Proceeding Paper

Sons al Balcó, a Citizen Science Approach to Map the Soundscape of Catalonia [†]

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† Presented at the 8th International Electronic Conference on Sensors and Applications, 1–15 November 2021; Available online: https://ecsa-8.sciforum.net.

Abstract: Sons al Balcó (Catalan for "Sounds of the balcony") was a project born to study the effect that the COVID-19 pandemic lockdown caused on the perception of noise in Catalonia. One of the aims of the project was to combine the research activities—acoustic and image processing, urbanistic analysis and health and annoyance evaluation—with the dynamic collaboration with citizens and other stakeholders to create social and environmental impact, to raise awareness and design tools to improve citizenship development and empowerment. This first year of Sons al Balcó has shown that citizens are willing to participate in initiatives that work with their everyday life, because one year after the lockdown, a new soundscape map of Catalonia has been built with their collaboration and their perceptual impact from their balconies or windows. This has allowed the inclusion of other issues that enhance the final goal of describing and finding relationships between the annoyance caused by noise, and other factors as the environment (urban, suburban, rural) and the landscape, including the soundscape and noise levels in this evaluation. Objective measurements of L_{Aeq} have been conducted during the lockdown and in the months afterwards to describe the average noise and its possible link with outdoor activities. During this second collecting campaign, Sons al Balcó managed to gather more than 220 contributions. In this work, we detail the definitions of the metrics that include urbanistic and health-related environmental elements (water, trees, etc.), together with the socio-economic and demographic data that correspond to the answers of the questionnaires, and finally, the information extracted from the audios and the videos sent by the citizens. Preliminary results show encouraging dependencies between perception gathered with the questionnaires and the objective data collected, still in process of analysis, and a clear bias to a worse soundscape in 2021 in comparison to the 2020 campaign.

Keywords: smart city; citizen science; lockdown; annoyance; perception; soundscape map

1. Introduction

Nowadays we are aware that every year, environmental noise causes more than 48,000 new cases of heart disease and more than 12,000 deaths in Europe, according to the World

Health Organization (WHO) report [1]. Chronic high annoyance is generated to more than 22 million people, and chronic sleep disturbance is suffered by more than 6.5 million [2].

When the COVID-19 pandemic started in Wuhan (China), the WHO declared a public emergency on 3 January 2020 [3], and the authorities in most European countries reacted implementing closures of facilities, travel restrictions and in general, home lockdown for everybody but essential services [4]. During the lockdown, a citizen science project named *Sons al Balcó* was opened thanks to the cooperation of ISGlobal and La Salle-URL [5], in order to collect and represent the soundscape of the lockdown in Catalonia. Furthermore, several scientific studies were conducted to analyze the changes of the soundscape of the cities at that moment, which was very modified [6] due to the change of the outdoor activities. Noise from traffic [7], railway noise, port noise [8], airport noise [9] and leisure noise [10] were mainly decreased in most of the studied urban environments [11,12], and even in quiet residential areas [13]. Nevertheless, nearly all activities seem to come back to normal after the severe lockdown, and most of the cities around Europe are coming back to their original noise levels in the street [14].

Sons al Balcó aims to initially study the effect of the lockdown due to the pandemic caused to the perception of the street noise in Catalonia by means of a Citizen Science proposal, as other projects developed in Europe [15,16] and in USA [17]. One year after the severe lockdown, *Sons al Balcó* has opened the collecting campaign again during the same period, in order to map the soundscape of Catalonia one year after.

This paper is structured as follows. Section 2 describes briefly the methodology followed to collect the participatory samples from volunteers, and the details about the questions and the new fields of study in terms of architecture. Section 3 describes the preliminary results of the questionnaires and finally, Section 5 reflects the conclusions of this preliminary evaluation of the opinions of the volunteers.

2. Methods

One year after the COVID-19 lockdown, we performed a second socio-acoustic digital participatory survey implemented in LimeSurvey [18]. The goal was to conduct several questionnaires to people living in Catalonia about the changes in the soundscape one year after the COVID-19 lockdown, and their perception about them. Both La Salle and ISGlobal institutional profiles supported the initiative, and social media and press were the main channels to reach the citizens and encourage them to be contributors.

