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Research Article

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Framework for urban sound assessment at the city scale based on citizen action, with the smartphone application NoiseCapture as a lever for participation

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Abstract: The development of citizen-based approaches to the diagnosis and decision-making on urban noise environments responds to a demand from both local authorities and residents. However, the methods for fostering the involvement of citizens and the valorization of local knowledge have yet to be invented. This article reports on a co-constructed experiment between researchers and local authorities, in the city of Rezé (France), of an urban noise diagnosis based on the residents and the use of the smartphone application NoiseCapture, which allows a participative measurement of sound levels. The framework also includes focus group discussions. The dynamics of the recruitment and data collection phase are analysed, showing the importance of creating public events around the initiative. Maps of noise levels, but also of the presence of sound sources, such as road, rail and air traffic, or animals, are produced in a collaborative way. Finally, the focus group discussions highlight that (i) repeated noise measurement modifies participants' relationship to sound environments; (ii) NoiseCapture enhances the formation of a group of residents active on noise issues. Such a framework can

provide a citizen-based basis for decisions on noise environments; the next step will be to study its adaptability to different territories.

Keywords: participatory noise mapping, NoiseCapture smartphone application, valorization of the residents' knowledge, co-construction regarding noise

1 Introduction

The management of sound environments is a major issue in urban planning, in the context of urban densification, increased mobility, and strong social demand for calm [1]. However, this management comes up against a gap between quantitative and qualitative approaches to noise. On the one hand, objective and normative quantitative approaches prove useful to quantify the exposure of populations to noise, but are sometimes far removed from residents' perceptions. On the other hand, sensitive and qualitative approaches get closer to perceptions but sometimes make it difficult to generalize. Moreover, the management of sound environments lies within a context where urban governance is increasingly oriented towards citizen involvement [2]. It is therefore crucial to (i) work towards methods of diagnosing sound environments that are closer to the perceptions of residents while remaining useful supports for decision-making, and (ii) define the modalities of a discussion between political decision-makers, residents, and experts on the management of sound environments.

In Europe, the Directive 2002/49/EC is used to map noise levels and to identify populations exposed to excessive levels [3]. It consists of an inventory of the main noise sources (road, air and rail traffic, and main industries), followed by acoustic modelling. The method has proved to be very valuable in quantifying the number of people exposed to excessive levels and in assessing the

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health burden of noise [1]. However, the maps produced do not include the diversity of sound sources as well as the sound events that make up the sound environments, which may distance them from the perception that residents have of their sound environment [4–6].

In parallel to this research on the mapping of sound levels, research on soundscapes has been developed, which is defined as the “acoustic environment as perceived or experienced and/or understood by a person or people, in context” [7–9]. This research highlights a distinction between the perception of mechanical, natural, and human sounds [4]. It also highlights the importance of preserving quiet urban neighbourhoods [10,11], which have been shown to have a positive effect on well-being and health and therefore require special attention [12]. Finally, the soundscape approach encourages the involvement of different stakeholders (policy makers, residents, and experts) when making decisions that have an impact on sound environments [8,13,14]. These recommendations echo a need expressed by local authorities to involve residents in the decision-making process, as well as an increasing desire of residents to be engaged in urban governance [2].

Experiments aiming to involve residents in the diagnosis or in decision-making concerning urban sound environments have been carried out in recent years. In the study by Alves *et al.* [14], interviews including questions about sounds and visual elements are conducted to gather viewpoints of all stakeholders prior to an acoustic intervention as part of an indirect participation in a decision-making process. Survey data on perceptions are used to prioritize the factors that influence residents’ assessment of the quality of their living environment [15]. In the study by Manola *et al.* [16,17], focus group interviews are conducted to observe the dynamics of the development of a soundscape diagnostic method within different professional (acousticians, space designers, and artists), institutional, and resident groups. An unsupervised installation allowing users to play audio content from their own devices over publicly provided speakers is proposed and evaluated [18]; it is seen as a relevant strategy for interacting with both residents and city decision-makers on matters related to urban sound. In the study by Van Renterghem *et al.* [19], a co-creation process with the spatial planning teams and city dwellers of Antwerp is proposed, based on a three stages process of information, co-creation, and evaluation. Finally, a smartphone application, namely Hush City, is developed and included within a framework that aims to empower local communities to map and evaluate quiet spots in their neighbourhoods, with the idea to impact participatory planning processes [20,21]. One of the main difficulties in these

approaches is to define the methods for involving citizens and enable the valorization of their residents’ knowledge. While the diversity of postures and practices of the different stakeholders concerning noise environments is underlined by Manola *et al.* [16], the modalities of a discussion between policy makers, residents, and experts therefore remain to be defined.

This article explores the hypothesis that participatory measurement could contribute both to an alternative characterization of sound environments and to stimulating the involvement of residents in sound environment issues. The method is therefore presented as a complementary alternative to regulatory noise maps. The idea of smartphone applications to measure sound levels is that each resident can make geo-localized measurements via their smartphone, which are sent to a server where post-processing is carried out [22]. The advantage of this approach, apart from the possibility of collecting data from all over the territory, is to involve the residents in the collection process. Various applications have been proposed over the last ten years: NoiseTube [23], EarPhone [24], Ambiciti [25], or NoiseCapture [22]. However, no experimentation on the constitution of a group of “expert residents” in the long term, based on the dissemination of a smartphone application for measuring noise, has been carried out to date.

This is the objective of the Sonorez   project, which was the result of a collaboration between the city of Rez   and the Gustave Eiffel University. The project includes the recruitment of participants, the creation of participatory noise maps integrating different indicators, and the constitution of groups of residents aiming to develop concerted proposals for noise mitigation. The objectives are twofold: (i) test a protocol for diagnosing noise environments involving residents on a city scale, (ii) evaluate the interest of a smartphone application for measuring noise, namely NoiseCapture, as a vector of this citizen participation in the context of noise. The idea is for the city to be able to draw on resident knowledge when designing new urban developments. At the same time, an assessment is made of how access to this tool modifies the residents’ perception of their soundscape and facilitates their empowerment and the enhancement of their knowledge. The article is organized as follows. Section 2 describes the case study, the smartphone application NoiseCapture, and the framework of the experiment. Results regarding the participatory diagnosis of the sound environment, the residents’ perceptions, and the empowerment questions are given in Section 3. The limitations of the experiment and the further required research to enable the dissemination of the approach to other territories are discussed in Section 4. Section 5 concludes with the next challenges for this

research and its main benefits for noise mitigation that includes both residents and local elected officials.

2 Methods

2.1 Case study

Rezé is a town in the Nantes conurbation with a population of around 43,000, structured by various road and rail routes, close to Nantes-Atlantique airport, and crossed by significant commuting traffic. However, the town also has remarkable environmental amenities: the edges of the Loire and Sèvres rivers, the Jaguère stream, the Illette valley, the urban forest, and numerous green spaces (Figure 1). One of the distinctive features of Rezé is its proximity to the Nantes Atlantique airport. The town is therefore affected by noise pollution plans, as well as by noise-related non-building zones. Some residents, quite educated about noise issues, express the gap between the regulatory noise maps and their own perceptions. In terms of governance, Rezé is led by a citizens' movement. Issues of "citizen dialogue" are central to the municipality, which has set up several participation tools (citizen conference in 2021, citizen consultation vote in 2022, youth and mobility commissions, *etc.*).

2.2 The NoiseCapture application

The development of the Android application NoiseCapture started in 2014, in partnership between CNRS and Gustave Eiffel University [22]. It allows each user to make noise measurements from their smartphone (if it is an Android smartphone, the application not being available yet on iOS). Each noise measurement is combined with its GPS track. No sound recordings are made, and the data collected are completely anonymized, as described in the privacy policy page of the application's website: https://noise-planet.org/NoiseCapture_privacy_policy.html. Once the measurement has been taken, the user has access to the application for his or her exposure during the journey, which can allow him or her to easily visualize the noisy and quiet areas crossed. Finally, a tag mode allows the user to indicate the sound sources heard and the conditions of the measurement (indoor/outdoor, windy, rainy, *etc.*). The data sent by the user are then processed on a server to create an interactive noise map that can be viewed online: https://noise-planet.org/map_noisecapture. Noise maps produced based on NoiseCapture are sensitive

to all sound sources, compared with regulatory noise maps. Thus, the sound levels are closer to those perceived by the residents. On the other hand, in contrast to regulatory noise maps, it is less easy to determine which sound sources can be attributed to the measured sound levels.

The NoiseCapture application has been subjected to numerous tests concerning the validity of the measurements. Ideally, smartphones are calibrated before use, which consists of correcting the sound level given by the smartphone according to the value given simultaneously by a reference smartphone or a sound level meter, and based on a controlled sound source [22]. In this way, a set of up to ten smartphones can be calibrated simultaneously (Figure 2).

Noise mapping methodologies based on the NoiseCapture application have been proposed, including a calibration and interpolation phase [26]. In addition, a dense collection protocol has been designed, called NoiseCapture Party, which has been widely tested (cities of Bastia, La Coruña, Salerno, *etc.*)¹. A NoiseCapture Party is an event that brings together a large number of participants, which makes it possible to cover a large area in a short period and to mobilize the residents around the issue of noise environments. In total, the application has nearly 100,000 contributors worldwide at the date of publication and over 5 years of data collected. All the data from the application are returned to the community as open data under the ODbL license² and constitute, to our knowledge, the largest open database in the world in the field of environmental acoustics. Codes are also open access. Finally, the application serves as an educational tool for numerous interventions [27]. The application has been widely deployed in the scientific community since its creation, and it is used both for educational purposes and for scientific work [28–31]. However, its dissemination in a large-scale experiment as carried out within this framework is an innovation.

2.3 Framework

The objective of the experiment was twofold: (i) to establish a cartography of the sound environments of the city of Rezé based on measurements made by residents, (ii) to constitute an expert group of residents able to discuss the issues concerning the sound environments of the city.

¹ https://noise-planet.org/noisecapture_party.html.

² <http://data.noise-planet.org/index.html>.

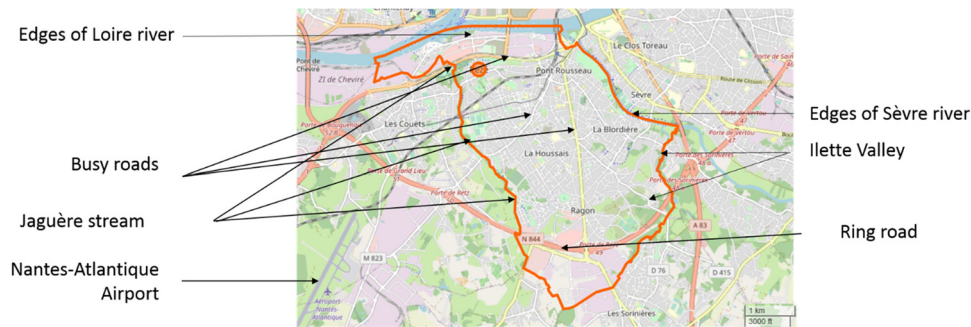


Figure 1: The city of Rezé.

