engineering proceedings

MDPI

Proceeding Paper

Sons al Balcó: A Subjective Approach to the WASN-Based LAeq Measured Values during the COVID-19 Lockdown †

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† Presented at the 10th International Electronic Conference on Sensors and Applications (ECSA-10), 15–30 November 2023; Available online: https://ecsa-10.sciforum.net/.

Abstract: The lockdown in Spain due to COVID-19 caused a strong decrease of the urban noise levels observed in most cities, clearly followed in the case that these cities had acoustic sensor networks deployed. This fact had an impact on people's lives, who, at that moment, were mainly locked at home due to health reasons. In this paper, we present a qualitative analysis of the subjective vision of the citizens participating in a data collecting campaign during the COVID-19 lockdown in Girona, a Catalan city, named 'Sons al Balcó'. The alignment of the subjective data gathered-too scarce to conduct to final conclusions, but already giving a bias of the results-indicate that the objective L_{Aeq} measurements, which showed a clear decrease of noise in the streets during the lockdown, were supported by the fact that new sounds found during the lockdown were not very annoying. Former existing noise sources, as road traffic noise or leisure noise, are depicted as annoying but their decrease during the lockdown improved the soundscape of many homes. This paper goal is to show the possibility of gathering both objective and calibrated data with perceptive approximation for the first time in 'Sons al Balcó', and how this supports our conclusions, in a limited-in number of participants-but exceptional survey conducted during the 2020 lockdown period in Catalonia.

Keywords: lockdown; soundscape; L_{Aeq}; annoyance; perception; WASN; Girona; citizen science

Citation: Dorca, E.; Bonet-Solà, D.; Bergadà, P.; Martínez-Suquía, C.; Alsina-Pagès, R.M. Sons al Balcó: A Subjective Approach to the WASN-Based LAeq Measured Values during the COVID-19 Lockdown. *Eng. Proc.* **2023**, *56*, 0. https://doi.org/

Academic Editor: Firstname Lastname

Published: 15 November 2023

1. Introduction

Since the outbreak of COVID-19 at the end of 2019 a number of social changes have impacted on almost all countries around the world. First of all, health authorities imposed unprecedented containment measures, whose goal was to reduce the impact of COVID-19 on national health systems. These policies, such as long-period lock-downs, social distance in public places, face masks impairing human communications, brought a number of collateral social effects. Among others, man-made noise was considerably diminished in urban scenarios therefore, many research activities have been carried out to study the effects of lockdown on noise pollution. The aim of this paper is to compare the objective outcomes gathered by a number of noise sensors in the city of Girona (Catalonia), i.e., [1], with the subjective responses gathered by a survey conducted in the aforementioned city. All data and subjective surveys are collected during the COVID lockdown in 2020.

Regarding the relationship between objective and subjective sound pressure level measurements, previous research works, such as [2], studied the accuracy with which individuals may estimate the sound pressure level on their current day life. This research work claims that the reported results indicate that young adults are able to make a reasonable estimate of the noise level of events in their daily lives. This analysis has also been conducted with a wider scope in [3], where the authors study how people reacted to the unexpected situation of the lockdown, getting to the conclusion that people had a positive reaction to the lower noise level.

Other research works, e.g., [4], studied subjective methods of measurement suitable for Active Noise Reduction (ANR) devices. They reported differences between subjective and physical measurements of up to 20 dB at 250 Hz and below when applying pink noise with maximum noise level of 80 dB SPL (Sound Pressure Level) for a device in which the sound pressure level varied substantially near the ear canal. Since noise annoyance and excessive noise exposure have been linked to adverse physical and mental health issues, some research initiatives, such as [5], investigated the disparities in noise complaints in the city of New York since 2010, including the lockdown period in 2020 and beginning of 2021. The results showed that communities with high proportion of low-income residents reported a higher number of noise complaints, which increased over time specially during warmer months.

The only previous work facing subjective answers of citizens, also in this conference and with reference [6], detailed the first stages of the analysis of the questionnaires results, without entering to the comparison of the answers by citizens to the place in town where the questionnaire was being uploaded, gathering together all the results in Catalonia. The purpose of this work is to conduct a subjective approach, coming from a group of questionnaires data gathered during the lockdown in Girona, in order to contrast their opinions with the objective measurements already published in [1], which was also done in Barcelona in [7]. The former works always put the focus in objective data given by sensors, never entered the comparison with what citizens gave us as perception of their soundscape. In order to be maximally meaningful in results, only the questionnaires filled in by people living in a maximum distance of 1 km from the sensor has been taken into account, assuming that even this situation gives an approximation, specially due to the low number of answers by citizens in the campaign. Nevertheless, and assuming the qualitative approach of the description in this work, the results converge to what objective data measured and analyzed during (and before, and after) the lockdown, which encourages the team to keep on working in citizen science campaigns in order to increase the number of contributions obtained in each campaign.

