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Relationships between noise annoyance, urban soundscape and acoustic indicators in the French city of Lorient

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ABSTRACT

As part of the ANR CENSE project, which has started in 2016, a questionnaire was sent to approximately 2000 households in a 1 km² study area in the city of Lorient in France. The main objective of this questionnaire was to collect information on the perception by residents of sound environments in their neighborhood (representation of the soundscape), on their street (representation of the soundscape), and in their home (noise annoyance). In the same study area, 123 sensors were positioned in order to cross-referenced the perceptual data collected through the questionnaire with acoustic indicators. A noise mapping of the city of Lorient was also carried out. These three methods for assessing sound environments are presented in this article and a very first cross-analysis is presented showing links between the responses to the questionnaires and the noise map.

Keywords: Soundscape, Noise annoyance

1. INTRODUCTION

Noise impact on human health has been revealed by numerous studies, whether due to traffic in urban context or to the railway and aircraft transportation (1). But the links between the noise environment and impacts on quality of life are more complex and are not limited to the simple noise levels. The soundscape approach has been preferred to address the issue of the urban sound environment, in a more complex way, taking into account that some sounds such as bird singing or water streaming, can also enhance the pleasantness of an urban situation (2).

When focusing about annoyance factor, researchers try to find a relationship between sound exposure and long-term annoyance. Noise annoyance is then considered as a one-dimensional variable. At an individual level, it has been shown that variance of the annoyance explained by sound levels exposure is limited to about 30% (3). At a community level, dose response curves based on L_{DEN} or L_{DN} make it possible to predict for example the percentage of highly annoyed people. These indicators characterizing the sound exposure levels derive from the long temporal weighted equivalent sound levels calculated over 24h. However, these indicators are limited, for example they do not take into account the short temporal variations of sound levels.

With the development of the soundscape approach, questionnaires began to include all the different emotional dimensions that support the affects, including all the positive and negative aspects. Some of these dimensions, and especially the pleasantness/unpleasantness dimension, have been correlated not only with acoustic indicators but also with perceptual variables dedicated to sound sources such as their time of presence, their sound level, or their dominance.

In both approaches, researches have been seeking to cross-reference the acoustic indicators with the impacts on people, which is difficult for several reasons. The importance of personal behaviors

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and social attitudes on long-term affects is very important and the statistics need many individual data to be significant. Generally, participants are contacted through mailings or telephonic campaigns. As it is impossible to measure sound levels in front of each house over a long duration, calculations are used, which result in approximated sound levels exposure. In the short-term approach, people are more often questioned in the streets. It is then easier to measure the acoustic indicators with simple monophonic microphones or with more sophisticated binaural or ambisonic ones, even with mobile microphones. Finest description of the acoustic signal can be computed as the short-term temporal variations of sound levels, but as people are questioned one by one, it is difficult to collect a large amount of data in the same experiment.

In this paper, we present a campaign of questionnaires distributed in the city of Lorient as part of the CENSE project, which also includes tasks on the modeling of urban sound environments and on a deployment of a sensor network of 123 nodes. One of the objectives of this protocol is to compare the perceptions of residents, while allowing the results of the questionnaires to be compared with numerous acoustic indicators thanks to a dense network of measurements. This paper presents first elements of this analysis. Section 2 describes the questionnaire that was sent to the inhabitants. Section 3 describes the measurement network that covers the same zone. Section 4 describes the simulations. Finally, first elements of analyze are discussed.

2. QUESTIONNAIRE

2.1 Questionnaire – General information

A questionnaire was sent to about 2000 households in a 1 km² study area in the city of Lorient in France during the second week of January 2019. Until 15 March 2019, it was possible for residents to return a paper version of the questionnaire or to fill it via a web platform. The questionnaire lasts about 20-25 minutes and is composed of 5 parts detailed in the following section.