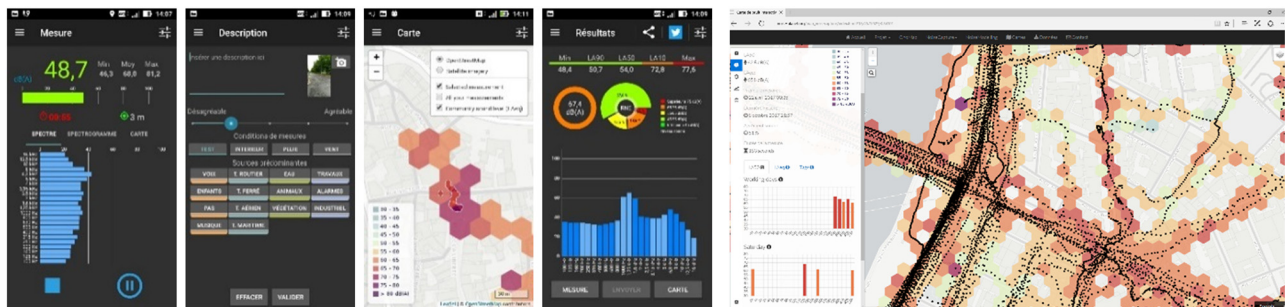


Figure 2: Screenshot of the NoiseCapture application (left) and website for mapping the collected data (right). Source: Bocher *et al.* [32].

2.3.1 Recruitment of participants

A series of events were organized, supported by the city's communication services, in the form of a special section on the city's website and press release, in order to communicate about the project and the search for participants (see their date in the agenda of the experiment in Figure 3):

- A public kick-off meeting brought together more than 30 residents to launch the project on 01 December 2021;
- The project then received media coverage from the regional and national French press during the month of December. This dissemination allowed publicizing the approach while communicating with the general public on urban noise environments issues.
- A special event was organized as part of the “Unesco Week of Sound,” which is an international event that promotes noise awareness, on 15 January 2022.
- One article was published in the city local journal in February 2022.
- Four events were organized on the city's markets in March 2022, during which the project members had a stand and went to meet the residents.

The participation process was completely open. Residents informed of the experiment through the various

communication channels were invited to download the application and take measurements and eventually to approach the researchers to join the group of participants by leaving their e-mail address or join the social network group. The focus group interviews were also the subject of a communication, internally via the group of participants constituted, and through the city's communication services.

2.3.2 Data collection

Data collection lasted 7 months, extending from December 2021 to June 2022 inclusive. The participants were free to take measurements whenever they wished, with the instruction either to take measurements in spots of at least 1 min or to take mobile measurements, taking care not to pollute the measurements with their own steps and to pay attention to the weather conditions (avoid either rain or gusts of wind). In addition, a page dedicated to perception, present in the NoiseCapture application, allowed participants to fill in perceptual variables: tag the sound sources heard (on/off), and give a sound environment pleasantness rating.

A smartphone calibration was carried out at each organized event for participants who wished to do so,

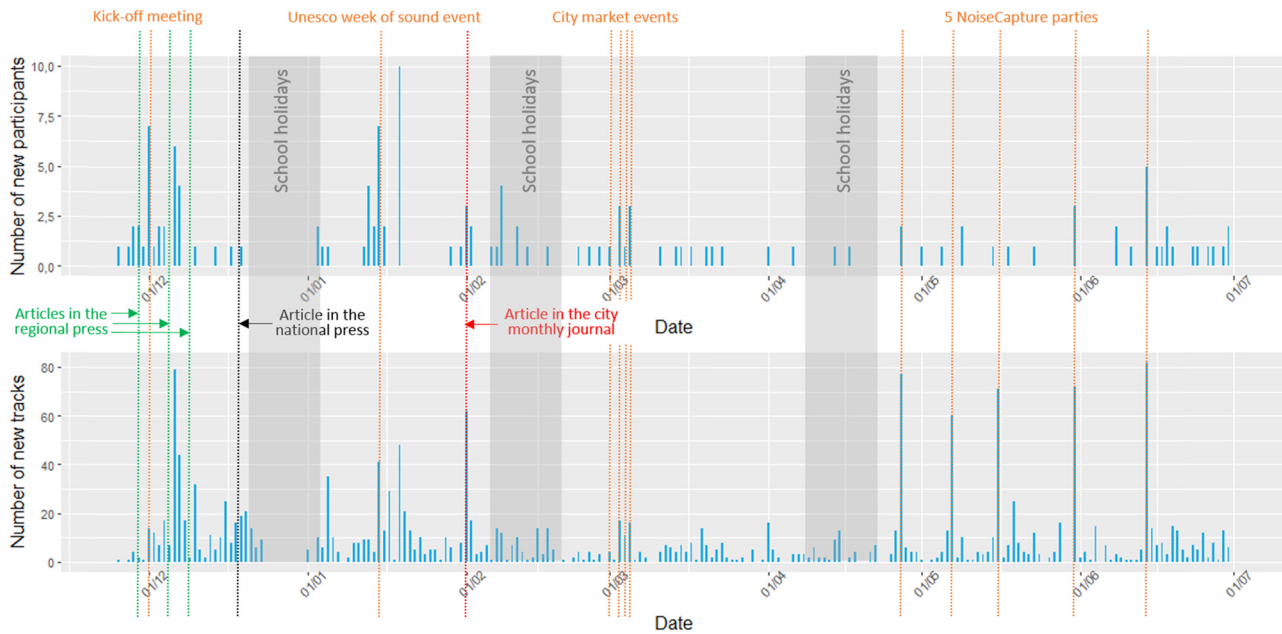


Figure 3: Dynamics of data collection. Top: Number of new measurement tracks as a function of time. Bottom: Number of new participants as a function of time.

in order to improve the quality of the collected data. A mailing list and a social network discussion group were created, in order to maintain the momentum around the project. However, since for reasons of anonymity, it is not possible to know the telephone number of the people who have downloaded the application, it was not possible during the project to send messages to people who are taking measurements and have not left their e-mail addresses. As a result, some of the data collected came from not calibrated smartphones, which the application keeps track of.

Finally, five NoiseCapture parties were organized from the 5th month onwards, with the idea of carrying out measurements in areas poorly covered by the experiment, with internal communication. These NoiseCapture parties took place on 27 April 2023, 07 May 2023, 16 May 2023, 31 May 2023, and 14 June 2023. The idea was to bring together residents to carry out measurements over a period of about 30 min and then followed by an informal discussion on the sound environments heard.

Measurement tracks, which consist of the sound levels and GPS position at a 1 s resolution, the presence of sound sources for the whole measurement track, and meta data (calibration value of the smartphone and Id number of the participant), were sent continuously by the participants through the experiment (an option in the smartphone application allows a participant to either send the data at the end of each measurement track or by batch at a chosen time). Finally, data were post-processed

for the production of noise maps. Therefore, the objective is not to relate the collected data to long-term health impacts but rather to follow a short-time capture approach, more related to short-term disturbance. The influence of measurement duration and timing on the maps produced is discussed in Section 4.1.

2.3.3 Data treatment

2.3.3.1 Production of sound levels maps

Each raw $L_{Aeq,1s}$ collected value is associated with a position, a time value, and Meta data such as a participant Id number, and possibly a calibration value. Each of the raw $L_{Aeq,1s}$ value is then processed in two steps:

- Step 1: Correction with the calibration value. For participant Id numbers with no specified calibration value, a calibration value is estimated, in order to counteract the fact that data from non-calibrated smartphones have a higher variability. The method consists of applying the difference for each non-calibrated smartphone, between the median of the $L_{Aeq,1s}$ values collected with the smartphone and the overall median of the $L_{Aeq,1s}$ values calculated over all the smartphones. This method is a simplified approach derived from the method presented by Can *et al.* [33]. The underlying idea is that a smartphone that systematically gives measures biased by an average given value is highly probably accurate but with a bias of that value.

- Step 2: Once a calibration value is assigned to each smartphone, the next step consists in correcting according to the time of the measurement, in order to counteract the fact that differences in measured sound levels can be due to the moment when the measurement is achieved. The correction for the time of the day is based on previous works, described by Aumond *et al.* [34]. For each hour of the day, taking separately “Monday to Friday,” “Saturday,” and “Sunday,” the difference between the median of $L_{Aeq,1s}$ values at this time slot and the median of all data collected between 8 h and 18 h during a weekday is applied. This way, the produced noise maps are L_{A50} values between 8 h and 18 h during a weekday.

Finally, spatial processing enables the production of the $L_{A50,[8-18h]}$ noise map on a regular hexagonal grid of 50 m sides. The spatial processing consists of a Kriging described in the study by Aumond *et al.* [35]. The variogram and Kriging algorithms presented in this study are computed using the functions vgm (computation of the variogram), fit, variogram (best fit of the variogram), and kriging (Kriging function) of the package gstat [36].

2.3.3.2 Production of sound sources maps

Sound sources maps are produced for the following four sound sources: road traffic, rail traffic, air traffic, and animals. Only the measurement tracks, for which a sound source tag is indicated, are kept for this analysis. In addition, tracks of more than 3 min or 500 m length are filtered out, to avoid assigning tags at the wrong location. This treatment leads to keeping 58.1% of the tracks. A regular hexagonal grid of 50 m sides is created over the study area beforehand. For each of these four sound sources, for each hexagon of this grid, the proportion of tracks containing a tag that intersects with the hexagon, whose tag is that of the source, is represented.

2.3.4 Focus group interviews

In addition to the kick-off meeting, which brought together more than 30 residents, the event of the 15 January 2022 and the five NoiseCapture parties, each of which gave rise to informal exchanges about sound environments, two focus group interviews were organized. These focus group interviews involved elected officials, residents, and researchers, with the idea that the residents freely express themselves on the city’s sound environments, in their positive or negative components. Focus group

interviews are a recurring feature of soundscape research. They are for example used by Bruce and Davies [37] to show the impact of expectations relative to a soundscape on its appreciation, by Jia *et al.* [38,39] to question the dimensions of soundscape worthy of preservation, or by Davies *et al.* [40] to show the descriptive elements used by individuals to describe soundscapes. In the study by Manola *et al.* [16], focus group interviews were conducted to observe the dynamics of the development of a soundscape diagnostic method within different professional (acousticians, space designers, and artists), institutional and resident groups.

The focus group interviews, which lasted about 90 min, were prepared in advance together by the elected officials and the researchers:

- The first focus group brought together nine participants on 4 April: six residents, one local elected official, and two researchers. The residents were invited to bring an object related to their relationship to the city’s sound environment, to initiate a round table discussion. The open discussions were then oriented on the perception of the sound environments of the city, along with questions on the sensitivity to noise and the variety of the listening situations. Questions were then asked about how the experimentation was modifying the participants’ relationship with the city’s sound environment. First elements concerning possible noise mitigation solutions were finally discussed.
- The second focus group brought together seven participants on 18 May: four residents (one of whom had taken part in the first discussion group), two elected officials, and one researcher. After a quick round table discussion, the discussion focused on the links between sound environments and ways of living in the city. A collective discussion then focused on the actions that could be implemented to improve the city’s sound environments, introduced by an overview of possible actions against noise presented by the researcher.