2.1. The Questionnaires

The survey, as the one conducted in [5], included socio-demographic questions, as well as the quality of the residential soundscape and several questions about the perception of the noise experienced from home. The survey required the contributors to upload a 30 s video recorded with the mobile phone, with the permission to publish it in the framework of a soundscape map of Catalonia. The questionnaire also inquired the contributors asking which sound sources could be related to their experience, including: car traffic, trains, aeroplanes, industry, construction, commercial activities, leisure, neighbors, pets, birds, water-related sounds and vegetation.

2.2. Health-Related Issues

The knowledge of the sound sources identified provides information about the environment of the subject that is taking the survey, allowing us to extract some metrics as the presence of nature near the subject's home, transportation ways (road, air or rail ways) and the activities that surround the place, related to leisure or commerce. The other personal information collected in the survey, as gender, age and studies, help to stratify the results obtained.

Furthermore, in the 2021 campaign of *Sons al Balcó*, also time spent, location and use of the place—living room, kitchen, bedroom, etc.—where the video was recorded were

asked to contributors. This will allow a further study about the influence of the use and the exposure to the results obtained.

2.2.1. Image Processing Methods

In relation to image processing, some aspects will be analyzed to identify how architecture and landscape conditions may affect sound perception. Instance segmentation from video keyframes will allow us to obtain valuable information regarding different aspects. This includes location and building context with a focus on the urban patterns (downtown, sprawl, peripheries, rural), the orientation (street, courtyard) and the views (buildings, vegetation, mountains, sea). Moreover, information could also be retrieved from the way video has been recorded, which can give us an idea of the subjective feeling over this space (horizontal/vertical movement, frontal view, sky view, ground view, aleatory). When the recording of the video makes it possible, data regarding the physical characteristics of the balcony or window, considering its size (window, balcony, terrace, patio, garden), the pavement (tiles, timber, grass, stone, gravel) and the handrails (glass, brick, mortar, timber, steel, stone) will also be recovered. Further, information regarding the uses related to the balcony or window, by means of the objects identified (vegetation, clothes, table, hammocks, machinery, swimming-pool, storage, empty space) could also be addressed.

2.2.2. Acoustic Event Detection Methods

The work around acoustic event detection will be focused on identifying the sound sources that are already listed in the questionnaire: road traffic, train, plane, industry, works, commercial activities, leisure activities, neighbors, pets, birds, water and vegetation. The goal is to identify whether the sound sources answered by the contributors are present in the videos recorded, and if they are, which is the saliency relationship between the sound sources and the background noise. The Signal-to-Noise ratio of all the labeled sound sources will be evaluated to evaluate its relationship with annoyance.

2.2.3. Data Merging with L_{Aeq}

New parts of the questionnaires, as the location in the house where the video was recorded, and the time spent in that room will also be part of the analysis conducted to all the data gathered in the 2021 campaign. Finally, the L_{Aeq} values from cities where noise is usually monitored will complete the entire picture, from which *Sons al Balcó* will conclude the changes in the soundscape of Catalonia one year after the lockdown.

2.3. General Data Processing Workflow

The workflow for the data in the entire project is the following:

- The citizen decides to participate in *Sons al Balcó*, and opens the questionnaire entering the socioeconomic data, and the location.
- The citizen uploads a 30 s video to the platform.
- The citizen answers the other questions in the questionnaire, mainly about the location in the house of the place where the video was recorded, and about the several sound sources that could be found in the video, as well as rating their annoyance.
- All the data are stored in the cloud, and the image processing algorithms start working in the detection of the location of the video, the orientation and the views, in order to extract information about the video.
- At the same time, the acoustic event detection algorithms also work on the audio of the videos, with the final goal of detecting the sound sources listed in the questionnaire (e.g., road traffic, train, plane, industry...).
- The automatically detected data (image and acoustic signal processing) will be compared to the answers in the questionnaires, in order to obtain coincidences for all the contributors.
- Finally, all the data from all the contributors will also be analyzed in therms of their socio-economic and demographic information.

3. Results and Discussion

In total, 237 volunteers from nearly all around Catalonia completed the questionnaire and uploaded their video. As a result, we depicted the first soundscape of Catalonia one year after the COVID-19 lockdown.

