Soundscape pleasantness in urban places: dimensions and relation with health aspects

Karmele Herranz-Pascual[1], Igone Garcia[1], Itziar Aspuru[1]

[1] Tecnalia Research and Innovation, Energy and Environment Division, Derio, Bizkaia, Spain

Corresponding author's e-mail address: itziar.aspuru@tecnalia.com

ABSTRACT

The aim of this paper is to present results in terms of effects on perceived health obtained in a research about soundscape pleasantness. Main conceptual framework has been the Environmental Experience Model and the ISO of Soundscape. This work was undertaken as part of the CITI-SENSE project. 55 people were engaged to provide 153 observations in the city of Vitoria-Gasteiz in four urban places. The soundscape was evaluated using a Semantic Differential scale of five points. Results indicated that the principal component of soundscape, named tranquility and pleasantness, is inversely related to perceived stress of people assessing the urban spaces. Other important aspects are the ability of sound environment to be fun, its congruence with the landscape, as well as the natural content of the sounds. This study reinforces the interest of designing urban spaces adapted to the environment characteristics and to the people using them. This can be made facilitating direct participation of citizens that use the analysed spaces. Nevertheless, further research and experiences are needed to better understand positive effects of soundscape at public spaces in health.

INTRODUCTION

The overall aim of this paper is to present results in terms of effects on perceived health obtained in a research about soundscape pleasantness. Our main conceptual framework has been the ISO of Soundscape and the Environmental Experience Model.

In relation to Soundscape, its key principles [1–5] have been developed within the ISO 12913 standard, with regard to its definition and conceptual framework [1], as well as data collection [6]. According to this standard, soundscape is “the acoustic environment as perceived or experienced and/or understood by a person or people in context”. In other words, soundscape is defined as the way people perceive, experience, or understand the acoustic environment in a physical setting. Therefore, acoustic environment refers to physical phenomena, while soundscape is a perceptual construct [7].

In every environment-person relationship, a set of psychological and physiological mechanisms are triggered enabling us to understand the effects on health on people enjoying environment and to gather and obtain information about the place. The sensations received are integrated into content and meaning units that enable us to recognize, compare or explore the environment. We experience sensations and emotions and we act accordingly by integrating personal motivations and interests. We appreciate environmental characteristics and social content arising from the place. In short, we have an environmental experience.

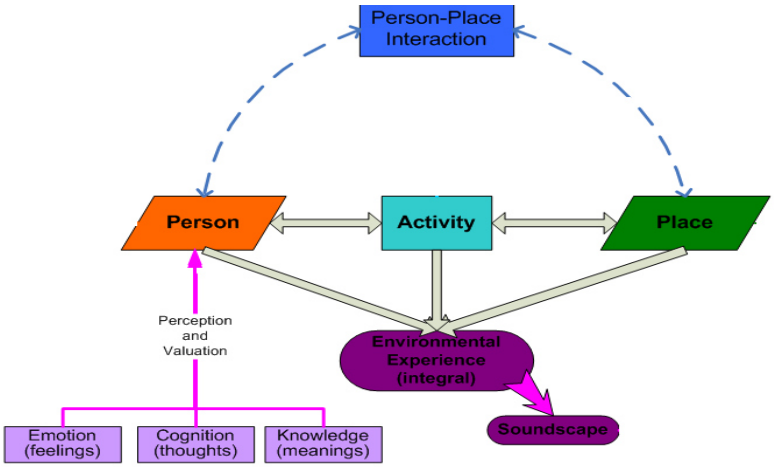

Figure 1: Conceptual model (summarized) of environmental experience for studying soundscape, from Herranz-Pascual et al. [8]

This model [8] combines a review of the latest research related to soundscape and Tecnalia's experience in psychosocial perception and assessment studies of urban environments (noise, urban thermal comfort, odour, soundscape, etc.). The first conclusion of this review is that the factors for studying soundscapes can be grouped into three main categories: context, person, and activities [9]. However, in order to include relevant interactions and increase clarity and simplicity (i.e., parsimony), our model is organised into five dimensions: person, place, person-place interaction, activity, and the environmental experience itself (see Figure 1). This conceptual framework will be used to identify the parameters that influence the soundscape in urban public spaces.