These discussions were audio-recorded, with the verbal informed consent of all participants, to be transcribed for detailed analysis while preserving the anonymity of the participants.

2.3.5 Semi-directive interviews

Ten individual semi-directive interviews with participants were also conducted by a Master 2 student [41] at the end of the project, in order to determine the residents’ reasons for participating in the process and to

understand whether their perceptions of the sound environment had changed and their involvement in the project and their willingness to participate in a citizen's group committed to the issues of the noise environment at the city scale.

2.3.6 Closing seminar

Finally, the project gave rise to a closing seminar on 25 June 2022 for the residents of Rezé. The event included a scientific report, consisting of a presentation of the maps produced and a summary of the focus group interviews. The residents were also invited to give feedback on the experimentation. The seminar also included original artistic performances, as local artists (a saxophonist, a drummer, and a couple of circus performers for three performances of 8 min each) were invited to present improvisations based on an audio sound scene representative of the Rezéan sound environments, composed from field recordings. The project was also accompanied by an illustrator, who helped to make the approach tangible for the residents. Finally, a round table involving residents, the city of Rezé (elected officials and technical services), and researchers was organized. The participation of residents in the diagnosis and improvement of sound environments was discussed, as well as a possible follow-up to the project, with all parties agreeing on the relevance of continuing the experiment.

3 Results

3.1 Insights from the data collection experimentation

3.1.1 Dynamics of measurements

After 7 months of data collection of the experiment, the number of participants was 134. The total number of measurement tracks made was 1,566, for a total duration of 93 h, which is a mean measurement duration of each measurement track of more than 3 min. The median duration of measurement tracks is 66 s; 90% of the measurement track last 6 s or more, and 10% of the measurement tracks last 5 min 40 s or more. The detailed temporal evolution of the number of participants and the number of data collected is depicted in Figure 3. More details on the dynamics of measurements can be found in Can *et al.* [42]. The main results are as follows:

- The importance of the events organized to maintain activity around the community, with a strong increase in the participation observed after each event.
- The constant slowdown in participations, with for instance few measurement tracks collected in March. This shows the difficulty in getting people involved in the measurement in the long term. This is however countered by events such as the NoiseCapture parties organized during the last two months. Indeed, the 5 NoiseCapture parties amounted to 3.9, 1.8, 1.8, 2.8, and 1.9% of the total duration of collected data, respectively, that is a total of 12.3% of the collected data in a short duration.
- The impact of external factors such as school holidays or weather conditions on participation, with almost no data collected during the Christmas school holidays, whereas the good dynamics of the two first weeks of December. In addition, the number of measurements per participant is heterogeneous. Among the 134 participants, 48 participants took five or more measurement tracks, 30 participants took 10 or more measurement tracks, 18 participants took 20 or more measurement tracks, and 4 participants took between 100 and 230 measurement tracks. The same heterogeneity stands for measurement durations. Among the 134 participants, 72 participants took 5 min or more of measurements, 45 participants took 15 min or more of measurements, 22 participants took 1 h or more of measurements, and nine participants took between 3 and 10.5 h of measurements.

The temporal distribution of the collected data is depicted in Figure 4. The distribution of measurements within the week is heterogeneous, with almost three times more measurement tracks collected on Tuesday than on Sunday. The distribution of measurements is also heterogeneous during the day, with a strong peak in the number of collected measurement tracks between 16:00 and 17:00. All time periods between 4:00 and 23:00 are represented, although the times of the day before 7:00 and after 21:00 are poorly covered. The absence of data collected at night explains the choice of selecting the $L_{A50,[8-18h]}$ as an indicator, since data would have lacked for estimating L_{night} and consequently L_{den} values. However, given the data treatment described in Section 2.3.3, which relies on the difference between the median of $L_{Aeq,1s}$ values at a given time slot and the median of all data collected between 8 h and 18 during a weekday, the temporal heterogeneity during the day and during the week has no influence on the calculated $L_{A50,[8-18h]}$ value.

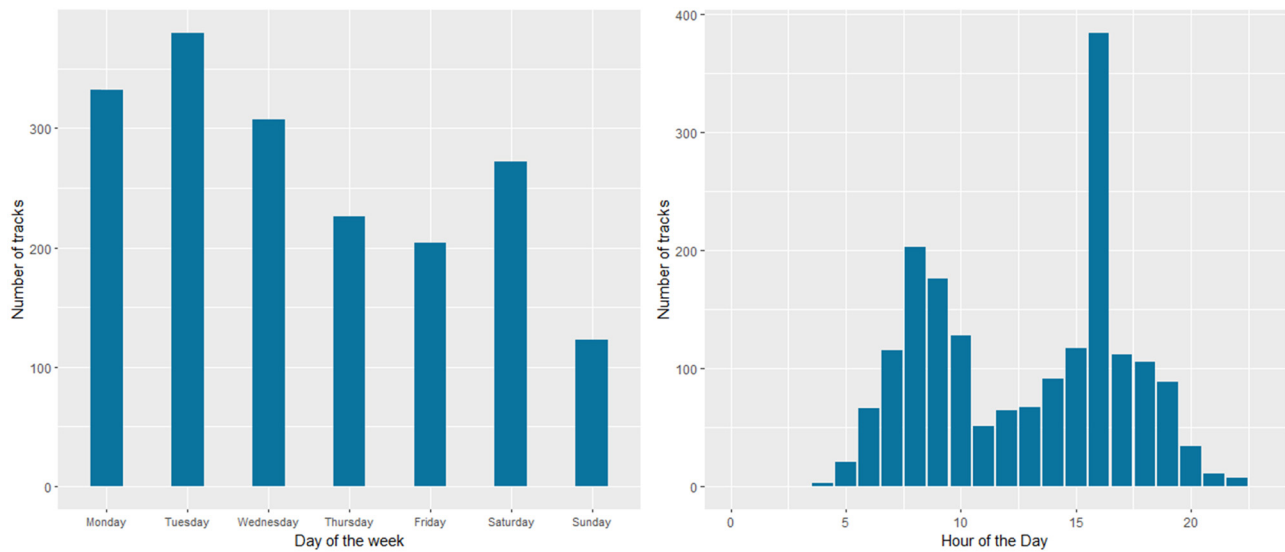


Figure 4: Temporal distribution of measurement tracks. Left: number of tracks for each day of the week. Right: number of tracks for each hour of the day.

The spatial distribution of the collected data is depicted in Figure 5. It highlights the spatial heterogeneity in data collection, with a much higher density of measurements in the north of the city than in the south. This is explained by the fact that the population densities are higher in the north, which contains many buildings than in the south, which contains mainly individual houses. The five organized NoiseCapture parties (see Section 2.3.2 and black circles in Figure 5)

helped to counter this heterogeneity and to gather data in areas poorly covered.

3.1.2 Produced sound environment maps

Sound environment maps were produced following the method described in Section 2.3.3. The maps depicted in Figures 6 and 7 are those that were presented and discussed with the residents during the final seminar on 25/06/2022. Possible improvements to the method are discussed in Section 4.2. The $L_{A50,[8-18h]}$ map depicted in Figure 6 can be compared to the multi-sources (road traffic + rail traffic + aircraft traffic + main industries) L_{den} strategic noise map. The produced $L_{A50,[8-18h]}$ map is in accordance with expectations. It highlights the contrast in sound levels between major and minor roads, although the lack of data around the ring road in the South prevents highlighting the high sound levels here. Interestingly, the produced $L_{A50,[8-18h]}$ map is sensitive to sound level variations in no traffic zones as parks (see North East along the river for instance), whereas the strategic noise map depicts no data here. Some inconsistencies, however, such as high-level spots in quiet neighbourhoods, were noted by residents. They are the result of an insufficiently long data collection, which is thus sensitive to outliers in measurements. In addition, participatory measurements cannot cover all the weather conditions that occur during a year, which are averaged under the strategic noise maps modelling.

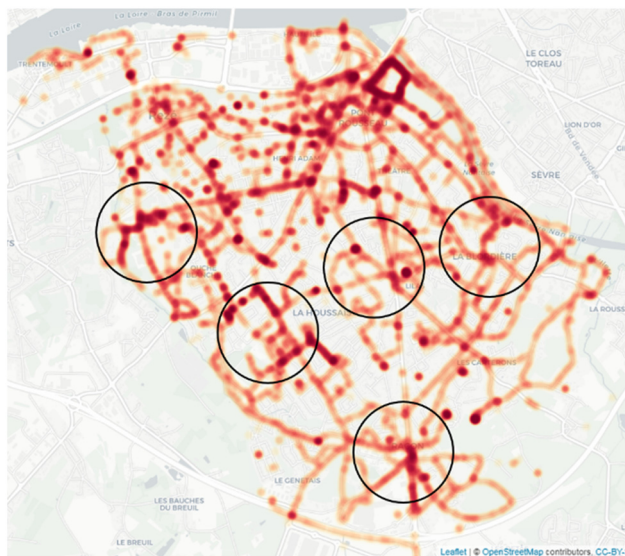


Figure 5: Density map of the $L_{Aeq,1s}$ data collected. The black circles represent the five NoiseCapture parties.

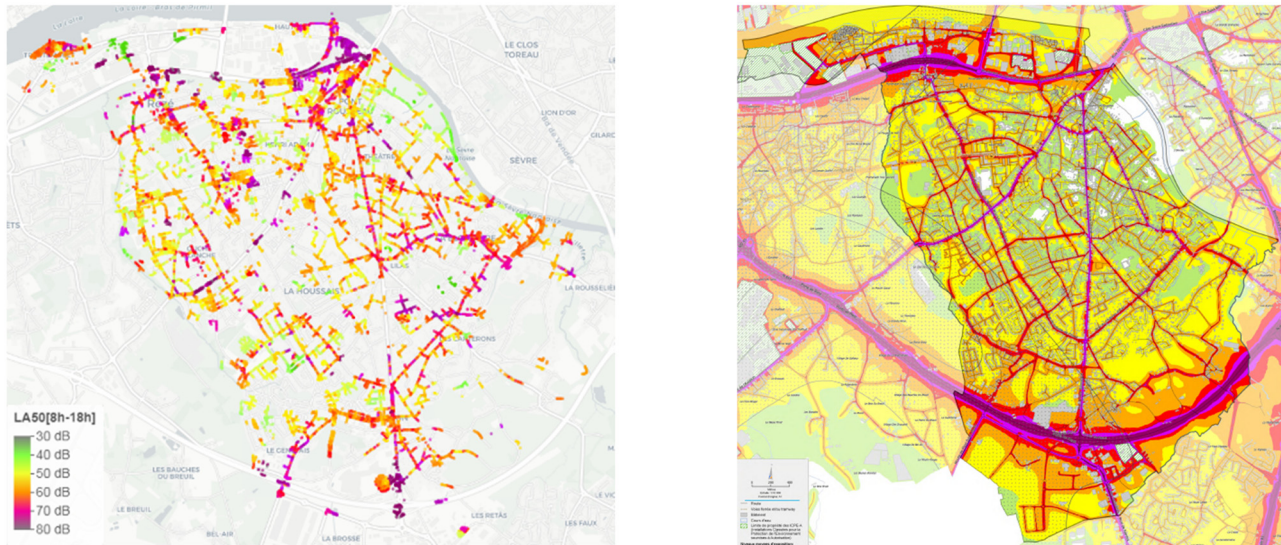


Figure 6: Produced sound levels noise map. Left: map of $LA_{50,[8-18h]}$ produced during the project. Right: multi-sources (road traffic + rail traffic + aircraft traffic + main industries) L_{den} strategic noise map.