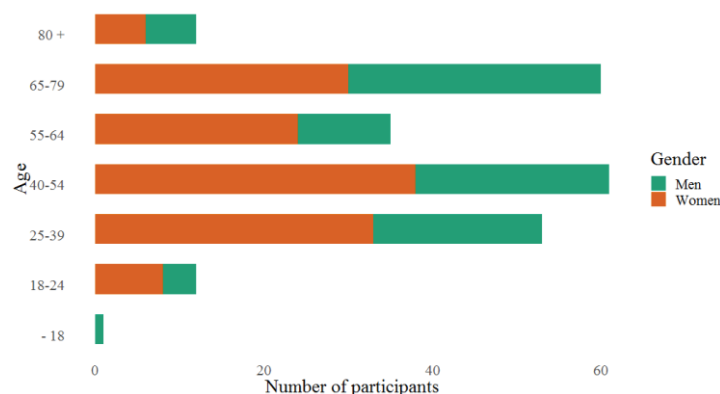


Figure 1 – Age and gender of the participants

161 people completed the paper form of the questionnaire and 157 responded through the web platform, thus resulting in 318 responses. Figure 1 presents some demographic information about the participants. In order to encourage participation, a draw will be held in July 2019 for 5 gift certificates of 50€. The French version of the questionnaire can be consulted in the website of the project: <http://www.cense.ifsttar.fr>.

2.2 Questionnaire in detail

In the first section of the questionnaire, the respondent had to assess the quality of the sound environment in his/her neighborhood and then in his/her street (when walking or cycling home). The evaluation relied on 5 bipolar semantic scales (7 levels) inspired on the Swedish protocol (4). Table 1 presents the French semantic elements as well as a proposal for translation into English.

Then the respondents had to inform a table on the perceived time of presence ratio and on the perceived sound level of 13 sound sources that they can hear when they come in or out of their homes, on foot or by bike, on their streets, and during the year. The nomenclature had been previously

established using information from sound sources *in situ*, bibliographic work and previous studies (5). Table 2 presents the sources that are assessed. A free comment window closed this first section.

Table 1 – Elements of the bipolar scales. The last column corresponds to their codification

<i>Désagréable</i>	Unpleasant	<i>Agréable</i>	Pleasant	Pl
<i>Inerte, Amorphe</i>	Inert	<i>Animé, mouvementé</i>	Eventful	Ev
<i>Bruyant</i>	Noisy	<i>Silencieux</i>	Silent	Si
<i>Ennuyeux, Inintéressant</i>	Boring	<i>Stimulant, Intéressant</i>	Exciting	Ex
<i>Agité, Chaotique</i>	Chaotic	<i>Calme, Tranquille</i>	Calm	Ca
<i>En inadéquation avec vos attentes</i>	In inadequacy with your expectations	<i>En adéquation avec vos attentes</i>	In adequacy with your expectations	Ad

The second section of the questionnaire focused on the annoyance. Questions on the annoyance following the Guidelines from the noise Team of ICBEN were asked to residents (6). This section of the questionnaire can be summarized with this sentence:

“Thinking about the last 12 months, when you are here

- at home with your windows closed,
- at home with your windows open or on your balcony or in your garden,
- in the street, when you arrive at home by bike or on foot,

how much does

- global noise
- noise from (noises sources from Table 2)

bother, disturb, or annoy you: Extremely, Very, Moderately, Slightly or Not at all?”

Table 2 – List of sources that were assessed in the questionnaire

Road Traffic (Tra)	Sirens, alarms (Sir)	Children's voices (schools, playgrounds) (ChV)	Gulls* (Gul)
2-wheel motor vehicles (2Wh)	Urban maintenance (cleaning, garbage...) (UMa)	Music from bars, restaurants, shops... (Mus)	Sources from neighboring dwellings (voices, steps, animals, crafts, music...)
Rail traffic (Rail)	Expressive voices, festive voices, laughter, shouts (ExV)	Wind in the vegetation (Wnd)	Other ...
Air traffic (Air)	Calm voices, conversations... (CaV)	Small birds (Brd)	Other ...

* Lorient is a harbor city with several complaints in the local press about the noise of gulls.

In the third section of the questionnaire, four areas make a free expression possible for residents about the remarkable environments (pleasant, unpleasant, conducive to walking and conducive to rest) of their neighborhood.

In the fourth section of the questionnaire, personal information was collected: noise sensitivity of

the inhabitants based on the 6-item Weinstein's noise sensitivity scale (WNSS) (7), gender, age, socio-professional category, membership (or not) to an association fighting against noise.

Finally, in the fifth section of the questionnaire, residents were invited to provide information on where they live: the exact location, so that the questionnaires can be linked with the acoustic measurements or simulations made in the area and a set of questions on housing (Table 3).

Table 3 – Questions about the housing of participants

Tenant / Owner	Courtyard or garden area? (yes/no)	Has quiet room? (yes /no)
House/Apartment	Living space overlooking the street? (yes/no)	Double glazing? (yes /no)
Time of occupancy? (<1 year, 1-3 year, >3 year)	Living space with a view on natural elements? (no, a little, a lot)	Insulation of the facade <10 years ago? (yes/no)

Finally, the respondents had to give their level of satisfaction (5 levels) on four dimensions:

- Acoustic insulation of their housing;
- To what extent they are globally satisfied with their (home/street/neighborhood) as a place to live.