This paper is structured as follows. Section 2 details the methodology of data collection used. Section 3 details several sensors in Girona with the comparison of the objective measurements and the subjective results, and Section 4 details the conclusions of this work.

2. Data Gathering

Subjective data gathered by citizens have been used in this work as qualitative data. Despite the lack of enough statistical reliability to get enough supported conclusions, the methods of data gathering and collection campaign description are detailed in this section, specially taking into account the replicability of the method. In order to carry out the study presented in this paper, data of diverse nature have been examined. On the one hand, we have analyzed the data obtained through a questionnaire responded by a representative number of participants. On the other hand, data on equivalent levels measured by sensors deployed in the city of Girona have also been analyzed. Thus, the following quantitative data have been studied: (1) Surveys to citizens about their perception of the soundscape both before and during the lockdown, with details about the most annoying sounds and quantifying this annoyance; (2) Recordings collected thanks to the citizen science web platform during the lockdown; and (3) equivalent acoustic levels (L_{Aeq}) measurements, carried out by sensors calibrated in the city of Girona during the lockdown.

2.1. Data Collection Campaign

Three campaigns of data collection were carried out and later on analyzed in this study. A socio-acoustic digital participatory survey was implemented in order to obtain perceptive data representative for all of the citizens of Catalonia. A web service platform allowing an online question-and-answer, with different response formats and even video uploading was set. The LimeSurvey [8] application was selected, which is an open source online application that offers a web platform to create and edit surveys. Furthermore, their source

code is also available to be deployed in any other server that supports it. Specifically, an Amazon EC2 cloud computing instance running a Bitnami Stack for LimeSurvey 4.2.3-0 on Ubuntu 16.04.6 LTS was chosen. In addition, an Amazon S3 bucket was used to upload the videos directly from the devices of the participants, in order to reduce traffic. Finally, a Fine Uploader library running on EC2 was used to manage and sign requests allowing access to the S3 bucket. The survey included questions on the following topics: sociodemographic data, residential soundscape quality, and individual positive and negative perception before and during the closure. In addition, participants could select from different categories of noise sources. See [9] for more details.

2.2. Sensors Data

This work has used the Wireless Acoustic Sensor Network (WASN) of the city center of Girona, which was mainly used to conduct a previous work, giving detailed values of variation during the COVID-19 lockdown in Girona [1]. The WASN used to gather the data of Girona has eight sensors deployed in several points (see Figure 1 in [10]). The sensors give a detail of L_{Aeq} with a maximum temporal resolution of 1 min. In this study, we analyzed raw data from these sensors 24 h a day for 7 days a week working at $L_{Aeq,1min}$. A detailed description of the locations can be found in [1].

3. Comparative Analysis

In this section we analyze the most relevant sensor data gathered in Girona together with the subjective contribution of the participants in the campaign. Former research papers, i.e., [1,11], analyzed gathered data *only* from the sensors-so, only objective data-in Girona and reached the following conclusions. During the Lockdown period a high decrease of noise level was measured in most of the sensors in Girona, except for those locations where traffic noise was totally predominant since they are the main connection roads. Leisure noise source almost disappeared, specially during the lockdown and curfew period nights, mainly following the strict regulations set by the government. As the number of respondents in Girona is not statistically relevant, in this section we are interested in showing whether the perception of citizens shows some kind of coincidence and exhibits a tendency toward the above conclusions. We have chosen three different sensors that correspond to different acoustic realities. Sensor 2 gathers noise from a mixture of leisure and traffic noise in a wide central street, whereas sensor 3 is placed in a narrow street and mainly records leisure noise and finally, sensor 4 is located in a big drive with heavy traffic noise. The aim is to expose respondents to different noise realities to detect a common pattern or on the contrary, whether there is a particular behavior in each environment.

3.1. Sensor 2

This sensor corresponds to a city centre location (i.e., Ramon Folch street) with both heavy traffic and leisure noise sources such as the post office, the city court, a theatre, a cinema, and several outdoor restaurants. It is worth mentioning that the railway, uplifted 6 m, crosses this street. Although there were 22 respondents in Girona, only 4 of them were less than 1 km near this sensor. These people were either men or women between the ages of 38 and 42. The respondents were asked to describe their home sound environment before the lockdown and only one of them described it as “Good”. These data stand out with that obtained during the lockdown, in which three out of four respondents considered their sound environment to be “Very good”. According to the poll, there was a major improvement in the sound quality after the lockdown as all of the respondents described the sound environment of their home after the lockdown as “Very good” or “Good” versus just one that chose those options before the lockdown. As reported in [11], the data from the sensors obtained during the confinement showed that the sound environment was improved during the confinement. During the confinement noise levels were drastically reduced between March and May 2020, due to the reduction of citizen movement and travel within the city. During the lockdown almost three quarters of the respondents, on