Finally, Figure 7 represents the map of the perceived presence of rail traffic sounds, aircraft traffic sounds, road traffic sounds, and animal sounds. These sound sources are selected because they are related to perceived sound pleasantness [4]. The other tags contained in NoiseCapture offer the possibility to map amongst others the perceived presence of voices, children, music, vegetation, water sounds, works, or industrial sounds. The sound source-oriented noise maps are in line with expectations and were considered by the residents during the closing seminar as an interesting alternative to the classical noise maps. The details are as follows:

- The map of the perceived presence of rail traffic sounds follows the tramway line, which crosses the city. It is in accordance with the strategic L_{den} map for rail noise. The rail traffic tag was activated for 3.5% of the tracks that contained an activated tag;
- The map of the perceived presence of aircraft traffic sounds shows a higher density in the heard air traffic sound sources in the south west of the city, as one gets closer to the airport, which is located 4.5 km southwest of the city limits. It is in accordance with the strategic L_{den} map for aircraft noise. The air traffic tag was activated for 28.3% of the tracks that contained an activated tag;
- The map of perceived presence of road traffic sounds shows a high density in the heard road traffic sound sources everywhere in the territory. This map however fails to discriminate between major and minor roads, as the sound sources tag under NoiseCapture is “on/off.”

The road traffic tag was activated for 80.4% of the tracks that contained an activated tag;

- The map of the perceived presence of animal sounds is consistent with the parks and green areas of the city, hence potentially highlighting areas suitable for restorativeness. The animal tag was activated for 30.8% of the tracks that contained an activated tag.

3.2 Insights from the focus group and the semi-directive interviews

The transcripts of the focus group and the semi-directive interviews were analysed according to a reading grid stressing the dimensions of diagnosis, impact of the experimentation, and empowerment. The two focus group interviews involved six and four residents. The semi-directive interviews involved ten residents (Section 2.3.5). These were not necessarily those who were most active during the data collection phase. For example, two participants said that they had not taken any measurements because they did not own an Android smartphone. Others acknowledged that they had taken very few measurements. Different profiles of participants can be drawn from the participants in these focus groups. Some participants came to the experiment clearly with a negative a priori about the city’s noise environments, some belonging to the anti-airport noise association. Some participants came out of political sympathy for the elected team, and some belonged to the local elected party. Some participants were young

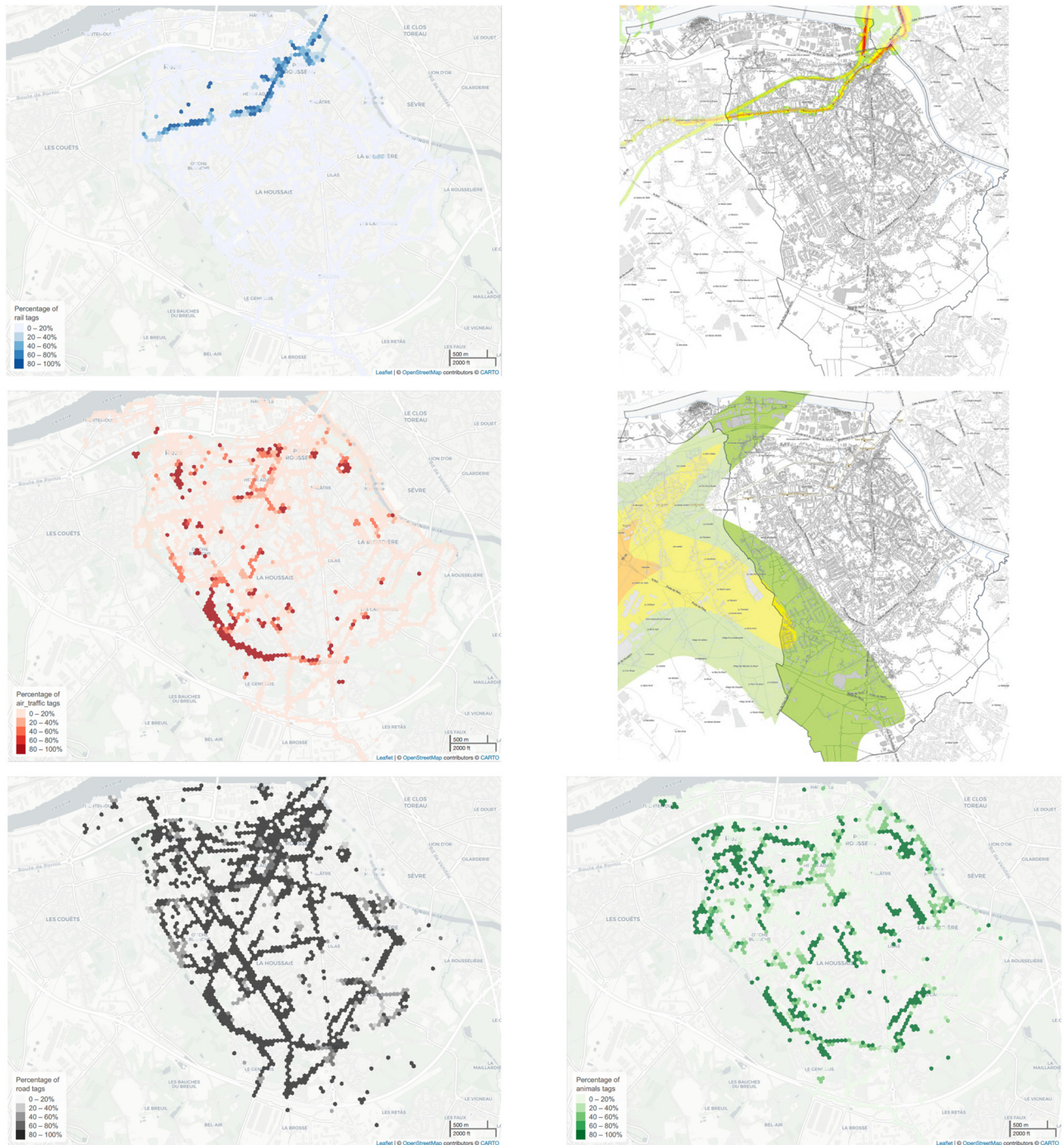


Figure 7: Sound-oriented noise maps. Top left: map of perceived presence of rail traffic sounds. Top right: strategic noise map for rail noise. Middle left: map of perceived presence of aircraft traffic sounds. Middle right: strategic noise map for aircraft noise. Bottom left: map of perceived presence of road traffic sounds. Bottom right: map of perceived presence of animals.

retirees involved in local life associations. The detailed contribution of the participants in the focus groups and semi-structured interviews is given in Appendix 1 (Table A1). For ease of reading, the quotes are transcribed in English; the exact texts, in French, are given in Appendix 2 (Table A2).

3.2.1 Towards a discursive diagnostic of sound environments

The focus group interviews drew up a discursive diagnosis of the sound environment of the city of Rezé, highlighting the diversity of the sound sources heard in the

area, but also the diversity of perceptions and the importance of the different temporalities making up the city's sound environments.

3.2.2 Diversity in sound sources, perceived both negatively and positively

Two sound sources were at the core of the discussion and on which there was consensus, namely road traffic and air traffic, illustrating the concerns of residents of a city crossed by significant commuting traffic and under an air corridor of an airport located less than 5 km away. Air traffic, in the first place, focuses the attention and is a source of exasperation manifested by the residents: *"I remember one morning at the end of the summer... I sleep with the window closed, it's not possible otherwise... and even so, with the window closed, I had about ten planes taking off between 6 and 7 in the morning, it was hellish."* (P2). Road traffic, perceived more as a continuous stream present without respite at all hours of the day, is also a source of exasperation: *"I really have the impression that now; maybe even more in the South of the ring road, there is traffic all the time! All the time! At any time of the day. and then in the morning, it's incredible [...] And it's trucks, trucks, trucks."* (P2).

Other sound sources perceived negatively, which may seem more anecdotic but which constitute urban sound mixtures, were also mentioned, such as glass containers, stadium, or manhole covers. It seems that, for these sound sources, further focus group interviews involving new participants would multiply the diversity of testimonies: *"I witnessed it one day, in the Place du 8 Mai, people were putting in the receptacle for the glass, a horror. I didn't have the application to measure the noise, but it was really a horror."* (P11). *"There is another noise that is quite infernal, and I didn't think it would be so much, it's the stadium"* (P2). *"The manhole cover... the trucks when they pass over it, and then as it is always in bad balance it... 'clong clong'"* (P3).

The focus group interviews also drew a portrait of a city with quality sound environments, driven by green spaces and preserved residential areas. Hence, sources such as parks (cited as a location rather than as a sound source), music, or birds were cited: *"Then there are three parks there, I don't know if you know the area... which are rather pleasant, and if I have to take one of the parks, there is a square behind the buildings, so it's quite protected from all the road noise, passage... and when you're there, you don't feel like you're in the city."* (P7); *"There are some very pleasant noises, not only the noise of planes. I live not*

far from the Balinière, between the planes I hear very pleasant things, as it's the music school, we walk in the streets, we enjoy the children and adults who play at the Balinière school, and it's true that in the summer in particular, it's great because they have the doors and windows open there, and so do we, and everyone in the district enjoys it. It's very pleasant, the piano, the violin..." (P12); *"It's a cherry blossom tree, where there are a number of birds, and they make the most noise."* (P9).

3.2.3 A diversity in perceptions among the residents

A strong link between the perceptions expressed by the residents, their living environment, and their experience of sound appeared in their comments. The perceived sound environments thus take on an individual dimension, which leads to a lack of consensus on certain sound sources, such as stadiums or cafés: *"No, there is a need for cafés. The new café on Charles Rivière Street, I find it closes early."* (P9). *"And I find that the streets are very pleasant, when I'm on my terrace I can hear the children in the playground on rue Salengro. It's something that reassures me, it's lively at the same time [...] I actually love this neighborhood."* (P12).

Finally, the discourse on sound environments was accompanied by a psychological dimension, which is known from the literature and is widely acknowledged and expressed by the residents. This is particularly true when the discussion focused on mobility or aircraft noise: *"Noise is very strongly linked to the psychology of noise association. Personally, there is a big problem with airplanes, it's not just the noise, it's a next step, I think ok the problem with airplanes is the conflict between modern society which says we must protect the planet, take the plane less often, the CO₂ and then we see the traffic increase. And when I think afterwards, all the citizens of Nantes who say ok we have to reduce CO₂, and then they take the plane for the weekend to go to Portugal for a drink with friends. It's not consistent for me, and maybe that adds to the aggression against noise."* (P4).

