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Multidimensional analysis to monitor the effects of COVID-19 lockdown on the urban sound environment of Lorient.

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Abstract
As part of the ANR CENSE project, a questionnaire was sent in January 2019 to households in a 1 km² study area in the city of Lorient, France, to which 300 responded. The main objective of this questionnaire was to collect information on the inhabitants' perception of the sound environments in their neighborhood (soundscape representation), in their street (soundscape representation), and in their dwelling (noise annoyance). Starting from 2018, a hundred sensors were continuously positioned in the same study area, and fifteen of them were selected for testing sound source recognition models. The French lockdown due to the COVID-19 crisis occurred during the project, so we decided to send a second questionnaire during April 2020. About 60 of the first 300 first survey respondents answered to this second questionnaire. This unique longitudinal dataset, both physical and perceptual, allowed us to undertake a multidisciplinary analysis of this period. The analysis revealed the effectiveness of integrating source recognition tools, soundscape observation protocol, in addition to physical level analysis, to accurately describe changes in the sound environment.

Keywords: Lockdown, Soundscape, Urban sound environment.

1 Introduction

The emergence and spread of the Covid-19 pandemic from late 2019 to 2020 has forced governments to take unprecedented social distancing measures to slow the spread of the virus. The most emblematic of which was the lockdowns imposed in a large number of countries in the spring of 2020. They had an immediate and drastic impact on the sound environments. From a research point of view, this unprecedented event raises the question of how can we observe and objectify the physical changes in urban sound environments during this period, as well as their perception by populations. This question is crucial for understanding the impact of such a crisis, which is likely to change the perceptions of and the expectations about noise in a lasting way, but also for proposing protocols for capturing and understanding the impact of slower and less dramatic changes in noise environments.

Despite initiatives to homogenize observations, such as that proposed by Asencio et al [1], observation protocols in the recent literature on the subject are very disparate, from acoustical measurements to the use of questionnaires. For example, cities equipped with noise measurement networks have highlighted the decrease in noise levels of about 4 to 6 dB(A) reported on average in Lyon [2], Madrid [3], Milan [4]. In [2], [5], [6], questionnaires were distributed to residents, the analysis of which highlighted the perceived change in noise environments, namely a decrease in transport and mechanical noise sources and an increase in natural sound sources.

This study proposes an approach that combines both a measurement network that integrates an automatic sound source recognition module and questionnaires distributed before and during the lockdown. The objective is not to define a universal characterization of the impact of the lockdown, but to demonstrate the relevance of such a protocol to characterize such an event. As such, this paper is only a brief summary of the methods and results obtained.

2 Material and methods

2.1 Questionnaire

In the second week of January 2019, a questionnaire was sent to approximately 2000 households in a study area of 1 km² in the city of Lorient, France. Until 15 March 2019, it was possible for the inhabitants to return a paper version of the questionnaire or to fill it in via a web platform. The questionnaire takes about 20-25 minutes and is composed of 5 sections detailed in [7]. A second questionnaire was sent out during the lockdown period in 2020, from early April to mid-May. It was identical in every respect to the first two sections. 318 people completed the first questionnaire and 62 of these participants also completed the second questionnaire.

2.2 Measurement network

Specific low-cost noise monitoring sensors have been developed within the CENSE project to be integrated into a measurement network [8]. In April 2020, approximately 70 sensors were installed in the study area. Among these sensors, we strategically selected 15 that operated continuously over the study periods and were best spatially distributed to match the residents' questionnaires. To facilitate data processing, only the first 10 minutes of each hour are analyzed assuming that they are representative of the whole corresponding homogeneous period as suggested in [9].

2.3 Sound Recognition

In addition to analyze perceptual assessments and acoustic indicators, we investigated variations in the content of sound environments through automatic sound source recognition. Specifically, a deep neural network was designed to identify the time presence ratios of cars, trucks, motorbikes, voices, small birds, seagulls and background noise activities from the sensor network [10].

3 Results

3.1 Perceptual analysis

Comparative statistical analyses between the responses given in the pre-lockdown period and during the lockdown period were carried out. In particular, this showed strong decrease of the perceived presence time of road traffic, two-wheelers and "expressive" voices (shouts, laughter) during the lockdown. In contrast, the perceived presence time of birds increased significantly. In general, the sound environment perceived by the residents in front of their homes was assessed much calmer, more pleasant and less eventful during the lockdown period than before.

3.2 Sound level analysis

The analysis of the measured sound levels shows first of all that globally the typical daily and weekly pattern is maintained for both study periods. However, a statistical analysis indicates that the period effect for the mean measurements of all the sensors is about 7 dB(A). A difference of up to -15 dB(A) is even observed between the period before and during lockdown for a station located close to a boulevard.

3.3 Sound recognition analysis

We initially observe that the expected general diurnal and weekly behavior is observed for most of the variables (e.g., morning birdsong peaks at sunrise), which reinforces the confidence in the source recognition model. Statistical tests show a strong increase in the perceived presence time of birds, and a decrease in the perceived presence time of road traffic, estimated by the algorithm. We also observe a decrease in the estimated presence time of voices during the lockdown period in the hyper center and near the bars, but an increase in the small streets or on the pathways along the riverbank.

3.4 Cross-comparison of the different evaluation methods

Pearson correlation coefficients with their respective significance (p-values) between the questionnaire variables, source recognition, but also the physical indicators directly were calculated. They show that the perceived sound level and the measured sound level indicators L_{Aeq} and L_{A50} are significantly inversely correlated. The same dynamics are also observed when comparing the measured sound level L_{Aeq} and L_{A50} and the perceived traffic presence time. The perceptual indicators and those from source recognition for the time of presence of birds and road traffic are also significantly correlated.

4 Conclusion

In this study, three methods of sound environment analysis were considered for periods before and during the lockdown due to the COVID-19 crisis in the city of Lorient, France. The analysis of sound levels reflects the results of many other studies on the subject, namely an average decrease in equivalent sound level of about 5-10 dB(A). The analysis of the questionnaire results allows us to investigate the changes in the perceived presence of certain sources over time, such as the drastic decrease in road traffic and the increase in the perceived presence of birdsong.
This study also introduces the integration of the analysis of the presence of sound sources both from the questionnaires and from the automatic estimation using a deep convolutional network algorithm. The analysis of the latter reveals temporal details on the presence of sources which are very complementary to that of the questionnaires. The differences between the questionnaires and the algorithm also allow us to question the perceptual or algorithmic biases that may be present in each measuring method.
When confidence in the results of the algorithm will progressively increase, this type of cross analysis will certainly allow us to highlight perceptual biases. In spite of some methodological and technical limitations of the study, this shows the interest of introducing multidisciplinary analyses of the urban sound space, in particular to explore particular phenomena such as the lockdown related to COVID-19, or more generally to testify of the short- and long-term evolutions of the urban sound environments and their appreciation. More information about the methods and results obtained will be given during the presentation and in a full paper that is in the final stage of writing.

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