












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

Xavier Baño², Pau Bergadà¹ , Daniel Bonet-Solà¹ , Alba Egea¹, Maria Foraster³ , Marc Freixes¹ , Gerardo Jose Ginovart-Panisello¹ , Roger Mallol^{1*} , Xavier Martín⁴ , Anna Martínez⁴, Carme Martínez-Suquía¹ , Ferran Orga¹ , Xavier Sevillano¹  and Rosa Ma Alsina-Pagès^{1,*} 

- ¹ Grup de Recerca en Tecnologies Mèdia (GTM), La Salle-URL, C/Quatre Camins, 30, 08022 Barcelona (Spain);
² Research and Transference Office, La Salle-URL, C/Sant Joan Baptista de La Salle, 42, 08022 Barcelona (Spain);
³ ISGlobal, Parc de Recerca Biomèdica de Barcelona (PRBB). Doctor Aiguader, 88, 08003 Barcelona (Spain);
⁴ IAR - La Salle-URL, C/Quatre Camins, 30, 08022 Barcelona (Spain)
* Correspondence: rosamaria.alsina@salle.url.edu Tel.: +34-93-2902425
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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

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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 Jan 3rd 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 analyse 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-sec 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, neighbours, 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 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

82 from video keyframes will allow to obtain valuable information regarding different
83 aspects. This includes location and building context with a focus on the urban patterns
84 (downtown, sprawl, peripheries, rural), the orientation (street, courtyard) and the views
85 (buildings, vegetation, mountains, sea). Moreover, information could also be retrieved
86 from the way video has been recorded, which can give us an idea of the subjective feeling
87 over this space (horizontal/vertical movement, frontal view, sky view, ground view,
88 aleatory). When the recording of the video makes it possible, data regarding the physical
89 characteristics of the balcony or window, considering its size (window, balcony, terrace,
90 patio, garden), the pavement (tiles, timber, grass, stone, gravel) and the handrails (glass,
91 brick, mortar, timber, steel, stone) will also be recovered. Also, information regarding
92 the uses related to the balcony or window, by means of the objects identified (vegetation,
93 clothes, table, hammocks, machinery, swimming-pool, storage, empty space) could also
94 be addressed.

95 2.2.2. Acoustic Event Detection Methods

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

103 2.2.3. Data Merging with L_{Aeq}

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

109 2.3. General Data Processing Workflow

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

- 111 • The citizen decides to participate in *Sons al Balcó*, and opens the questionnaire
112 entering the socioeconomic data, and the location.
- 113 • The citizen uploads a 30-sec video to the platform.
- 114 • The citizen answers the other questions in the questionnaire, mainly about the
115 location in the house of the place where the video was recorded, and about the
116 several sound sources that could be found in the video, as well as rating their
117 annoyance.
- 118 • All the data is stored in the cloud, and the image processing algorithms start
119 working in the detection of the location of the video, the orientation and the views,
120 in order to extract information about the video.
- 121 • At the same time, the acoustic event detection algorithms also work on the au-
122 dio of the videos, with the final goal of detecting the sound sources listed in the
123 questionnaire (e.g. road traffic, train, plane, industry...).
- 124 • The automatically detected data (image and acoustic signal processing) will be
125 compared to the answers in the questionnaires, in order to obtain coincidences for
126 all the contributors.
- 127 • Finally, all the data from all the contributors will also be analysed in terms of their
128 socio-economic and demographic information.

129 3. Results and Discussion

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

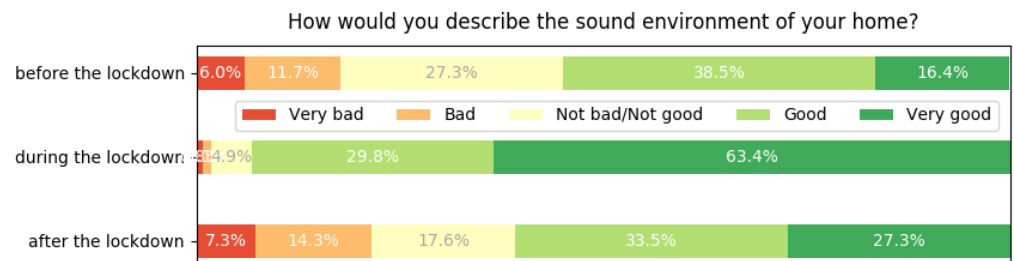


Figure 1. Overall assessment of the sound environment before, during and after the lockdown.

133 In this first evaluation of results, we compare the results of the questionnaires in
 134 2021 campaign with the results in the COVID-19 campaign, during the lockdown. As
 135 we can observe in Figure 1, the 27.3% of the respondents found their sound environment
 136 "Very good" one year after the lockdown, remarkably similar to the 16.4% that answered
 137 that their soundscape before the lockdown was "Very good", and a really small number
 138 in comparison to the 63.4% of contributors that answered the same during the lockdown.
 139 The difference in the "Good" category is not as clear as it is in the "Very good", but before
 140 and after the lockdown the values are also similar. The neutral or negative categories
 141 ("Not good, not bad", "Bad" and "Very bad") results are also so close between the before
 142 the lockdown and after the lockdown, giving only to during the lockdown really low
 143 values.