3.2.4 Sound environments as temporal markers

The discursive description of the sound environments finally inscribed noise as a strong temporal marker. Participants in particular shared the strong expectation of quiet periods. So much so that one of the residents brought back a calendar as a significant object of her perception of the city's sound environments: *"I brought*

this: [...] it's a calendar, and I put Sundays in fluorescent, because Sundays are really much nicer, when you open a window in the morning... so here I have all the Sundays in April, and then I have a public holiday, and public holidays are even better than Sundays." (P10); "On Sunday mornings, the noise from the ring road is reduced by three. you get a feeling of calm." (P3).

As a result, the noise was described by the participants as even more violent aggression during the periods considered as restful: "The entrance to the MiN for example [national interest market]... lorries coming from the road... Well... there is traffic at 3 am." (P3); "There will always be traffic, and for the noise, well, there will always be a car passing by and during the night, as there is no traffic, it will pass quickly, it will accelerate." (P7); "Because between 6 and 7 o'clock in the morning that's when it takes off the most." (P2).

3.2.5 How participating in experimentation changes the relationship to sound environments

Another interesting point emerging from the discussion was the modification of relationships to sound environments induced by experimentation, which can be broken down into an increase in technical expertise and a greater sensitivity to societal issues. The use of the smartphone application initially led them to listen to their sound environment in a more conscious way: "Already during the recordings, it's something quite phenomenal, but the fact of recording opens us up to all the noises around us, so that, on a personal level, it's rather nice because it reinforces the sense of hearing and listening." (P8). By measuring sound levels and carrying this careful listening to sound environments over a period of several months, participants learned about ambient sound levels and realized that sound levels were not the only thing shaping their perceptions and feelings. Repeated listening to sound environments lead them to distinguish between sound level and perception: "The first two things that surprised me were the rumor, which was something that had been bothering me for a few years, and then when I measured it I realized that it wasn't loud, and the noise of the birds, which is really loud in my garden and doesn't bother me at all." (P9); "Then another thing, it's SonoRezé that made me aware of this, it's the noise of the birds, so a pleasant noise. They are really present, there are a lot of birds." (P14). If some people are bothered by the noise of a constant rumor, others are more sensitive to the contrast between rumor and emergencies: "For me it's a contrast between silence or very quiet areas, because where I live

there are a lot of private houses, it's rather quiet [...], but then there are noise peaks that come. [...] I hear, not the ring road, but the road to Pornic I think. And that's a very diffuse noise, continuous, and it doesn't bother me much, but I think that the peaks are really not pleasant." (P4).

This conscious listening initiated by taking measurements also led them to distinguish places that seemed pleasant from a sound point of view, because they were lively and animated: "The whole walking area along Trentemoult because it's quite noisy but it's nice noises, even if it's only the Navibus, it's a little boat noise, we're close to the Loire, there are noises of discussions, cheerfulness, it's lively." (P8). Other places exposed to low noise intensities seem to be unpleasant to them, because of either the permanence of the noise: "The ring road has been a permanent background noise for the last 2 or 3 years, especially in the morning, and when I measured it, it's not very loud." (P9), or the type of noise and the meaning given to it: "I have the impression that all the noises that bother us the most are manufactured noises, not natural noises. It's things that we are subjected to because it's traffic, it's planes... it's things that are mechanical in fact." (P2).

For some participants who had a negative perception of their city's sound environments, taking measurements lead to an awareness of the complexity of sound environments and of the presence of positive sound sources as well: "With the project I started to see the positive noises. Because before I had a very big focus on negative noises. As this app has little buttons for animals, children, I said ok there are positive noises too." (P4); "Now I am more attentive to unpleasant noises AND a little more attentive to pleasant noises, that's true. Because before it was the total absence of noise that I considered pleasant, but that is not always the case, there are pleasant noises too." (P4); "For me, who is on the Avenue Général Leclerc, there are a lot of bicycles that go by and I have to admit that it is a lot quieter than the cars, so it is more pleasant. So that allowed me to highlight the positive points rather than the negative ones." (P6).

On the other hand, the experiment reinforced negative feelings towards certain sound sources too. This was the case in particular for road traffic and its humming present throughout the territory. For these residents, taking part in the experiment was therefore a possible source of increased annoyance: "Before there was noise, I didn't pay much attention, now I pay more attention." (P9); "Since I have the approach in mind, I listen! In fact, I'm becoming obsessed; I can hear the ring road." (P13); "When I go to people's houses or when I go to a new place, it's immediately "can we hear the ring road"... and it's

hellish!” (P2). Some have become aware of the possibility, at a short distance, to access quieter places: *“The other time when we did the measurements [...] I just had to move 200 m away and I didn’t perceive the noises of this busy street anymore.”* (P11). Finally, the participants in the process were able to distinguish the neighborhood unpleasant places because they are noisy: *“There is the road to Pornic of course. [...] but the road to Pornic is unpleasant because it is very busy.”* (P6), and quiet places: *“There are peaceful places by the rivers, by the Loire or by the Sèvre, a real treat!”* (P2), *“Well, these are the two areas that I know well, and they are pleasant because it is very green, the Jaguère there is a small forest and you can no longer see the buildings, there are birds and it is quite calm.”* (P4).

3.2.6 Towards the formation of a group of residents empowered to discuss improving the sound environment

Several signals from the participants in the process allow us to perceive the potential of the formation of a group of motivated residents who can increase their expertise on sound environment issues.

First of all, although they are not experts on the subject, they have for them the mastery of use and the search for solutions on a daily basis, sometimes developing strategies to avoid noise: *“I ride my bike a lot, so I don’t take my street by bike, I immediately turn off to another one, for my ears, for my safety.”* (P1); *“It’s obvious, all the main roads are noisy because of the traffic. On the other hand, when I go to the market by bike or on foot, I always manage to go through the back streets that are not busy.”* (P5). They show curiosity and reflexivity on the issue of noise: *“I wonder if the noise models are accurate. You see the planes directly; there is nothing to stop the noise. On the other side of the street, my house blocks the noise and for the neighbors it’s ok.”* (P4), about the phenomena that cause it: *“When the winds are dominant you can hear the ring road”* (P3); *“So when it’s an easterly wind, there’s clearly much more noise. When it’s an easterly wind, we’ll have, for example, the noise of planes landing, which is reduced”* (P14), and how it should be taken into account by society: *“When I speak with colleagues, they ask me the problem for you is CO₂, pollution? I answer no, it’s noise. it is not present in the society I find.”* (P4).

There was also a desire to join a collective project. Out of the ten semi-directive interviews conducted after the project, half of the interviewees said they were interested in the subject and the approach, beyond the consideration of their own exposure to noise, and said they

were motivated by the fact that they were involved in a common project on their territory of life: *“Because I found the subject interesting, and then it’s also a way of participating in the city of Rezé and in what is happening there. I can’t say that it’s a form of commitment because the commitment is weak but there is a bit of that, you can’t just be a spectator, from time to time you have to be an actor too.”* (P5); *“I was interested in being able to contribute to a common project with a rather original and innovative approach to taking noise pollution into account, a subject that is not necessarily put forward regularly.”* (P8).

This participation in a collective encourages a certain empathy among the participants, allowing them to put their personal cases into perspective and to have a more global vision of the noise experience in their city. The latter managed, as passers-by, to adopt the point of view of the residents and even to extrapolate these experiences, in order to develop a collective diagnosis: *“I feel sorry for the people next door [...] It’s a punctual thing, but it’s repeated many times...”* (P3); *“I don’t hear them at home but I put myself in the place of the people next door.”* (P12); *“I can’t imagine the nuisance it will cause to the population”* (P11); *“I assume that for the people living nearby it must be very impactful.”* (P11).

The residents who participated in the process also showed their lucidity regarding the past and current mutations of the city as well as their repercussions on the daily sound environment. Changes have been noted in terms of new forms of mobility: *“There is a noise that appeared two years ago, at the beginning, it made me strain my ears all the time. Today it has become THE noise of the city as I have integrated it... it is the noise of the scooter that stops... and then, that looks for where it is going to deliver.”* (P10).

The residents described too, through the discourse on noise environments, a changing city, and the burden of rapid urbanization on the sound environments and the lives of the residents: *“Very stupidly, I thought that I would escape very quickly to the green by settling here. It’s true that in 15 years this environment has changed a lot [...] it was really the old village of Rezé.”* (P10); *“In Ragon 15 years ago I remember having breakfast outside during the week... and not today!”* (P10); *“I was very disappointed that the part along the river had been concreted, it could have become a very beautiful green area. But 12 or 15 years ago it was not yet on the agenda, we concreted more than we greened the cities.”* (P5).

The last point, which concerns local issues and actions to be taken, drew a portrait of residents educated in health issues and practices that lead to sound environments of quality: *“That was my question too, how bad is the noise?”*

This permanent background noise or this instantaneous noise?” (P3), and aware of practices that lead to sound environments of quality: electric vehicles, silent pavements, residential areas. Although it is not possible to know whether this knowledge preceded the experimentation, this point suggests an educated debate on the possible mitigation of noise using innovative materials or a certain design of the space: “Electricity is great for that, for noise it can change a lot of things.” (P7); “They now use a form of surface coating, when you drive by it’s much quieter all of a sudden... have you noticed that?” (P7); “I confirm I live in a housing estate, you come in from a street, a roundabout, you come out from the same place, as soon as you’re behind you don’t hear anything. There is no passage.” (P9); “For me, the main axis that could make the sound evolve in the city is really not to do 100% road.” (P8).

These discussions were also the place to question the elected representatives present on certain elements, such as urban planning rules, which are perceived as an injustice in the face of noise: “Who accepts building 20 m from the ring road? I mean, come on!” (P3); or to show legislative inconsistencies in their view of noise management: “We wonder why it’s forbidden to use the lawnmower in the garden on Sundays, and why planes can fly.” (P4). Finally, the fight against noise requires, according to the participants, a collective awareness and a modification of mobility practices: “For me, we are responsible for this, as citizens. it is our way of life that creates this noise...”, (P2) “I’m happier riding a bike than driving a car in the city. I’m always on time for my appointments, it doesn’t cost me anything, I don’t make any noise, I do some sport...”, (P2); “We must discourage people from taking their car” (P2).

4 Discussion

4.1 Discussion on the experiment

A methodological framework is proposed for the constitution of a group of residents educated on the question of sound environments and able to contribute to the diagnosis and decisions. The original experimentation drawn up is in itself rich in lessons. One of the conclusions concerning the dynamics of participation of the residents is the strong impact of the energy put into the animation of the network of participants, with increases in participation observed after the public interventions and the communication sequences. It is therefore quite difficult

to draw up transposable conclusions, insofar as the project team was involved in the protocol: what seems to be a low or high level of mobilization is partly the result of the energy put into the animation. Other experiments, testing other facilitation methods, in other territories, will allow confirming the elements that work or not. It is however already possible to give hints on some points concerning the participation regarding data collection: (i) a beginning of the recruitment in winter, as proposed here, is undoubtedly handicapping, with a decrease in the measurements certainly related to the climatic conditions, (ii) the proposal of collective measurement sessions, as it was done from the fifth month, is, according to the residents, very efficient to maintain the interest around the project. Finally, the study area, the city of Rezé, had the difficulty of being relatively sparsely populated, with 3,120 residents/km², which reduced the number of people recruited per km² and therefore the density of measurements expected. This figure can be compared with the density of cities such as Lyon and Barcelona, where NoiseCapture parties already took place, and which have respective densities of 10,909 residents/km² and 16,675 residents/km². The production of noise maps and citizen diagnostics would be facilitated in such cities.