As the soundscape concept deals with the perception of acoustic environments by communities [10], perception is usually evaluated by collecting people's perception via questionnaires (either distributing them physically or by means of ICT tools) to understand how citizens perceive urban spaces. Questionnaires include semantic scales with descriptions of the acoustic environments [3], and questions about the pleasantness of sound sources [11]. So, it has been recognised that the public must participate in the soundscape evaluation process [12]. In published studies, the information had to be post-processed in order facilitate interpretation and make the data useful for research and for decision-making purposes. Other studies identified three components of soundscape that explain the most significant part of the variance: pleasantness, eventfulness, and familiarity [13]. Also, there is increasing evidence that the congruence between the different elements of a place is important in human preference [14], and also that these elements influence the expectations of the place [7].

Considering this framework, this paper aims to identify the dimensions that most influence soundscape pleasantness, considered here to be a global indicator of acoustic comfort, one dimension of urban comfort understood as the ability of an urban space to create a pleasant environmental experience for the people who use it, contributing to the population's health.

To know how soundscape influences health, the relationship between soundscape and perceived health is also analysed. The meaning of health is holistic, according to the definition of WHO: health is a biopsychosocial state, that is, a state of complete physical, mental and social well-being, which is subsequently added, in harmony with the environment

The ultimate goal of this research is to contribute to the understanding of how an urban soundscape can create a pleasant environmental experience (acoustic and urban comfort) for the people who use it, contributing to population's overall well-being and health.

The analytical method used is presented in the following section.

METHODOLOGY

The method applied in this paper is based on the use of a tool that allows citizens to make on-site acoustic comfort assessments by simultaneously collecting objective and subjective measurements. The tool was developed by Tecnalia in the framework of the CITI-SENSE EU project. The overarching intention of this project is to develop "citizens' observatories" (CO) designed to empower citizens to contribute to and participate in environmental governance and enable them to support and influence community and societal priorities and the associated decision making [15, 16]. The CITI-SENSE project is based on three fundamental concepts: technological platforms for distributed monitoring, information and communication technologies (ICT), and societal involvement. The COs are intended to promote the citizens' contributions as active participation in environmental governance [17, 18].

In this project Tecnalia has designed a tool to assess acoustic comfort based on a kit and protocol to measure sound levels and evaluate perception (using an embedded questionnaire that is filled in at the same time the measurement is recorded). The kit provides easily-interpretable data by combining the results of the two approaches (objective and subjective measurements) [19]. The data collection method corresponds roughly to that described in ISO 12913:2 on soundscape, which is still in draft form [6].

The kit developed for making observations of urban comfort in the CITI-SENSE project involves the use of a smartphone [20] (with an internal service that allows it to act as a sonometer), as well as an external microphone protected with a wind screen, since the mobile's internal one has certain restrictions with regard to taking acoustic measurements outdoors (see Figure 2).

Previous papers [21, 22] provided details of the methods and tools used for empowering citizens in the assessment of acoustic comfort in outdoor public spaces, analysing the accuracy of the values measured.

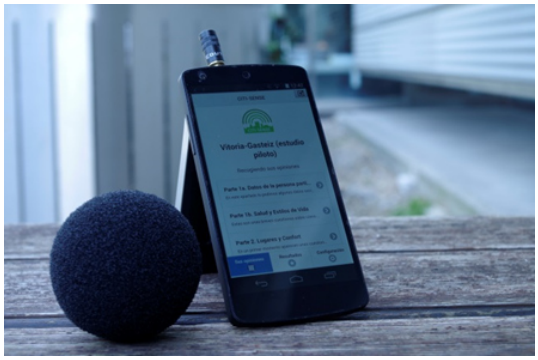

Figure 2: The CITI SENSE kit for the observations

One of the most interesting aspects of this method for the purposes of this paper is the questionnaire designed to assess acoustic urban comfort that is deployed via the app.