3. MEASUREMENT NETWORK

Specific low-cost noise monitoring sensors have been developed within the CENSE project in order to be integrated in a large measurement network. The network is composed of 123 noise sensors connected to the cloud through a hybrid communication network based on wireless and public street lamp network equipped with power-line communication systems. The sensors have been specially developed regarding urban sound environment constraints (8). They transmit acoustic indicators continuously thanks to wireless communications based on 802.15.4 modulation with 6LoWPAN MAC layer as described by IEEE RFC4944. The microphones used are MEMS microphones, and recording and transmitting systems are based on STM32L4 microcontroller or on small single-board computers Raspberry-Pi.

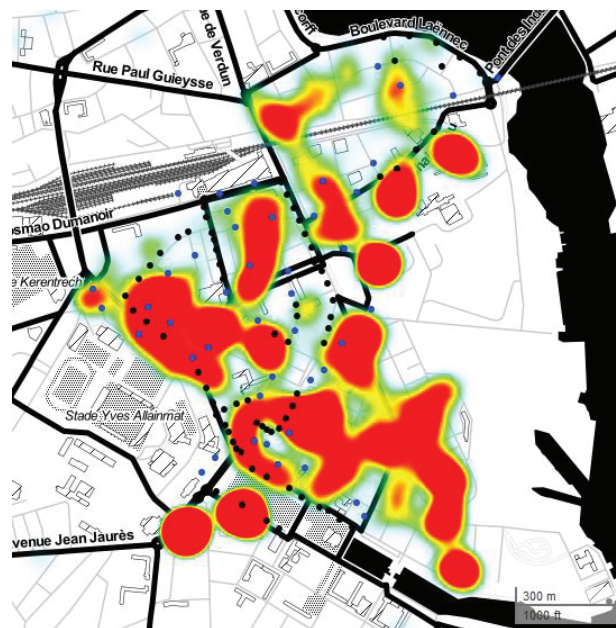


Figure 3 – CENSE study area. Dots correspond to the deployed sensors, and the heat map to the density of responses to the questionnaires

Real-time audio processing are included in both sensors in order to perform the calculation of the $L_{Aeq,1s}$ and $L_{Zeq,1s}$ acoustic indicators, as well as the acoustic spectrum each 125 ms, using third octave bands from 20 Hz to 12.5 kHz and A-weighting filtering. The sampling rate is 32 kHz.

Figure 3 shows the comparison between the position of the measurement points (black and blue dots) and the spatial distribution of the responses to the questionnaires (heatmap). The network is still being deployed, so the comparisons between measurements and questionnaires unfortunately cannot be presented in this paper. Also, the next step will be to cross-reference all the responses from the questionnaire with the acoustic indicators measured by the sensors. In that way, work has been initiated to automatically estimate perceptual variables, such as the perceived presence time of traffic, birds, voices, etc., from the acoustic signal (9).

4. NOISE MAP

On the same area a noise map was also computed. In order to enable the cross-reference, a receiver was positioned in the simulation on the "street side" façade of each questionnaire response. Only road traffic noise levels were included in the map. The input databases (e.g. built-up characteristics, ground topology, road traffic data, ground characteristics, etc.) are a compilation of data collected from CEREMA, IGN and the city of Lorient. The sound emission and propagation methods used were CNOSSOS included in the free and open-source software NoiseModelling v3.0.