A question arises about the social profile of the participants and the impact that the experimentation had on the relationship that the participants develop with the sound environments. A bias observed in this experiment in the representativeness of the participants in the focus groups is the absence of the category of people under 30 years old, which may make the views of this category invisible. Regarding participants’ motivation to get involved, studies show that people annoyed by noise are more likely to participate in noise discussion groups and that aircraft noise generally induces more protesting behaviour than road traffic noise [43]. One could therefore have expected to see the discussion groups or even the diagnostic phase by measurement, monopolized by the city’s anti-airport associations, which was not the case. Some participants clearly expressed their exasperation with noise, and in particular with aircraft noise, and some participants indicated their membership in anti-noise associations, which are thus over-represented in the sample of participants. Nevertheless, the wide range of topics addressed during the discussions shows the openness of the participants, whose interventions were constructive and not limited to the annoyance due to aircraft noise.

Although difficult to demonstrate, a rise in expertise with regard to noise issues seems to be observed, with residents illustrating their arguments with acoustic data

in decibels, for example (Section 3.2.2). This result echoes work that has shown that taking repeated measurements allows participants to better recognize the noise levels in decibel values to which they are exposed and a finer determination of soundscapes [44]. Finally, the study showed that the focus on sound environments that implies in this framework repeated measurement and careful listening could reinforce negative feelings about unpleasant sound environments for some participants. Some of them, such as P9 and P13, even reported an obsession. This echoes recent work, which showed that communicating with focus group participants about noise exposure increased awareness, to the point that some may regret having had this knowledge [37]. However, this is not the case in our study, where it is rather militant anger that has been aroused than regret.

4.2 Expected technical ameliorations

The statistical processing proposed in this article is relatively simple and is limited to the one performed to produce the maps presented to the residents during the project presentation meeting. The three phases of data processing presented in Section 2.3.3 could be refined. The calibration phase could integrate a better qualification of the input data, as underlined by Picaut *et al.* [45], by introducing information about the technical performance of the smartphone and the measurement protocol or detecting anomalies in the collected data. Spatial information such as the street category could be integrated, when comparing the values to those of the rest of the smartphones. The temporal profiles could also be refined, also using a categorization of streets, as it is done for example in the study by Can *et al.* [46]. Spatial interpolation could also be improved, using for example Kriging functions [35]. Even so, the lack of data and the spatial heterogeneity of the collected data constitute a basic shortcoming for the production of a representative noise map over the entire territory. The NoiseCapture party approach developed at the end of the project greatly improves on this point, as it allows dense data collection in a short time. In addition, a limitation of the production of a noise map based only on smartphone data is the difficulty of reconstructing daily average noise patterns, which vary over the territory. The absence of data at night is also a limitation, in particular in view of determining sleep disturbance. One avenue of research to investigate for the future is to rely jointly on smartphone measurements and a fixed measurement network. Combining mobile

measurements and a fixed measurement network, the latter capturing temporal variations has proven effective by Can *et al.* [47]. This work could also build on the recent results of deploying low-cost sensor networks [41,48,49]. If no measurement network is deployed in the city, it would be of interest to be able to get a few highly motivated participants living in strategic locations to take continuous measurements for a few days. Finally, the protocol for mapping the perceived time of presence of sound sources could be improved. It is not clear for instance if the absence of a tag, which is not included in the protocol, is relevant information that should be accounted (in the proposed protocol, the ratio of tags of a given sound source is represented, calculated amongst the measurement tracks that include a tag).

The experimentation also allowed pointing out areas for improvement concerning the NoiseCapture application. The lack of development on iOS was regretted by some participants and can be easily countered by making available reconditioned smartphones, in the form of a mobile sensor library. Finally, the application could be technically improved to get closer to the soundscape paradigm [8], by integrating for example questions about the animated character of the sound environment and asking the heard sound sources on continuous scales, as recommended [50], where the NoiseCapture application only queries a presence through an “on/off” tag. An automatic identification of sound sources within the application is also envisaged for the future, adapted from the deep learning techniques developed in [51]. Finally, work on the representation of the maps is required to improve their comprehensibility for elected officials and residents. This requires work on the graphic semiology, as well as technical questioning on the automated sharing of the maps via a web interface.

4.3 Discussion on the perpetuation and deployment of the framework

One of the stakes for the perpetuation of the framework is to be able to support the decisions relating to the sound environments of the groups of expert residents constituted. As discussed in Section 4.1, the number of participants does not allow concluding on the possibility of building the long term because it is very dependent on the investment of the researchers in the experimentation. However, some indicators suggest a long-term involvement of the residents. First, a discussion on the definition of quiet zones, organized by the city of Rezé 5 months

after the end of the experimentation, gathered eight residents, including seven members of the project. Second, a question asked during the debriefing seminar established that 78% of the respondents (14) wish to be involved in the long term. The long-term (several years) involvement of participants in participatory sensing cannot be analysed in the framework of this study. It is likely that a large proportion of the participants who are attracted by the measurement process will turn away from the experiment over the long term. This is probably not detrimental from the point of view of characterizing sound environments, as the turnover in participants is already high on a scale of a few months. A long-term operational issue is the possibility of testing changes in noise environments as a result of noise control measures (potentially as a result of a co-construction with residents), based on participatory measurements. This would require the involvement of participants over a period of several years or the targeting of specific measurement campaigns with strong community involvement. This question cannot be answered within the framework of this study. Finally, a completely open protocol was tested in this article. It would be interesting to test sampling strategies with more guidance for the participants or with the involvement of the city's technical staff.

In addition, the semi-directive interviews made it possible to question whether the expectations of the participants were met [52]. The conclusions are as follows. Regarding their relationship with the sound environment, most of the participants were at least a little sensitive to the subject of sound because of their experience; they felt concerned and wanted to get involved in this research subject. This project allowed them to realize how important sound quality was in their daily lives. The majority of the residents tended to say that they did not involve themselves enough, not because they did not want to, but mainly because they were not sufficiently available. However, most of them are waiting to see what kind of dialogue will be established with local officials and what the project will lead to and are waiting for possible solutions that could have been proposed. This is undoubtedly a crucial issue for the continuation of the residents' involvement in a participatory process like this one. However, the participants all remain globally satisfied with the project and, for the most part, plan to continue the adventure if it were to be repeated.

Finally, a question arises as to how to implement such a protocol in other territorial contexts and without the intervention of the research team. The positive results discussed in this article concerning the involvement of residents and local elected officials are certainly partly

dependent on a favourable context. The city's elected officials are part of a citizen movement promoting social dialogue and the involvement of residents in decision-making. Moreover, on the side of the residents, the city of Rezé is also a promising territory for citizen participation in noise, with some participants belonging to anti-noise associations or who belong to the local political movement association. A next step will be to extend the experiment to other territories of different sizes, with different social and sound contexts, to understand how the protocol can be extended. This work is planned within the framework of the Sonorezé II project, funded by the French National Research Agency (ANR). It is planned, in this second part, to work with various territories (dense cities and small towns), to develop an analysis grid of the project to understand the success factors of the approach. Finally, it will also be useful to analyse in greater detail the interplay between the "researchers/residents/local elected officials" triptych. One of the challenges for the success of the process is to ensure a balance in this triptych. For this reason, it is interesting to note that the second part of the project will include the presence of a Third Party Monitor, whose role is to offer an outside view, and to identify the sources of misunderstanding, misunderstandings or tensions between the partners, and to provide solutions.

5 Conclusion

A framework was set up, under a case study in Rezé (43,000 residents), to involve the residents in the process of characterizing the city's noise environments and to set up a community of residents aware of the noise issues and able to carry out discussions regarding sound environments in liaison with the local authorities. Participatory noise data collection and focus group discussions form the core of this framework. The conclusions are as follows:

- A noise map of the territory can be supported by participatory data collection, although some improvements to the method are listed, such as the improvement offered by organized collective measurement sessions, which help to cover the territory more homogeneously.
- Maps representing the perceived presence of urban sound sources (road traffic, rail traffic, aircraft traffic, and animals in the case study) can also be produced.
- The experiment enabled the creation of a group of residents educated to the noise issue, favoured by the use of the smartphone application NoiseCapture.

- The focus group discussions draw up a portrait of residents on whom elected officials can rely to build concerted decisions related to sound environments.

The next step of this research will be to understand how this protocol can be deployed over various territories.

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Data availability statement: All the data from the NoiseCapture smartphone application are returned to the community as open data under the ODbL license, and can be downloaded here: https://noise-planet.org/noisecapture_exploit_data.html.

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Appendix

Appendix 1. Detailed contribution of the participants to the focus group and semi-directive interviews

Table A1: Details of the participation of participants amongst the two focus group interviews and the semi-directive interviews

	Focus group interview from 06/ 04/2022	Focus group Interview from 18/ 05/2022	Semi-directive interview
P1			×
P2	×		×
P3	×		×
P4		×	×
P5			×
P6			×
P7	×		
P8			×
P9	×	×	×
P10	×		
P11		×	
P12		×	
P13	×		
P14			×

Appendix 2. Details of the citations quoted in the article

Table A2: Original citations in French with their translation in English as quoted in the article, and their origin