Questionnaire

The questionnaire applied in the CITI-SENSE project collects information from 100 variables. Those most relevant for the objectives of this article are the following:

1. General questions related with perceived health: perception of stress.
2. Sound environment perception or soundscape: participants are asked about their perception and evaluation of the environmental sounds and the global acoustic atmosphere, as well as their evaluation of the congruence of the sounds with the urban place. The soundscape is evaluated using a SD [23] that contains items such as: pleasant, calm, relaxing, natural, vibrant, informative, and clear (5 point scale). The wording of this scale is: Now, could you describe the sound environment from your point of view (using pairs of adjectives)? Value 1 means pleasant, 5 means unpleasant and 3 means neither.

Case study

As part of the CITI-SENSE project, a demonstrative exercise was carried out in the city of Vitoria-Gasteiz (Spain), consisting of inviting citizens to conduct observations on the quality of four public spaces using the tool designed for collecting environmental data and also their perceptions of nine areas in those spaces. The urban spaces which were evaluated are (Figure 3):

- Calle Los Herran (bus station area): the city's central bus station was previously located in this space. The area is surrounded by high traffic flow roads and is close to a school.
- Parque Salinillas de Buradón: this park is situated in a new urban area and is on a small hill, close to the city's green belt. At the moment when the park was assessed, it had no vegetation.
- Plaza de la Constitución: this public space is situated next to the northern entrance to the city. To the left of the square is a relatively green, calm street.
- Parque Olarizu: the park is part of the city's green belt and the Environmental Research Centre (CEA) is located here, which receives thousands of visitors during the year. Some of those visitors spend the day in the surrounding area.

Two of the spaces have urban characteristics (Los Herran and Constitución) and other two are more natural (Salinillas and Olarizu).

In each space, two separate areas were assigned, with the exception of Los Herran where three different areas were identified, as can be seen in Figure 3. In total nine areas were considered (represented by nine evaluation points).

The nine areas display a great deal of homogeneity in terms of maintenance, which is generally high, of presence of water, landmarks and heritage. But there are differences in other characteristics, such as: the existence of facilities, of traffic, economic activity, trees and green areas, and also there is variability in the degree of artificiality, as well as the openness of the place.

Figure 3: Pictures of the four spaces, indicating the evaluation points (areas)

It can be said that the set of selected places reflects types of public places that can we can find in our cities.

Procedure and sample [24]

Participants were volunteers recruited from among the citizens of the city of Vitoria-Gasteiz, either through their participation in civic associations or by direct contact. 54 volunteers assisted to an initial workshop. In this workshop the project was introduced and participants received specific information about the tasks they would be asked to carry out relating to the observation of urban places. 55 people were ultimately engaged to make field observations in the four urban spaces selected in the city. They made a total of 153 observations (120 valid), and each participant evaluated at least two sites. During the observations, 104 photos were taken and participants uploaded 215 feedback comments on their preferences (i.e., 139 positive “most liked elements” and 76 negative “most disliked elements”). Since the observational procedure is both crucial and complex, in order to assure that it is applied correctly during the demonstrative exercise, the participants were accompanied by members of the project team who guided them.

The observations in the four urban spaces were made from 17 to 30 April, 2015, being scheduled according to the participants’ availability. Experiences were collected, typically, at the hours places are most used, that is, between 10:00 and 13:00 in the morning and between 17:00 and 20:00 in the afternoon. The average duration of experiences was 12.45 minutes (SD = 6.76), with no significant differences between places.

There are no relevant social or demographic differences between the people observing each of the four spaces. Most of the differences between them are considered non-significant. Therefore, we can analyse it as a single sample.

RESULTS

Results presented in this chapter are structured into 3 parts. The first details the descriptive results. The second part involves a factorial analysis to define the main dimensions of soundscape. Finally, other analyses were conducted in order to understand how the soundscape in urban places is related with perceived health.

Descriptive Results

In relation to the health variables (Table 1), we can say that the level of stress perceived in the month before the experience (Stress_Time1) is medium-low (mean = 2.54), and it is low (mean = 2.04) at the end of the experience (Stress_Time2). That is, the environmental experience evaluated has led to a slight reduction of stress (Strees_Diff). The evaluation was made with a 5 point scale was used and value 1 means very low, 5 means very high and 3 means neither.

