%.

To determine whether the participants’ performance was above chance, a t-test was performed for each matching, comparing the number of correct answers to the value of chance choice accuracy. The null hypotheses in this case is H_0: the mean value of the correct answers is equal to chance choice accuracy value. Results showed that only for matching 1c and 2a the participants’ performance was significantly above chance at a confidence level of 95% ($p<0.05$): (1A: t=0.936 p=0.22; 1B: t=-6.05 p= 0.002; 1C: t=3.05 **p=0.046**; 2A: t=3.98 **p=0.028**; 2B: t=2.61 p= 0.060 ; 2C : t=0.2 p=0.437 ; 2D : t=1.67 p=0.172).

Table 1. Part 1: percentages of answers corresponding to the different urban space-sound matching. Correct answers are written in bold. Wide square is a rectangular 30000 m^2 square, covered square is a rectangular 6000 m^2 square covered on one-half with an about 4 m high steel roofing, small square is a octagonal 2000 m^2 square. Narrow street is 10.5 m wide with surrounded by buildings of around 15 m average height, wide street is 18 m wide surrounded by buildings of around 15 m average height,, avenue is 42 m wide surrounded by buildings of around 20 m average height. Correct answers are written in bold.

Matching 1A - squares

sample	choice		
	wide square	covered square	small square
wide square	**40.3**	43.1	18.1
covered square	38.9	**27.8**	31.9
small square	20.8	29.2	**50.0**

Matching 1B – streets

sample	Choice		
	narrow street	avenue	wide street
narrow street	**23.6**	26.4	50.0
avenue	48.6	**27.8**	23.6
wide street	27.8	45.8	**26.4**

Matching 1C- mix

sample	choice		
	wide street	narrow street	wide square
wide street	**45.8**	37.5	16.7
narrow street	37.5	**54.2**	8.3
wide square	16.7	8.3	**75.0**

Table 2. Part 2: percentages of answers corresponding to the different walking transitions from one space typology to another. Correct answers are written in bold.

Matching 2A

sample	choice			
	no variation	widening	narrowing	cross roads
no variation	**54.2**	12.5	12.5	20.8
widening	12.5	**38.9**	26.4	22.2
narrowing	12.5	38.9	**40.3**	8.3

Matching 2B

sample	choice			
	no variation	side street	cross roads	widening
no variation	**54.2**	15.3	9.7	20.8
side street	9.7	**37.5**	31.9	20.8
cross roads	12.5	23.6	**33.3**	30.5

Matching 2C

sample	choice	
	widening	narrowing
widening	**47.2**	52.8
narrowing	45.8	**54.2**

Matching 2D

sample	choice	
	cross roads	side street
side street	48.6	**51.4**
cross roads	**55.6**	44.4

A one-way analysis of variance (ANOVA) test revealed that age and education in architecture (that is, being an architect or a student of architecture or non of those two) have no influence on subjects’ performance, while musical training has an influence expecially in Part 2, as shown in Table 3. A post-hoc Bonferroni [9] test showed that the sample of people with at least 6 years of musical training has a mean of correct answers significantly higher than the ones with no musical training (Table 4). All the statistics analysis presented in this article were performed with IBM SPSS Statistics software.

Table 3. ANOVA test on results classified by subjects' age, educational field and musical training. P-values which are lower than α (=0.05) are written in bold.

	Age		Education field		Musical training	
	F(2, 69)	p	F(2, 69)	p	F(2, 69)	p
Part 1	0.340	0.713	0.115	0.892	2.888	0.062
Part 2	0.026	0.974	0.750	0.476	4.367	**0.016**

Table 4. Bonferroni test on results classified by subjects' musical training (0 = no training, 1= 1 to 5 years of training, 2 => 5years of training). P-values which are lower than α (=0.05) are written in bold.