Original citation	Translation in English reported in the article	Origin of the citation
<p>“Moi je me souviens d’un... matin à la fin de l’été là... euh donc moi je dors fenêtre fermée hein, c’est pas possible sinon... et quand même fenêtre fermée j’ai eu une dizaine d’avions qui ont décollé entre 6 h et 7 h du matin, mais c’était infernal quoi.”</p> <p>“J’ai vraiment l’impression que maintenant, peut-être encore plus dans le Sud du périphérique là, mais y a la circulation mais... tout-le-temps! Tout le temps!! A n’importe quelle heure de la journée... et alors le matin mais... c’est incroyable quoi [...] Et c’est des camions, des camions, des camions.”</p> <p>“J’ai été témoin un jour, place du 8 mai; les personnes mettaient dans le réceptacle pour le verre, une horreur. Je n’avais pas l’application pour mesurer le bruit, mais vraiment c’était une horreur.”</p> <p>“Y a un autre bruit aussi qui est assez infernal, et je pensais pas que ça serait autant, c’est le stade.”</p> <p>“La plaque d’égout... les camions quand ils passent dessus, et puis comme elle est toujours en mauvais équilibre ça... “clong clong””</p> <p>“Après y a 3 parcs là-bas, je sais pas si vous connaissez le coin, et... qui sont plutôt agréables, et si je dois prendre un des parcs y a un square qui est derrière les immeubles, donc assez protégé de tout ce qui est bruit routier, passage... et quand on est là-bas, on a pas l’impression d’être en ville.”</p> <p>“Il y a des bruits très agréables quand même, il n’y a pas que le bruit des avions. J’habite pas loin de la Balinière, entre les avions j’entends des choses très agréable, comme c’est l’école de musique, on se promène dans les rues, on profite des enfants et des adultes qui jouent à l’école de la Balinière, et c’est vrai que l’été notamment, c’est super parce qu’ils ont les portes et les fenêtres ouvertes là-bas, nous aussi, tout le monde en profite dans le quartier. C’est très agréable, le piano, le violon...”</p> <p>“C’est un cerisier fleur, où il y a un certain nombre d’oiseaux, et c’est eux qui font le plus de bruit.”</p> <p>“Non il y a besoin de cafés... Le nouveau café rue Charles Rivière, je trouve qu’il ferme tôt.”</p> <p>“Et je trouve que les rues sont très agréables, quand je suis sur ma terrasse j’entends les enfants dans la cour de récréation rue Salengro. C’est quelque chose qui me rassure, c’est vivant en même temps [...] effectivement j’adore ce quartier là.”</p> <p>“Le bruit est lié très fortement à la psychologie qu’on fait association bruit. Moi personnellement il y a un grand problème avec les avions, c’est pas que le bruit, c’est une</p>	<p>“I remember one morning at the end of the summer... I sleep with the window closed, it’s not possible otherwise... and even so, with the window closed, I had about ten planes taking off between 6 and 7 in the morning, it was hellish”</p> <p>“I really have the impression that now; maybe even more in the South of the ring road, there is traffic all the time! All the time! At any time of the day... and then in the morning, it’s incredible [...] And it’s trucks, trucks, trucks.”</p> <p>“I witnessed it one day, in the Place du 8 Mai, people were putting in the receptacle for the glass, a horror. I didn’t have the application to measure the noise, but it was really a horror.”</p> <p>“There is another noise that is quite infernal, and I didn’t think it would be so much, it’s the stadium.”</p> <p>“The manhole cover... the trucks when they pass over it, and then as it is always in bad balance it... “clong clong””</p> <p>“Then there are three parks there, I don’t know if you know the area... which are rather pleasant, and if I have to take one of the parks, there is a square behind the buildings, so it’s quite protected from all the road noise, passage... and when you’re there, you don’t feel like you’re in the city.”</p> <p>“There are some very pleasant noises, not only the noise of planes. I live not far from the Balinière, between the planes I hear very pleasant things, as it’s the music school, we walk in the streets, we enjoy the children and adults who play at the Balinière school, and it’s true that in the summer in particular, it’s great because they have the doors and windows open there, and so do we, and everyone in the district enjoys it. It’s very pleasant, the piano, the violin...”</p> <p>“It’s a cherry blossom tree, where there are a number of birds, and they make the most noise.”</p> <p>“No, there is a need for cafés. The new café on Charles Rivière Street, I find it closes early.”</p> <p>“And I find that the streets are very pleasant, when I’m on my terrace I can hear the children in the playground on rue Salengro. It’s something that reassures me, it’s lively at the same time [...] I actually love this neighborhood.”</p> <p>“Noise is very strongly linked to the psychology of noise association. Personally, there is a big problem with airplanes, it’s not just the noise, it’s a next step, I think ok</p>	<p>P2, FG1</p> <p>P2, FG1</p> <p>P11, FG1</p> <p>P2, FG1</p> <p>P3, FG1</p> <p>P7, FG1</p> <p>P12, FG2</p> <p>P9, FG1</p> <p>P9, FG2</p> <p>P12, FG2</p> <p>P4, FG2</p>

(Continued)

Table A2: Continued

Original citation	Translation in English reported in the article	Origin of the citation
<p>étape prochaine, je pense ok le problème avec les avions, c'est le conflit entre la société moderne qui dit on doit protéger la planète, prendre l'avion moins souvent, le CO₂ et après on voit le trafic augmenter. Et quand je pense après, tous les citoyens de Nantes qui disent ok on doit diminuer le CO₂, et après ils prennent l'avion pour le week-end pour aller au Portugal boire un verre avec des amis. C'est pas consistant pour moi, et peut être ça, ça ajoute à une agression contre le bruit."</p> <p>"J'ai apporté ça du coup: j'ai pris ce que j'avais un peu sous la main, c'est le mois d'avril, c'est un calendrier, et j'ai mis en fluo le dimanche, parce que vraiment le dimanche c'est bien plus agréable, quand on ouvre une fenêtre le matin... donc là j'ai tous les dimanches du mois d'avril, et puis j'ai un jour férié, et les jours fériés c'est encore mieux que le dimanche."</p> <p>"Le dimanche matin, le bruit du périph est diminué par trois... on a une impression de calme."</p> <p>"L'entrée du MiN par exemple... des camions qui viennent de la route... Ben... y a du passage à 3 h du matin."</p> <p>"Y aura toujours du passage, et pour le bruit ben y aura toujours une voiture qui va passer et pendant la nuit comme il n'y a pas de trafic elle va passer vite, elle va accélérer."</p> <p>"Parce qu'entre 6 h et 7 h en gros c'est là que ça décolle le plus."</p> <p>"Déjà pendant les enregistrements, c'est quelque chose d'assez phénoménal, mais le fait d'enregistrer nous ouvre à tous les bruits qui nous entourent, ce qui fait que, sur le plan personnel, c'est plutôt agréable parce que ça renforce le sens de l'ouïe et de l'écoute."</p> <p>"Les deux premières choses qui m'ont surpris, c'est la rumeur, qui était quelque chose qui me gênait depuis quelques années, et puis quand je l'ai mesurée, je me suis rendu compte qu'elle n'était pas forte, et le bruit des oiseaux, qui est très fort dans mon jardin et qui ne me gêne pas du tout."</p> <p>"Alors après un autre truc, c'est SonoRezé qui m'a fait prendre conscience de ça, c'est le bruit des oiseaux, donc un bruit agréable. Ils sont vraiment présents en fait, il y a vraiment beaucoup d'oiseaux."</p> <p>"Pour moi c'est un contraste entre le silence ou des zones très calmes, parce que là où j'habite il y a beaucoup de maisons particulières, c'est assez calme [...], mais après il y a des pics de bruit qui arrivent. [...] J'entends, non pas le périphérique, mais la route de Pornic je crois. Et ça c'est un bruit très diffus, continu, et ça ne me gêne pas trop, mais je trouve que les pics sont vraiment pas agréables."</p> <p>"Toute la zone de promenade le long de Trentemoult parce que c'est assez bruyant mais ce sont des bruits agréables, même si ce n'est que le Navibus, c'est un peu le bruit des bateaux, on est près de la Loire, il y a des bruits de discussions, de gaieté, c'est vivant."</p>	<p>the problem with airplanes is the conflict between modern society which says we must protect the planet, take the plane less often, the CO₂ and then we see the traffic increase. And when I think afterwards, all the citizens of Nantes who say ok we have to reduce CO₂, and then they take the plane for the weekend to go to Portugal for a drink with friends. It's not consistent for me, and maybe that adds to the aggression against noise."</p> <p>"I brought this: [...] it's a calendar, and I put Sundays in fluorescent, because Sundays are really much nicer, when you open a window in the morning... so here I have all the Sundays in April, and then I have a public holiday, and public holidays are even better than Sundays."</p> <p>"On Sunday mornings, the noise from the ring road is reduced by three... you get a feeling of calm..."</p> <p>"The entrance to the MiN for example [national interest market]... lorries coming from the road... Well... there is traffic at 3 am."</p> <p>"There will always be traffic, and for the noise, well, there will always be a car passing by and during the night, as there is no traffic, it will pass quickly, it will accelerate."</p> <p>"Because between 6 and 7 o'clock in the morning that's when it takes off the most."</p> <p>"Already during the recordings, it's something quite phenomenal, but the fact of recording opens us up to all the noises around us, so that, on a personal level, it's rather nice because it reinforces the sense of hearing and listening."</p> <p>"The first two things that surprised me were the rumor, which was something that had been bothering me for a few years, and then when I measured it I realized that it wasn't loud, and the noise of the birds, which is really loud in my garden and doesn't bother me at all."</p> <p>"Then another thing, it's SonoRezé that made me aware of this, it's the noise of the birds, so a pleasant noise. They are really present, there are a lot of birds."</p> <p>"For me it's a contrast between silence or very quiet areas, because where I live there are a lot of private houses, it's rather quiet [...], but then there are noise peaks that come. [...] I hear, not the ring road, but the road to Pornic I think. And that's a very diffuse noise, continuous, and it doesn't bother me much, but I think that the peaks are really not pleasant."</p> <p>"The whole walking area along Trentemoult because it's quite noisy but it's nice noises, even if it's only the Navibus, it's a little boat noise, we're close to the Loire, there are noises of discussions, cheerfulness, it's lively."</p>	<p>P10, FG1</p> <p>P3, FG1</p> <p>P3, FG1</p> <p>P7, FG1</p> <p>P2, FG1</p> <p>P8, SDI</p> <p>P9, SDI</p> <p>P14, SDI</p> <p>P4, SDI</p> <p>P8, SDI</p>

(Continued)