Table 1: Descriptive results

Health	**N**	**Min**	**Max**	**Mean**	**SD**
Health (perceived)	137	3	5	4.05	.700
Strees_Time1	137	1	4	2.54	1.029
Strees_Time2	137	1	4	2.04	.894
Strees_Diff (T2-T1)	137	-3.00	2.00	-.5036	1.08549
Soundscape	**N**	**Min**	**Max**	**Mean**	**SD**
Pleasant	137	1	5	3.03	1.218
Quiet	137	1	5	2.94	1.282
Relaxing	137	1	5	3.26	1.100
Continuous	137	1	5	3.61	.933
Family	137	1	5	3.91	.935
Facilitates conversation	137	1	5	3.40	1.067
Informative	137	1	5	2.92	.932
Clear	137	1	5	3.34	1.087
Characteristic	137	1	5	3.05	1.250
Vibrant	137	1	5	2.91	1.039
Funny	137	1	5	2.93	1.034
Natural	137	1	5	2.96	1.393
Very appropriate	137	1	5	3.58	1.048

In the following figure (Figure 4) the descriptive results of soundscape are shown, where it is observed that the majority of sound environments are perceived moderately in the list of pairs of adjectives of the scale. The best-valued aspects are familiarity, continuity and congruence (appropriate).

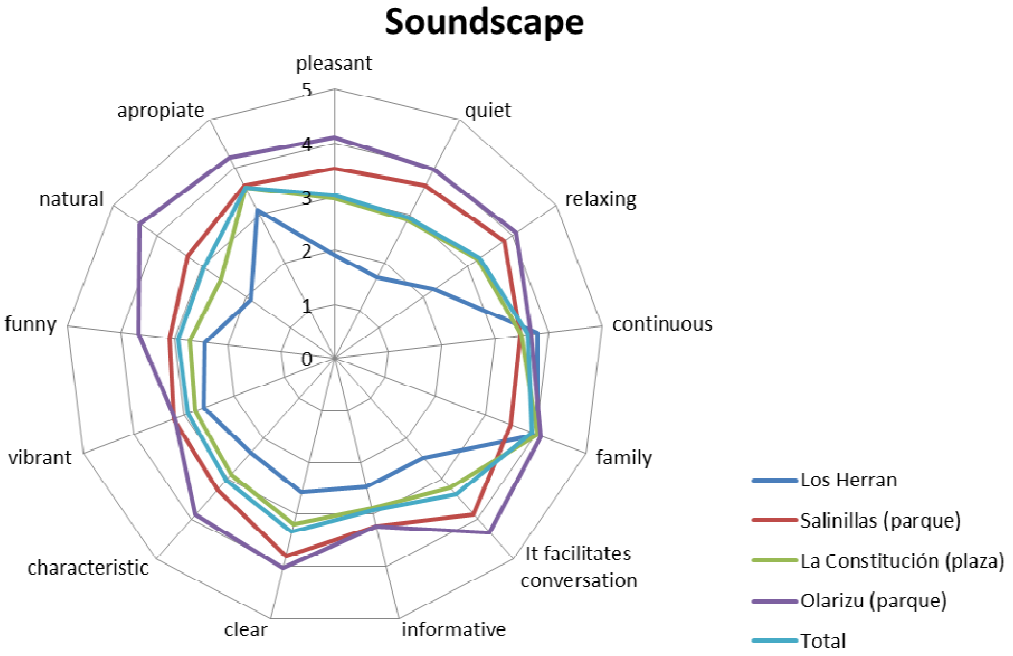

Figure 4: Descriptive results on Soundscape Semantic Differential in global and the four different places of Vitoria-Gasteiz

Soundscape dimensions

In order to analyse the main dimensions of the soundscape, we used the analysis of principle components, taking all the data of the sample. The thirteen items of the scale were initially included in the analysis. Given that some of them had low communality (items referred to the quality of the place of being *Characteristic* and of being *Appropriate*) or that they distributed their weights by more than one factor (items referred to the quality of the place of being *Informative,* being *Vibrant, Funny,* and being *Natural*), these 6 items were excluded from this analysis and were introduced as independent variables in later analyses.