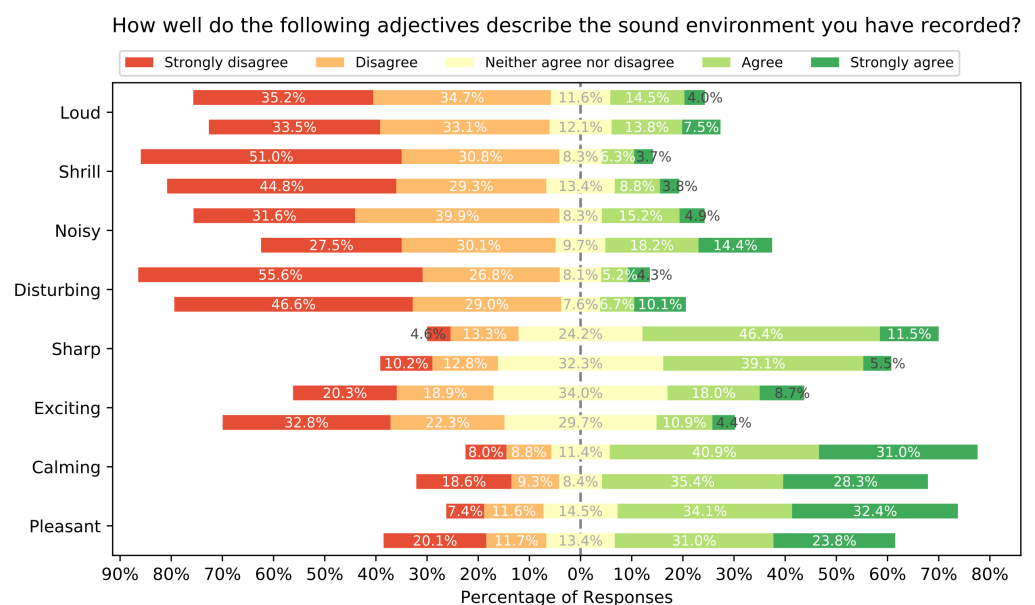


Figure 2. Descriptive assessment of the sounds present in the recordings during and after the lockdown: adjectives.

144 We have also compared the perception of the adjectives by the contributors in the
 145 previous campaign and in 2021 *Sons al Balcó* project campaign. The upper part of the
 146 results corresponds to the 2020 campaign and the lower part corresponds to the 2021
 147 campaign. Focusing in Figure 2, we can observe that all the adjectives that we may
 148 perceive as positives (e.g. "Exciting", "Calming", "Pleasant") present lower values of
 149 agreement in 2021 in comparison with 2020. On the other side, other adjectives probably

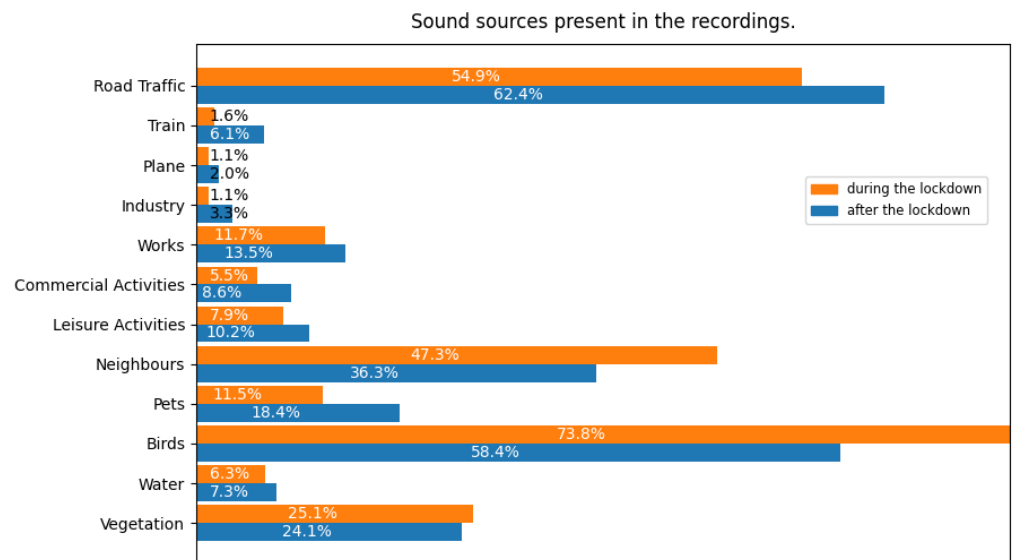


Figure 3. Descriptive assessment of the sounds present in the recordings during and after the lockdown: Types of sound sources.

150 closer to negative sensations (e.g. "Loud", "Shrill", "Noisy", "Disturbing"), present higher
 151 values of agreement in 2021 rather than in 2020. This presents very clear results in the
 152 case of "Noisy", which results have been shifted to the right in Figure 2.

153 Finally, in Figure 3, we can observe that after the lockdown, noise sources such as
 154 "Road Traffic", "Train", "Works" or "Industry" have dramatically increased, as well as
 155 "Birds", "Neighbours" or "Vegetation" have decreased substantially. The most common
 156 noise source during the lockdown in 2020 were "Birds", and the most common noise
 157 source one year after in 2021 is "Road Traffic".

158 4. Discussion

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

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

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

176 5. Conclusions and Future Work

177 The preliminary results presented show a clear evolution in the soundscape percep-
 178 tion by citizens. Despite the activity is not fully back yet, especially in urban environ-
 179 ments, the perception of the citizens is that the soundscape is clearly worse than during
 180 the lockdown and very similar to the stages previous to the lockdown. The positive
 181 adjectives are mainly reduced and the negative adjectives asked are increased. Also

182 the noise sources have varied slightly, changing "Birds" as the most common sound for
183 "Road Traffic".

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186 M Alsina-Pagès, acoustic event detection and audio analysis. 3. Pau Bergadà, Daniel Bonet-Solà
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188 Rosa Ma Alsina-Pagès, approach to the citizens, questionnaires design, design of the campaign
189 and support and leading of the communication campaign of the project. 5. Xavier Sevillano,
190 Alba Egea, computer vision algorithms to analysis the videos. 6. Marc Freixes, platform for the
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