average, did not identify the sounds present in the video recording neither as "Exciting" nor "Disturbing", see Figure 1. Moreover, the adjectives Noisy, Shrill and Loud appeared not to define the recorded sound environment either. The sounds recorded in sensor #2 could be considered Pleasant, Calming and Sharp as half of the survey answers selected "Agree" for all these three adjectives. It is interesting that even though sensor #2 is placed in a busy area, the sound environment is considered as neither Noisy nor Loud. This matches with the study in [11], in which the L_{Aeq} decreased throughout the lockdown both during the day, when urban traffic is notorious, and at night, when leisure noise is more frequent. Despite the scarce number of respondents of this sensor, the answers to the poll might show a trend toward a reduction of leisure noise but not a clear reduction of traffic noise.

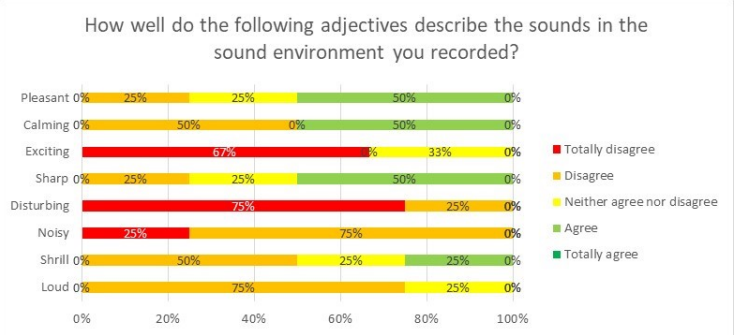

Figure 1. Descriptive assessment of the sound environment from sensor #2.

3.2. Sensor 3

Sensor #3 is placed in a narrow street (i.e., Figuerola street) in the city center where leisure noise dominates. The whole street is full of restaurants and bars that are open until late at night, which cause a number of complaints regarding the noise level [11]. Due to its location next to other heavy-traffic streets, cars and urban mobility related noise is also present. The railway splits the street in half and since sensor #2 is quite near similar results are expected. From the 22 respondents from Girona, seven were near enough to the sensor (less than 1 km) to be considered in its scope. They were both men and women from 38 to 50 years old. Regarding the sound environment of sensor #3, it is implied to be better after the lockdown rather than before the lockdown. Before the lockdown, only 29% of the people considered their environment to be "Good", 43% considered it "Not bad/not good" and the remaining 29% considered it "Bad". These results differ when asked after the lockdown, when it is suggested that the sound environment improved. As plotted in Figure 2, the respondents related their sound environment during the lockdown as Sharp since 43% selected they "Agree" with this adjective to describe their sound environment. Although it is not the majority of them, 29% selected "Neither agree nor disagree" and the remaining 28% "Disagree" or "Totally disagree", which make this adjective the one with greater agreement. The sound environment in sensor #3 is considered neither Exciting nor Disturbing as 62%, on average, "Totally disagree" with these adjectives. The remaining respondents selected the "Disagree" or "Neither agree nor disagree" options for these categories, versus a slight 14% that selected "Agree" in the Disturbing question. It is worth mentioning that even though the location of the sensor is known to be in a noisy place, the volunteers thought that their environment noise was neither Disturbing nor Loud. The tendency of the answers to the poll might show an indication that the global noise was reduced derived from the fact that other noise sources, which were previously squelched, were reported. It could also be suggested that there is some kind of parallelism with sensor 2, as traffic noise is still detected, while the feeling is that leisure noise is reduced.

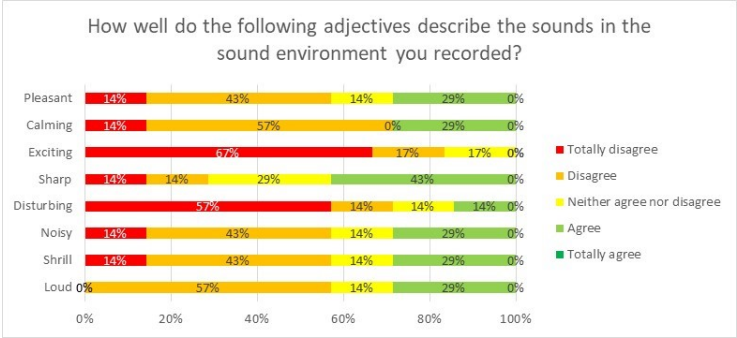

Figure 2. Descriptive assessment of the sound environment from sensor #3.