Therefore, the factorial analysis was carried out with the remaining seven items, which have a commonality of 0.7 or higher. The analysis of principal components draws two factors that explain 76% of the variability of the seven items. The first one that explains the 57.6% variance represents the **tranquillity and pleasantness** of the soundscape and is formed by the items relative to its characteristics of *Quiet, Pleasant, Relaxing, Facilities Conversation* and *Clear*. The second - which explains 18.7% of the variance, reflects the **familiarity of the soundscape** and groups the items relative to the soundscape features of *Familiar* and *Continue*.

Table 2: Results of Factorial Analysis (PCA) of Soundscape

Component Matrix

	Component	
	1	2
Relaxing	.935	
Pleasant	.922	
Quiet	.917	
Facilitates conversation	.857	
Clear	.855	
Continuous		.812
Familiar		.784

Soundscape and health

It is interpreted that factor found as the principal one, the one that refers to the **tranquillity and pleasantness of the soundscape**, is representative of the positive effect of the sound environment in people.

When analysing the relations between the soundscape and the health variables considered in this work it is observed (Table 3) that:

- The stress expressed at the end of the environmental experience (Strees_Time2) is inversely related to the principal component of the soundscape of **pleasantness and tranquillity** ($r = -0.3$; $p < 0.01$). Therefore, the greater the tranquillity and pleasantness perceived in the place, the less stress is manifested at the end of the environmental experience.

Thus, the ability of soundscape to positively affect health has been reflected.

Table 3: Significant Correlation between soundscape dimensions and health variables

	Strees_Time1	Strees_Time2	Strees_Diff.
Component of Pleasantness and tranquillity	---	-0.280**	---
Component of Familiarity	---	---	---
Informative	---	---	---
Characteristic	---	---	---
Vibrant	-0.258**		0.273**
Funny	-0.177*	-0.228**	---
Natural	-0.178*	-0.188*	---
Appropriate	---	---	-0.228**

* P<0.05; **p<0.01

In order to analyse the characteristics of the soundscape that explain the pleasantness with the soundscape, that is to say the acoustic comfort associated to the existing sound environment in urban spaces, a regression analysis (stepwise) was carried out with the other 6 characteristics of the soundscape that were excluded from the previous analysis.

In this analysis we conclude that the characteristics of soundscape that contribute significantly to explain its pleasantness are four: its naturalness, its congruence with the landscape, its differentiation and how much fun it is (*Natural, Appropriate, Characteristic* and *Funny*). Together these four characteristics explain 60% of the pleasantness and tranquillity with which a sound environment is perceived ($F(4.132) = 52.110$; $p < 0.001$).

Finally, we analyse the relations between the measured characteristics of the soundscape and the perceived stress (Table 3) and it is observed that:

- The characteristics of the soundscape that are related to the stress perceived at the beginning of the environmental experience and also to the stress they manifest in the end of the experience are: *Pleasant, Vibrant, Funny* and *Natural*.
- This relationship is the inverse. That is, the higher the initial or final stress less vibrant, funny and natural is considered the soundscape.

DISCUSSION AND CONCLUSIONS

The quality of soundscape in public spaces, as we enjoy them, influences our health. The study has focused on perceived stress. Previous work has also shown that the quality of soundscape influences the ability to recover from stress [25].

This study has shown that the pleasantness and tranquillity of the soundscape are related to a lower level of perceived stress. Therefore, the study of how these characteristics of soundscape can be enhanced could provide criteria to make public spaces that have a restorative function of stress and that contribute to the health of the population.

In this sense the characteristics of the soundscape that should be enhanced are: its natural component; how fun it is; being congruent with the landscape (appropriate); and unique (characteristic).