In this first evaluation of results, we compare the results of the questionnaires in 2021 campaign with the results in the COVID-19 campaign, during the lockdown. As we can observe in Figure 1, the 27.3% of the respondents found their sound environment "Very good" one year after the lockdown, remarkably similar to the 16.4% that answered that their soundscape before the lockdown was "Very good", and a really small number in comparison to the 63.4% of contributors that answered the same during the lockdown. The difference in the "Good" category is not as clear as it is in the "Very good", but before and after the lockdown the values are also similar. The neutral or negative categories ("Not good, not bad", "Bad" and "Very bad") results are also so close between the 'before the lockdown' and 'after the lockdown', giving only really low values to 'during the lockdown'.
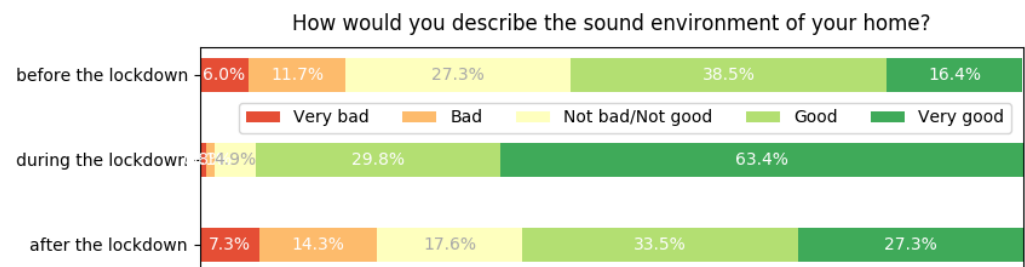

Figure 1. Overall assessment of the sound environment before, during and after the lockdown.

We have also compared the perception of the adjectives by the contributors in the previous campaign and in 2021 *Sons al Balcó* project campaign. The upper part of the results corresponds to the 2020 campaign and the lower part corresponds to the 2021 campaign. Focusing in Figure 2, we can observe that all the adjectives that we may perceive as positives (e.g., "Exciting", "Calming", "Pleasant") present lower values of agreement in 2021 in comparison with 2020. On the other side, other adjectives probably closer to negative sensations (e.g., "Loud", "Shrill", "Noisy", "Disturbing"), present higher values of agreement in 2021 rather than in 2020. This presents very clear results in the case of "Noisy", which results have been shifted to the right in Figure 2.

Finally, in Figure 3, we can observe that after the lockdown, noise sources such as "Road Traffic", "Train", "Works" or "Industry" have dramatically increased, as well as "Birds", "Neighbours" or "Vegetation" have decreased substantially. The most common noise source during the lockdown in 2020 were "Birds", and the most common noise source one year after in 2021 is "Road Traffic".
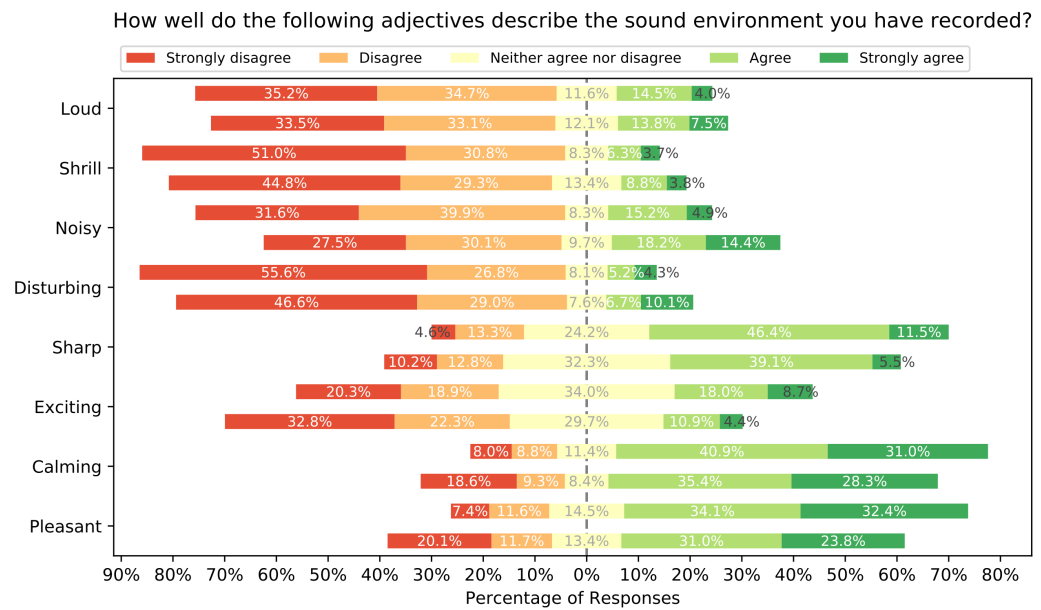
How well do the following adjectives describe the sound environment you have recorded?