Table A2: Continued

Original citation	Translation in English reported in the article	Origin of the citation
<i>“Le périph depuis 2, 3 ans c’est un bruit de fond permanent, surtout le matin, et quand je l’ai mesuré il est pas si fort que ça en fait.”</i>	<i>“The ring road has been a permanent background noise for the last 2 or 3 years, especially in the morning, and when I measured it, it’s not very loud.”</i>	P9, FG1
<i>“Moi j’ai l’impression que tous les bruits qui nous dérange le plus en fait c’est des bruits qui sont fabriqués, enfin... c’est pas des bruits naturels. C’est des choses qu’on subit parce que c’est la circulation automobile, c’est les avions, c’est... c’est des trucs qui sont... mécanique en fait.”</i>	<i>“I have the impression that all the noises that bother us the most are manufactured noises, not natural noises. It’s things that we are subjected to because it’s traffic, it’s planes... it’s things that are mechanical in fact.”</i>	P2, FG1
<i>“Avec le projet j’ai commencé à voir les bruits positifs. Parce qu’avant j’avais un très grand focus sur les bruits négatifs. Comme cette appli a des petits boutons pour animaux, enfants, j’ai dit ok il y a des bruits positifs aussi.”</i>	<i>“With the project I started to see the positive noises. Because before I had a very big focus on negative noises. As this app has little buttons for animals, children, I said ok there are positive noises too.”</i>	P4, FG2
<i>“Maintenant je suis plus attentif aux bruits désagréables ET un peu plus attentif aux bruits agréables, c’est vrai. Parce qu’avant c’était l’absence totale de bruit que je considérais comme agréable, mais ce n’est pas toujours le cas, il y a aussi des bruits agréables.”</i>	<i>“Now I am more attentive to unpleasant noises AND a little more attentive to pleasant noises, that’s true. Because before it was the total absence of noise that I considered pleasant, but that is not always the case, there are pleasant noises too.”</i>	P4, SDI
<i>“Pour moi qui suis sur l’avenue Général Leclerc, il y a beaucoup de vélos qui passent et je dois avouer que c’est beaucoup plus silencieux que les voitures, donc c’est plus agréable. Cela m’a donc permis de mettre en avant les points positifs plutôt que les points négatifs.”</i>	<i>“For me, who is on the Avenue Général Leclerc, there are a lot of bicycles that go by and I have to admit that it is a lot quieter than the cars, so it is more pleasant. So that allowed me to highlight the positive points rather than the negative ones.”</i>	P6, SDI
<i>“Avant il y avait du bruit je faisais pas trop gaffe, maintenant je fais plus attention.”</i>	<i>“Before there was noise, I didn’t pay much attention, now I pay more attention.”</i>	P9, FG1
<i>“Depuis que j’ai la démarche en tête, j’écoute!. En fait, moi ça devient obsessionnel, j’entends le périph...”</i>	<i>“Since I have the approach in mind, I listen! In fact, I’m becoming obsessed; I can hear the ring road...”</i>	P13, FG1
<i>“Quand je vais chez des gens ou quand je vais dans un nouveau lieu, tout de suite c’est ‘est-ce qu’on entend le périph’... et c’est infernal!”</i>	<i>“When I go to people’s houses or when I go to a new place, it’s immediately ‘can we hear the ring road’... and it’s hellish!”</i>	P2, FG1
<i>“L’autre fois lorsque nous avons fait les mesures [...] Il suffisait que je m’éloigne de 200 m et je ne percevais plus les bruits de cette rue passante.”</i>	<i>“The other time when we did the measurements [...] I just had to move 200 m away and I didn’t perceive the noises of this busy street anymore.”</i>	P11, FG2
<i>“Il y a la route de Pornic bien s û r. [...] mais la route de Pornic est désagréable parce qu’elle est très fréquentée.”</i>	<i>“There is the road to Pornic of course. [...] but the road to Pornic is unpleasant because it is very busy.”</i>	P6, SDI
<i>“Il y a des endroits paisibles au bord des rivières, de la Loire ou de la Sèvre, un vrai bonheur!”</i>	<i>“There are peaceful places by the rivers, by the Loire or by the Sèvre, a real treat!”</i>	P2, SDI
<i>“Bon, ce sont les deux quartiers que je connais bien, et ils sont agréables parce que c’est très vert, la Jaguère il y a une petite forêt et on ne voit plus les immeubles, il y a des oiseaux et c’est assez calme.”</i>	<i>“Well, these are the two areas that I know well, and they are pleasant because it is very green, the Jaguère there is a small forest and you can no longer see the buildings, there are birds and it is quite calm.”</i>	P4, SDI
<i>“Je fais beaucoup de vélo, alors je ne prends pas ma rue à vélo, je tourne immédiatement vers une autre, pour mes oreilles, pour ma sécurité...”</i>	<i>“I ride my bike a lot, so I don’t take my street by bike, I immediately turn off to another one, for my ears, for my safety...”</i>	P1, SDI
<i>“C’est évident, tous les grands axes sont bruyants à cause de la circulation. En revanche, lorsque je vais au marché à vélo ou à pied, je m’arrange toujours pour passer par les petites rues peu fréquentées.”</i>	<i>It’s obvious, all the main roads are noisy because of the traffic. On the other hand, when I go to the market by bike or on foot, I always manage to go through the back streets that are not busy.”</i>	P5, SDI
<i>“Je me demande si les modélisations du bruit ont une précision. On voit les avions en direct, il n’y a rien qui arrête le bruit. De l’autre côté de la rue, ma maison bloque le bruit et pour les voisins c’est ok.”</i>	<i>“I wonder if the noise models are accurate. You see the planes directly; there is nothing to stop the noise. On the other side of the street, my house blocks the noise and for the neighbors it’s ok.”</i>	P4, FG2
<i>“Lorsque les vents sont dominants, on peut entendre le périphérique.”</i>	<i>“When the winds are dominant you can hear the ring road.”</i>	P3, SDI

(Continued)

Table A2: Continued

Original citation	Translation in English reported in the article	Origin of the citation
<i>“Donc quand c’est un vent d’Est, on a clairement beaucoup plus de bruit. Quand c’est un vent d’Est on va avoir par exemple le bruit des avions à l’atterrissage qui est rabattu.”</i>	<i>“So when it’s an easterly wind, there’s clearly much more noise. When it’s an easterly wind, we’ll have, for example, the noise of planes landing, which is reduced.”</i>	P14, SDI
<i>“Quand je parle avec des collègues ils me demandent le problème pour toi c’est le CO₂, la pollution?, je réponds non c’est le bruit. c’est pas présent dans la société je trouve.”</i>	<i>“When I speak with colleagues, they ask me the problem for you is CO₂, pollution? I answer no, it’s noise... it is not present in the society I find.”</i>	P4, FG2
<i>“Parce que je trouvais le sujet intéressant, et puis c’est aussi une façon de participer à la ville de Rezé et à ce qui s’y passe. Je ne peux pas dire que c’est une forme d’engagement parce que l’engagement est faible mais il y a un peu de ça, on ne peut pas être que spectateur, de temps en temps il faut être acteur aussi.”</i>	<i>“Because I found the subject interesting, and then it’s also a way of participating in the city of Rezé and in what is happening there. I can’t say that it’s a form of commitment because the commitment is weak but there is a bit of that, you can’t just be a spectator, from time to time you have to be an actor too.”</i>	P5, SDI
<i>“Ce qui m’intéressait, c’était de pouvoir contribuer à un projet commun avec une approche assez originale et innovante de la prise en compte des nuisances sonores, un sujet qui n’est pas forcément mis en avant régulièrement.”</i>	<i>“I was interested in being able to contribute to a common project with a rather original and innovative approach to taking noise pollution into account, a subject that is not necessarily put forward regularly.”</i>	P8, SDI
<i>“Je plains les gens qui sont à côté. C’est ponctuel, mais répété plein de fois...”</i>	<i>“I feel sorry for the people next door [...] It’s a punctual thing, but it’s repeated many times...”</i>	P3, FG2
<i>“Je ne les entends pas chez moi mais je me mettais à la place des gens qui se mettaient juste à côté.”</i>	<i>“I don’t hear them at home but I put myself in the place of the people next door.”</i>	P12, FG2
<i>“J’ose pas imaginer les nuisances que ça va provoquer pour les populations.”</i>	<i>“I can’t imagine the nuisance it will cause to the population.”</i>	P11, FG2
<i>“Je présume que Pour les riverains ça doit être très impactant.”</i>	<i>“I assume that for the people living nearby it must be very impactful.”</i>	P11, FG2
<i>“Y a un bruit qui est apparu y a 2 ans, et au début, moi il me... il me faisant tendre l’oreille tout le temps. Aujourd’hui c’est devenu LE bruit de la ville telle que j’ai intégrée... c’est le bruit du scooter qui s’arrête... et puis, mais qui reste en route, et qui cherche en fait là où il va livrer”</i>	<i>“There is a noise that appeared two years ago, at the beginning, it made me strain my ears all the time. Today it has become THE noise of the city as I have integrated it... it is the noise of the scooter that stops... and then, that looks for where it is going to deliver.”</i>	P10, FG1
<i>“Donc très bêtement j’ai cru que je m’échapperais très vite vers le vert en m’installant ici. C’est vrai qu’en 15 ans ça a beaucoup évolué cet environnement [...] c’était vraiment le vieux village de Rezé.”</i>	<i>“Very stupidly, I thought that I would escape very quickly to the green by settling here. It’s true that in 15 years this environment has changed a lot [...] it was really the old village of Rezé.”</i>	P10, FG1
<i>“A Ragon y a 15 ans moi je me souviens prendre des petits déjs dehors en semaine... et pas aujourd’hui hein!”</i>	<i>“In Ragon 15 years ago I remember having breakfast outside during the week... and not today!”</i>	P10, FG1
<i>“J’ai été très déçu que la partie le long de la rivière ait été bétonnée, elle aurait pu devenir un très bel espace vert. Mais il y a 12 ou 15 ans, ce n’était pas encore à l’ordre du jour, on bétonnait plus qu’on ne verdissait les villes.”</i>	<i>“I was very disappointed that the part along the river had been concreted, it could have become a very beautiful green area. But 12 or 15 years ago it was not yet on the agenda, we concreted more than we greened the cities.”</i>	P5, SDI
<i>“Ça c’était ma question aussi, quelle est la nocivité du bruit? De ce bruit de fond permanent ou ce bruit instantané?”</i>	<i>“That was my question too, how bad is the noise? This permanent background noise or this instantaneous noise?”</i>	P3, FG1
<i>“L’électricité pour ça c’est génial, pour le bruit ça peut changer beaucoup de choses.”</i>	<i>“Electricity is great for that, for noise it can change a lot of things.”</i>	P7, FG1
<i>“Ils utilisent maintenant une forme de revêtement de surface... quand on passe en voiture d’un seul coup c’est beaucoup plus silencieux... vous avez remarqué ça?”</i>	<i>“They now use a form of surface coating... when you drive by it’s much quieter all of a sudden... have you noticed that?”</i>	P7, FG1
<i>“Je confirme j’habite dans un lotissement on rentre par une rue, un rond, on ressort du même endroit, dès qu’on est derrière on n’entend rien. Il n’y a pas de passage.”</i>	<i>“I confirm I live in a housing estate, you come in from a street, a roundabout, you come out from the same place, as soon as you’re behind you don’t hear anything. There is no passage.”</i>	P9, FG2
	<i>“For me, the main axis that could make the sound evolve in the city is really not to do 100% road.”</i>	P8, SDI

(Continued)

Table A2: Continued

Original citation	Translation in English reported in the article	Origin of the citation
<i>“Pour moi, l’axe principal qui pourrait faire évoluer le son dans la ville, c’est vraiment de ne pas faire du 100% routier.”</i>		
<i>“Qui accepte qu’on puisse... qu’on construise à 20 m du périph? Enfin quand même!”</i>	<i>“Who accepts building 20 m from the ring road? I mean, come on!”</i>	P3, FG1
<i>“On se demande pourquoi c’est interdit d’utiliser la tondeuse dans le jardin le dimanche, et pourquoi les avions peuvent voler.”</i>	<i>“We wonder why it’s forbidden to use the lawnmower in the garden on Sundays, and why planes can fly.”</i>	P4, FG2
<i>“Pour moi on est responsable de ça en fait, en tant que citoyen... c’est notre mode de vie qui crée ce bruit là...”</i>	<i>“For me, we are responsible for this, as citizens... it is our way of life that creates this noise...”</i>	P2, FG1
<i>“Je suis plus heureuse à circuler à vélo que circuler en voiture en ville hein! Je suis toujours à l’heure à mes rendez-vous, ça me coûte rien, je fais pas de bruit, je fais du sport.”</i>	<i>“I’m happier riding a bike than driving a car in the city. I’m always on time for my appointments, it doesn’t cost me anything, I don’t make any noise, I do some sport.”</i>	P2, FG1
<i>“On doit décourager les gens de prendre leur voiture.”</i>	<i>“We must discourage people from taking their car.”</i>	P2, FG1