This contributes to conceive the design of public spaces as looking for their uniqueness, as design should be adapted to each space, thought as idiosyncratic, and congruent with the landscape, and considering the cultural dimension of the people who use trying to make spaces fun for them. In addition, the importance of the perception of nature in our public spaces is clear, which is in line with other positive effects of the presence of natural elements in our cities (effects of contact with nature and policies for building nature based solutions).

In this sense, Tecnalia has proposed the concept of Comfort Urban Places (CUP) to reinforce the importance of spaces that are adapted to the environmental characteristics of their environment and to the expectations of the people who use them. CUP includes indicators and methodologies to carry out environmental comfort assessments to be incorporated into urban design or management strategies for public places.

This study reinforces the interest of quantifying indicators and objective data about comfort, obtained with the direct participation of citizens that uses the analysed spaces, since they are the real experts. The aim of this approach is twofold; First, to enrich evaluations by directly linking individual perceptions of a space with objective data related to the time of a specific inspection, and second, to promote a more participative framework that empowers the public in urban design processes.

In addition, Information and Communication Technology (ICT) tools can facilitate and improve the process of quantifying the indicators of environmental comfort in urban spaces. TECNALIA has developed a downloadable app (Citizensor) that works on any personal smartphone to enable members of the public to conduct environmental comfort assessments. The app guides the entire observation protocol and measures acoustic comfort. There is a verification procedure for the values measured by the smartphone. Other objective variables are accessed by the app from open data on established monitoring networks.

Acoustic comfort is one dimension of urban comfort, understood as the ability of an urban space to create a pleasant environmental experience for the people who use it, contributing to the population's general health. Nevertheless, to understand the contribution of urban soundscape pleasantness to the welfare and health of people and communities it is necessary to further explore the effects of acoustic comfort.

Acknowledgements

This research was supported by the CITI-SENSE EU project. The authors would like to thank partners in the project, especially project leader Alena Bartonova and colleagues from NILU, U-Hopper and Sintef, who participated in the development of the smartphone app. Special thanks, go to our colleagues at Iritziak Batuz, who conducted the participant recruitment for the demonstration exercise.

REFERENCES

[1]. ISO 12913:1:2014 Acoustics—Soundscape—Part 1: Definition and Conceptual Framework; International Association for Standardization: Geneva, Switzerland, 2014.

[2]. Botteldooren, D.; Andringa, T.; Aspuru, I.; Brown, L.; Dubois, D.; Guastavino, C.; Lavandier, C.; Nilsson, M.; Preis, A. Soundscape of European Cities and Landscape: Understanding and Exchanging. In Proceedings of the COST TD0804 Final conference: Soundscape of European Cities and Landscapes, Soundscape-COST, Merano, Italy, 22 March 2013; pp. 36–43.

[3]. Kang, J.; Schulte-Fortkamp, B. Soundscape and the Built Environment; CRC Press, Taylor & Francis Group: Boca Raton, FL, USA, 2016. Appl. Sci. 2017, 7, 173 17 of 18

[4]. Kang, J.; Aletta, F.; Gjestland, T.T.; Brown, L.A.; Botteldooren, D.; Schulte-Fortkamp, B.; Lercher, P.; van Kamp, I.; Genuit, K.; Fiebig, A.; et al. Ten questions on the soundscapes of the built environment. Build. Environ. 2016, 108, 284–294. [CrossRef]

[5]. Brown, L.A. A review of progress in soundscapes and an approach to soundscape planning. Int. J. Acoust. Vib. 2012, 17, 73–81. [CrossRef]

[6]. ISO 12913:2:2016 Acoustics—Soundscape—Part 2: Data Collection (Under Development); International Association for Standardization: Geneva, Switzerland, 2016.

[7]. Brown, L.; Gjestland, T.; Dubois, D. Acoustic Environments and Soundscapes. In Soundscape and the Built Environment; Kang, J., Schulte-Fortkamp, B., Eds.; CRC Press, Taylor & Francis Group: Boca Raton, FL, USA, 2016; pp. 1–17.

[8].Herranz-Pascual, K.; Aspuru, I.; García, I. Proposed Conceptual Model of Environmental Experience as Framework to Study the Soundscape. Proceedings of Internoise, Lisbon, 2010.