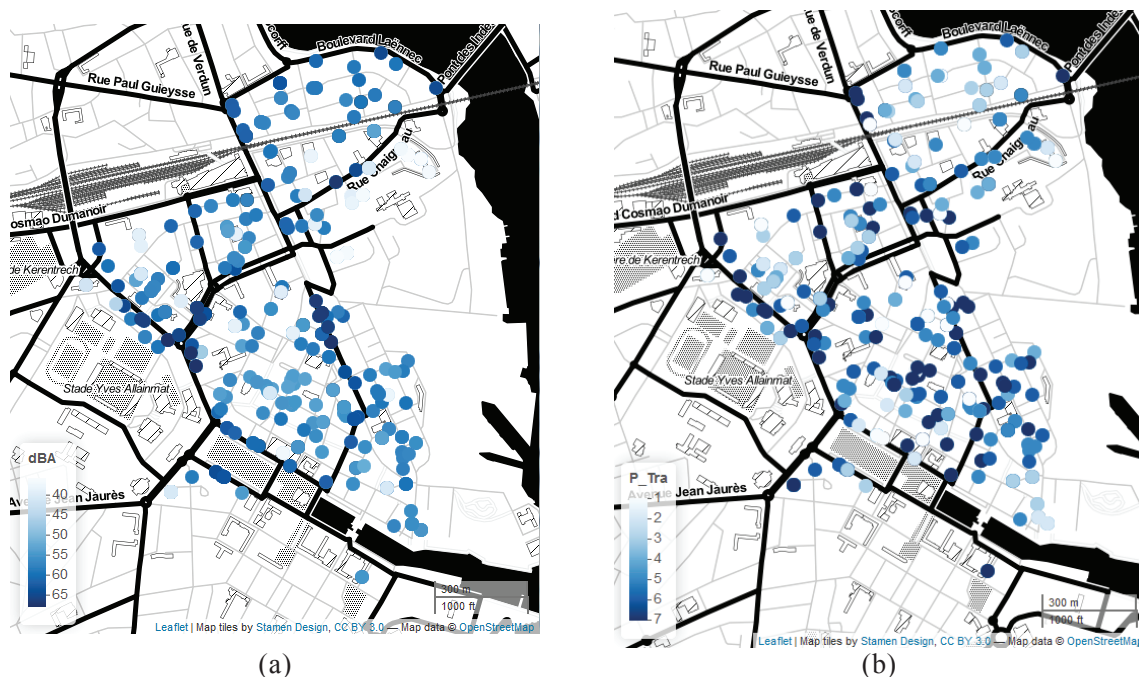


Figure 4 – (a) Simulated noise levels $L_{DEN} - dB(A)$ and (b) the perceived time presence of traffic; the dot locations correspond to the answers of the questionnaires

The Figure 4 shows a comparison between the L_{den} values in dB(A) at the “street side” façade corresponding to each questionnaire response and the perceived time presence of traffic. As expected, a spatial correlation ($r=.26$, $p<0.01$) can be observed between the simulated traffic-related noise levels and the perceived time presence of traffic. On some roads, strong dissimilarities may appear (e.g. near the park at the south). Most of the time, these are related to obsolete traffic data. Consequently, a data collection campaign will be conducted during the next month.

Figure 5 shows the percentage of people extremely annoyed by road traffic noise as a function of the L_{den} values at the receiver under three conditions (see Section 2 of the Questionnaire):

- closed windows (in black) ;
- open windows or on the balcony, in the garden (in blue) ;
- in the street (in red).

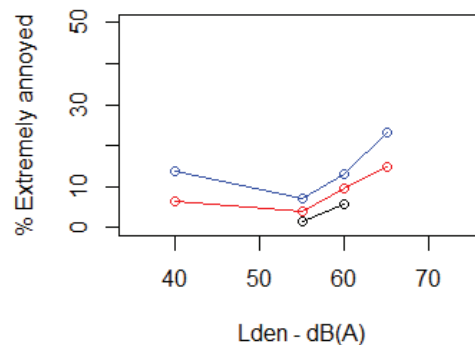


Figure 5 – percentage of people extremely annoyed as a function of the L_{den} value

For L_{den} values between 62.5 and 67.5 dB(A), one observes that 23% of people declare themselves extremely annoyed by the noise of road traffic when their windows are open. The same trends can be found but shifted by 6 dB(A) for the "closed windows" situation and shifted by 3 dB(A) for "in the street" situation. Similarly, this observation shows that, at the same noise level at the façade, residents are more annoyed when they are at home with open windows than in the street, which shows the importance of the feeling of private/public space.

In addition to the cross-referenced analyses between the noise map and the questionnaires, this noise map will also serve as an indicator to link the data from the measurement network to the questionnaire responses.

5. DISCUSSION

As part of the CENSE project, a dense measurement network will be deployed, a questionnaire has been already distributed and a road traffic noise map was computed in the same study area of Lorient. In this article, these 3 methods for assessing sound environments are briefly presented as well as an example of an analysis resulting from the crossover between the noise map and the responses to the questionnaires. In the coming months, the analysis will be greatly enriched following the acoustic data collection, which will allow a rich cross-referencing of information between questionnaires and acoustic indicators that involve the recognition of the presence time of sources typical of urban noise environments.

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