Figure 2. Descriptive assessment of the sounds present in the recordings during and after the lockdown: adjectives.
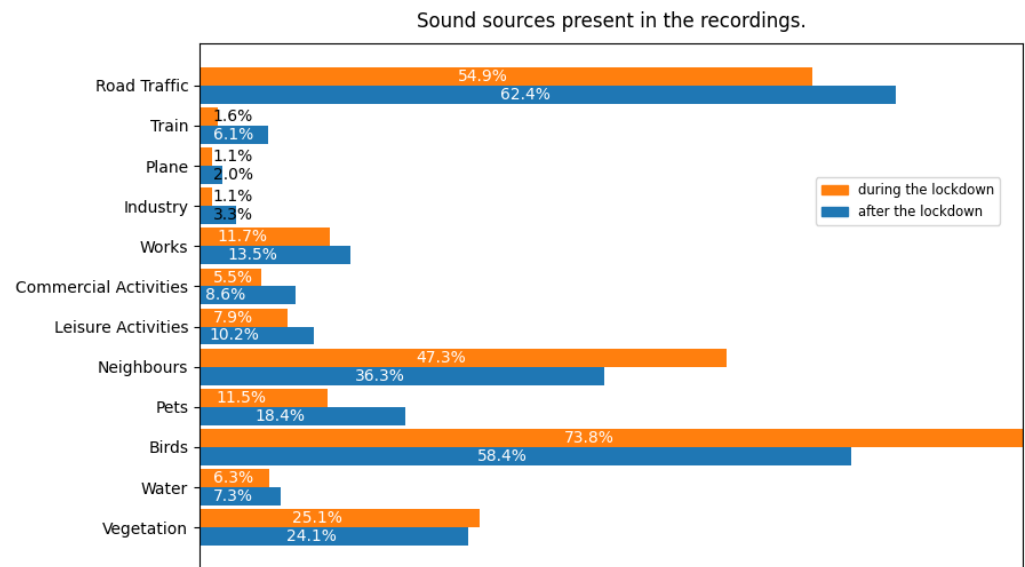

Figure 3. Descriptive assessment of the sounds present in the recordings during and after the lockdown: Types of sound sources.

4. Discussion

After this preliminary analysis, which led us to these results, the information coming from the questionnaires will also be contrasted with the objective data gathered in the videos, by means of automatic instance segmentation of objects by the image processing team and by means of the acoustic event detection by means of the audio processing team. The application of both algorithms is not an easy issue, because the locations and the type of recording of the videos is very variate, and supervision is required if the team intends to present reliable results.

The questionnaires results will be contrasted to the image and acoustic signal processing algorithm results in order to find coincidences or differences with the answers given to the questionnaires. Each video and location will also be analyzed in terms of the performance of the L_{Aeq} value of the closer acoustic sensor deployed in the city (if there is any, because most of the cities do not have static sensors deployed).

Finally, all the data gathered—objective and subjective—will be analyzed considering the socio-economic and demographic conditions described in the proper questionnaire. This last stage will allow us to obtain coincident behaviors of citizens living in similar locations—despite maybe not the same city—and with comparable socio-economic situation.

5. Conclusions and Future Work

The preliminary results presented show a clear evolution in the soundscape perception by citizens. Despite the activity not returning to pre-COVID-19 levels, especially in urban environments, the perception of the citizens is that the soundscape is clearly worse than during the lockdown and very similar to the stages previous to the lockdown. The positive adjectives are mainly reduced and the negative adjectives asked are increased. Further, the noise sources have varied slightly, changing "Birds" as the most common sound for "Road Traffic".

Author Contributions: M.F. (Maria Foraster), support in the questionnaires definition and analysis, together with R.M.; F.O., M.F. (Marc Freixes), A.E., G.J.G.-P. and R.M.A.-P., acoustic event detection and audio analysis; P.B., D.B.-S. and C.M.-S., analysis of the L_{Aeq} in the cities where available; X.B. and R.M.A.-P., approach to the citizens, questionnaires design, design of the campaign and support and leading of the communication campaign of the project; X.S. and A.E., computer vision algorithms to analysis the videos; M.F. (Marc Freixes), platform for the questionnaires support; X.M. and A.M., urbanistic and environmental definition of elements that impact people and potentially noise. All authors have read and agreed to the published version of the manuscript.