Part 1			Part 2		
	Means difference	p		Means difference	P
0-1	0.1560	1.00	0-1	-1.3528	0.179
0-2	-1.3568	0.076	0-2	-1.7823	**0.034**
1-2	-1.5128	0.151	1-2	-0.4295	1.00

3.2. Test with blind subjects

Regarding the preliminary phase of positioning of sounds over a scale of reverberation, results were close to those of the normal sighted persons. A t-test was performed on the two groups of sighted and blind or partially sighted subjects, considering the sum of correct answers of each individual in both groups. Results proved that the mean of correct answers of visually disabled people is significantly higher than the one of normal sighted subjects, hence confirming results found on previous echolocation studies [5]. Moreover, a one-way ANOVA test investigated the possible role of visual information, by comparing results of born blind, partially sighted and late blind people. Outputs of this test (Part 1: F(2,12)=3.772, p=0.057; Part 2: F(2,12)= 0.513, p=0.612) showed no significant differences among groups. Samples in this case are however very small and therefore too influenced by a single person performance to be significant and further investigations may be conducted.

3.3. Part 3

In Part 3 a complete recording of the soundwalk along via Baretti was presented to the testers, as it contained a good variety of urban spaces they already met in Part 1 and Part 2 of the experiment.

In a process which can recall the work by Kevin Lynch on mnemonic images of the city, all the signs used to draw the listened soundwalk were compared and analyzed in order to build up a set of symbols. Such symbols, like letters in an alphabet, constitute the code which people use to express an hypothetically limitless number of different sentences (a concept developed by generative grammar), which are, in this case, the description of a space. While Lynch studies a space that can be called "cognitive space", based on memory, in this case we can speak of a "perceptive space", as it is generated by a sound, which is a perceptive stimulus.

Symbols were derived from the spaces investigated in Part 1 ("elements") and in Part 2 ("connections" and "variations") and are presented in Figure 2. A necessary simplification has been made in presuming that subjects are perfect "transcribers", whose drawing is not affected by variables such as personal experiences or state of mind. In this way, through a classification of drawn shapes we can assume to classify mental images that the sound generates into listeners and identify similarities, variations and recurring rules.

Results of this part showed no significant differences among group of subjects by age, educational field or musical training. Moreover, no one of the interviewed subjects redrew all the walks correctly. Drawings analysis indeed confirms results of Part 1 and 2, showing that more than 70% of people recognize the presence of the square in the first half of the walk, distinguishing it from the narrow street which precedes and follows it, while no significant number of subjects correctly identified the crossroad. Moreover, only four people drew a space with only 2 variations (the square and another space variation), while all the other subjects reported a much complex space than the real one, adding a variable number of additional variations.

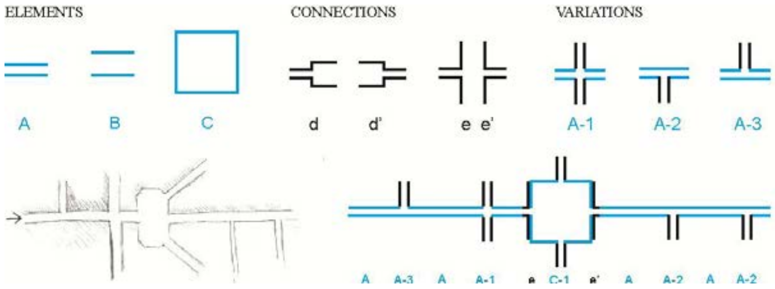

Fig. 2. Symbols derived from Part 1 and Part 2 of the experiment and example of drawing with its translation.

4. Conclusions

This work allows to draw some conclusions about our auditory perception of spaces. Among them, the fact that people perceived the differences in sound reverberation, but generally were not able to link such variation to the related spatial transformation. Moreover, drawings translations showed that is not possible to deduce a unique way of translating a sound into signs. Although some elements were generally recognized, they were represented with different kind of sequences (e. g.: the square can be e-C-e' or d-d-C-d-d'). In further studies it could be interesting, for instance, to investigate how different shapes of squares are perceived. Background in urban planning did not affect results, that is to say, education in architecture does not "educate" our ears to recognize spaces. Going back to the first posed question, the answer is that architects generally do not use their ears while drawing a space.

Far from presuming to be exhaustive, such conclusions can however be the first step of a method to translate an intangible way of perceiving and living our urban spaces into an objective language which can give us new perspective for the design of future urban spaces: a design not only driven by the visual esthetic but also, as wished by researchers like J.D. Porteus [10], by the multisensoriality which direct experiences of spaces entail.

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