3.3. Sensor 4

Sensor #4 is located in a big avenue with heavy traffic (i.e., Riu Güell street) all along the river Güell. It has several traffic lanes in both directions that continue to President Josep Tarradellas and Joan avenue. Both streets cross the entire city from end to end. The sensor is not placed in the centre of the city but on the path to multiple big supermarkets with their parking lots, a school, some residential areas and even an auditorium. The sound environment of this sensor is perceived better after lockdown than before the lockdown, since 91% of the respondents selected the "Good" and "Very good" answers when asked about their home's sound environment after the lockdown. Before the lockdown the "Good" and "Not bad/Not good" options are equally selected by 36% of the respondents and only 27% of the answers pointed to "Bad". The sound environment around sensor #4 is perceived as Sharp by 45% of the respondents. It is the most positive voted adjective followed by Shrill, Calming and Pleasant with 27% of the "Agree" option selected in each case. These outcomes contrast with the adjectives Exciting and Disturbing, which 81% on average relates to "Totally disagree" and "Disagree" answers. It would be noted that the perception of the adjectives Noisy and Loud spread along all possible options. According to [11] the street was considered to be noisy being traffic the main noise source. However, the most voted answer in both adjectives is "Disagree", and hence it would be not considered a noisy or loud street during the survey period. It would be pointed out that the "Totally agree" and "Agree" options are also presented by 19% on average but still the "Disagree" and "Totally disagree" options represent a bigger part, with values over 50%.

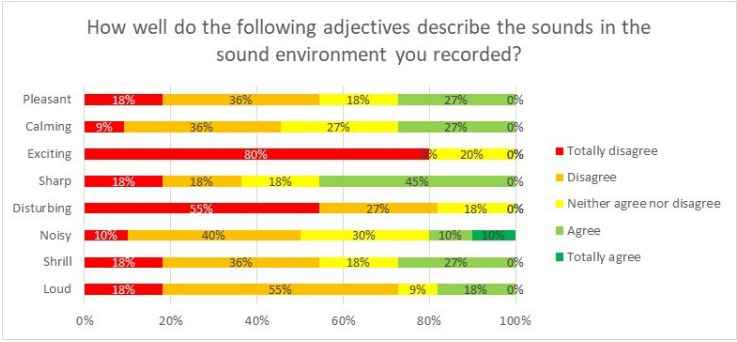

Figure 3. Descriptive assessment of the sound environment from sensor #4.

4. Conclusions

In this research work we have compared data from acoustic sensors scattered in a varied acoustic points in a medium size city (i.e., Girona, Spain) with the answers reported in a poll and conducted around the same points. The authors are aware that the subjective data analyzed is a very small set of information. Nevertheless, it satisfies the goal of opening the door to the possibility of evaluating the soundscape by means of objective and calibrated measurements-even coming from the administration-together with citizen science campaigns, opened to all people, maximizing-if possible- participation of a wider

number of citizens. The answers reported in the survey, despite being a preliminary analysis with few data, are able to distinguish the sound sources present around a certain sensor and also match those noise sources detected in sensors data analysis. The results presented in this work align the objective measurements related to noise levels into the perception of the neighbours-volunteers in this study-living in the surroundings. There is a coherence between the former analysis [1], when the authors also analyzed the environmental sound before and during the lockdown from all and each of the sensors evaluated. In this work, the noise sources have been contrasted with the opinions of the participants in the campaign, deepening the knowledge of what happened in the soundscape of these two cities during the 2020 lockdown.

Author Contributions: Conceptualization, R.M.A.-P. and P.B.; methodology, D.B.-S. and E.D.; validation, R.M.A.-P. and C.M.-S.; resources, R.M.A.-P.; data curation, D.B.-S., C.M.-S. and E.D.; writing—original draft preparation, P.B., D.B.-S. and E.D.; writing—review and editing, C.M.-S. and R.M.A.-P.; supervision, R.M.A.-P.; project administration, R.M.A.-P.; funding acquisition, R.M.A.-P. All authors have read and agreed to the published version of the manuscript.

Funding: The research that led to this contribution has been conducted thanks to funding from Secretaria d'Universitats i Recerca from the Departament d'Empresa i Coneixement (Generalitat de Catalunya) and Universitat Ramon Llull, under the grant 2020-URL-Proj-054 (Rosa Ma Alsina-Pagès).

Informed Consent Statement: Informed consent was obtained from all subjects in the study.

Acknowledgments: The authors would like to thank all the participants of this first data collection campaign of project *Sons al Balcó*. The authors would also like to thank *Ajutament de Girona* for the data collection in Girona monitoring network.

Conflicts of Interest: The authors declare no conflict of interest.

Abbreviations

The following abbreviations are used in this manuscript:

WHO	World Health Organization
EU	European Union
SPL	Sound Pressure Level
L_{Aeq}	A-weighted equivalent sound level

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