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

References

1. WHO/Europe | Noise—Data and Statistics. Available online: www.euro.who.int/en/health-topics/environment-and-health/noise/data-and-statistics (accessed on 6 September 2020).
2. Blanes, N.; Fons, J.; Houthuijs, D.; Swart, W.; de la Maza, M.; Ramos, M.; Castell, N.; van Kempen, E. *Noise in Europe 2017: Updated Assessment*; European Topic Centre on Air Pollution and Climate Change Mitigation (ETC/ACM): Bilthoven, The Netherlands, 2017.
3. Jee, Y. WHO International Health Regulations Emergency Committee for the COVID-19 outbreak. *Epidemiol. Health* **2020**, *42*, e2020013. [CrossRef]
4. Aletta, F.; Osborn, D. The COVID-19 global challenge and its implications for the environment—What we are learning. *UCL Open Environ.* **2020**, *1*, 5. [CrossRef]
5. Alsina-Pagès, R.M.; Orga, F.; Mallol, R.; Freixes, M.; Baño, X.; Foraster, M. Sons al balcó: Soundscape Map of the Confinement in Catalonia. *Eng. Proc.* **2020**, *2*, 77. [CrossRef]
6. Aletta, F.; Oberman, T.; Mitchell, A.; Tong, H.; Kang, J. Assessing the changing urban sound environment during the COVID-19 lockdown period using short-term acoustic measurements. *Noise Mapp.* **2020**, *7*, 123–134. [CrossRef]
7. Alsina-Pagès, R.M.; Alías, F.; Bellucci, P.; Cartolano, P.P.; Coppa, I.; Peruzzi, L.; Bisceglie, A.; Zambon, G. Noise at the time of COVID 19: The impact in some areas in Rome and Milan, Italy. *Noise Mapp.* **2020**, *7*, 248–264. [CrossRef]
8. Čurovič, L.; Jeram, S.; Murovec, J.; Novaković, T.; Rupnik, K.; Prezelj, J. Impact of COVID-19 on environmental noise emitted from the port. *Sci. Total. Environ.* **2020**, *756*, 144147. [CrossRef]
9. Vogiatzis, K.; Zafiropoulou, V.; Gerolymatou, G.; Dimitriou, D.; Halkias, B.; Papadimitriou, A.; Konstantinidis, A. The noise climate at the time of SARS-CoV-2 VIRUS/COVID-19 disease in Athens–Greece: The case of Athens International Airport and the Athens Ring Road (Attiki Odos). *Noise Mapp.* **2020**, *7*, 154–170. [CrossRef]
10. De Lauro, E.; Falanga, M.; Lalli, L.T. The soundscape of the Trevi fountain in COVID-19 silence. *Noise Mapp.* **2020**, *7*, 212–222. [CrossRef]
11. Asensio, C.; Pavón, I.; de Arcas, G. Changes in noise levels in the city of Madrid during COVID-19 lockdown in 2020. *J. Acoust. Soc. Am.* **2020**, *148*, 1748–1755. [CrossRef]
12. Alsina-Pagès, R.M.; Bergadà, P.; Martínez-Suquía, C. Changes in the soundscape of Girona during the COVID lockdown. *J. Acoust. Soc. Am.* **2021**, *149*, 3416–3423. [CrossRef] [PubMed]

13. Sakagami, K. A note on the acoustic environment in a usually quiet residential area after the 'state of emergency'declaration due to COVID-19 pandemic in Japan was lifted: Supplementary survey results in post-emergency situations. *Noise Mapp.* **2020**, *7*, 192–198. [CrossRef]

14. Noise Returns to Europe after COVID Quiet Interlude. Available online: https://www.politico.eu/article/noise-returns-to-europe-after-covid-quiet-interlude/amp/?__twitter_impression=true (accessed on 28 December 2020).

15. COVID-19: The Quiet Project—Call for Measurements. Available online: www.ioa.org.uk/news/covid-19-quiet-project-%E2%80%93-call-measurements (accessed on 20 September 2019).

16. Scienzia sul Balcone. Available online: comunicazione.cnr.it/evento/254/scienzasulbalcone-misuriamo-il-rumore-intorno-a-noi (accessed on 19 October 2019).

17. The Coronavirus Quieted City Noise. Listen to What's Left. Available online: www.nytimes.com/interactive/2020/05/22/upshot/coronavirus-quiet-city-noise.html?smid=li-share (accessed on 6 September 2020).

18. LimeSurvey Online Survey Tool. Available online: https://www.limesurvey.org/en/ (accessed on 12 October 2020).