[9]. P. Lercher, B. Shulte-Fortkamp, The relevance of soundscape research to the assessment of noise annoyance at the community level of the community, I: Proceedings of the ICBEN 8th International Congress On Noise As A Public Health Problem, Rotterdam, The Netherlands, 2003.

[10] W. Yang, J. Kang, Acoustic Comfort Evaluation in Urban Open Public Spaces, Applied Acoustics 66 (2005), 211–229.

[11] D. Dubois, C. Guastavino, M. Raimbault, A Cognitive Approach to Urban Soundscapes: Using Verbal Data to Access Everyday Life Auditory Categories, Acta Acustica 92 (2006), 865 – 874.

[12] C. Lavandier, P. Delaitre, C. Ribeiro, Global and local sound quality indicators for urban context based on perceptive and acoustic variables, I: Proceedings of the Euronoise 2015, Maastricht (2015).

[13] O. Axelsson, et al., A principal components model of soundscape perception, J. Acoust. Soc. Am. 128 (2010), 2836–2846

[14] G. Brambilla, L. Maffei, Responses to noise in urban parks and in rural quiet areas. Acta Acustica united with Acustica 92(6) (2006), 881–886.

[15] M. Kobernus, et al., A practical approach to an integrated citizens' observatory: The CITI-SENSE framework, I: Proceedings of the Workshop 'Environmental Information Systems and Services - Infrastructures and Platforms 2013' (ENVIP 2013). Neusiedl am See, Austria, October 10, 2013. Red.: Berre, A.J., Schade, S. (CEUR Workshop Proceedings, 1322).

[16] I. Aspuru, J.A. Acero, M. Gonzalez, Apps to encourage Citizen environmental participation in public space strategy and policy making, Smart City Expo World Congress 2014 Barcelona (2014).

[17] Global citizen observatory - The role of individuals in observing and understanding our changing world (European Environment Agency, 2009): http://www.eea.europa. eu/pressroom/speeches/global-citizen-observatory-the-role-of-individuals-in-observing-and-understanding-our-changing-world

[18] M. Engelken-Jorge, J. Moreno, H. Keune, W. Verheyden, A. Bartonova, CITI-SENSE consortium, Developing Citizens' Observatories for Environmental Monitoring and Citizen Empowerment: Challenges and Future Scenarios, I: Proceedings of the International Conference for E-Democracy and Open Government (CeDEM14). Danube University Krems, Austria, May 21-23, 2014. Editors: Peter Parycek, Noella Edelmann, pp. 49-61.

[19] J. Fogola, S. Masera, V. Bevacqua, Smartphone as a noise level meter? Proceedings of the ICSV 22, Florence, July, 2015.

[20] K. Herranz-Pascual, L. Gutiérrez, J.A. Acero, I. García, A. Santander, I. Aspuru, Environmental comfort as criteria for designing urban places, Architecture, Education and Society (4-6 June 2014, Barcelona).

[21] I. Aspuru, I. García, K. Herranz-Pascual, A. Santander, CITI-SENSE: methods and tools for empowering citizens to observe acoustic comfort in outdoor public spaces, Noise Mapp 3 (2016), 37–48.

[22] K. Herranz-Pascual, I. García, I. Aspuru, I. Diez, Progress in the understanding of soundscape: objective variables and objectifiable criteria that predict acoustic comfort in urban places, Noise Mapp 3 (2016), 247–263.

[23] C. Osgood, G. Suci, G. and Tannenbaum, The measurement of meaning. University of Illinois Press, 1957.

[24] I. Aspuru all. (2016). *CITI-SENSE Deliverable D3.4: Evaluation of the performance of the user cases: Public Places.* Final report, from http://co.citi-sense.eu/Portals/1/Deliverables/WP3-Public%20places_FINAL.pdf?ver=2016-12-23-103731-863.

[25] K. Herranz-Pascual, I. Iraurgi, I. García-Pérez, I. Aspuru, I. García-Borreguero, D. Herrero-Fernández. (2011) *Disruptive effect of urban environmental noise on the physiological recovery response after stress testing*. ICBEN 2011.