Research Article

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Lockdown during COVID-19 pandemic: impact on road traffic noise and on the perception of sound environment in France

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Abstract: Acoucité¹, centre of expertise in environmental acoustics and observatory of the sound environment, has investigated the changes in sound environment and its perception during the French lockdown period. The approach adopted is multidimensional, since it combines long-term acoustic measurements, large area noise mapping, as well as the study of sound perception self-reported by population sample through an on-line structured questionnaire. Data from 21 continuous sound monitoring stations² were analysed for the entire lockdown period in five conurbations in the south of France and compared to typical values in the “normal” situation (before lockdown) in order to quantify the reduction in terms of sound levels. Reductions from 4 dB to 6 dB (Lden) were observed for monitoring stations with highly dominant road noise. These results were used to obtain new Strategic Noise Maps for road noise (corresponding to the lockdown situation) for the conurbations of Lyon and Grenoble. The impact of such reductions in terms of noise exposure of their inhabitants was thus assessed. An estimation of the impact on health effects in comparison with the “normal” situation (Strategic Noise Maps “Round 3 CE-DE-2002”) was also carried out. This estimation considers a scenario where the above level reductions (4 to 6 dB) would take place in the long-term. An on-line perception questionnaire was available during the lockdown period with the aim of gathering information on the way that the changes in sound environment were perceived by people all over France and ended up with more than 3000 respondents. This paper reports

the main findings of the study in terms of acoustics and sound perception.

Keywords: acoustics, survey, measurement, mapping, Coronavirus outbreak

1 Introduction

In order to limit the spread of the COVID-19 (Coronavirus) epidemic, the French government has decreed, among other actions, a severe restriction on the movement of individuals from Tuesday 17th March to Sunday 10th May 2020.

Acoucité, aware of the impact that these actions can have in terms of the sound environment, has closely looked at the outcomes of sound levels from the permanent measurement network of the metropolis of Lyon, as well as the sound monitoring networks of its partner conurbations.

Data from 21 monitoring stations were collected and analysed for the entire lockdown period (8 weeks), as well as for the first 2 weeks after the lifting of lockdown.

In addition to the measurements of sound levels (physical dimension), Acoucité launched an on-line survey to obtain information on the inhabitant's perception of the sound environment during the lockdown period (perceptive dimension). Methods and main findings of this study are described hereinafter.

¹ Acoucité, Sound Environment Observatory, is a French non-profit organization focused on environmental noise in urban landscape. It is a centre of expertise that aims to promote exchanges between public research centres and the operational needs of cities, particularly in terms of the assessment of urban noise related to land transport.

² For more information, please visit www.acoucite.org

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2 Methods

2.1 Sound pressure level measurements

Lockdown have led to a sharp decrease in human presence in the public space. Means of transport (private and public), as well as professional and leisure activities, have been considerably reduced. The sounds produced by these activities have decreased in intensity.

In order to quantify this reduction, Acoucit conducted a comparison of the sound levels before, during and after lockdown at about twenty long-term measurement stations located in the territories of: metropolis of Lyon, Metropolis of Aix-Marseille-Provence, Metropolis of Grenoble-Alpes, Metropolis of Saint Etienne and Metropolis of Toulouse.

Each measurement station provides the A-weighted equivalent continuous sound pressure level value every second (LAeq,1s).

A comparison between the sound levels monitored in the “normal” situation and those for the lockdown situation has been carried out. The comparison is based on Lden, Ld, Le and Ln indexes (OJ L 189, 18.7.2002, p. 12–25). Measured data were coded and filtered for better representativeness³.

The calculation of the indexes in “normal” situation (before lockdown) covers the period from Monday 6 January 2020 to Sunday 15 March 2020. The lockdown period goes from Monday 16 March 2020 to Sunday 10 May 2020.

2.2 Effects on the perception of the sound environment

Changes affecting the sound environment are not limited to sound energy reduction. The reduction in sound levels is also accompanied by a hierarchical reorganisation of sound sources. All this has an effect on the inhabitants in terms of sound perception (individual experience on this change in the sound environment). In order to better understand the effect of this restructuring of the sound envi-

ronment, Acoucit has launched an on-line perception survey. A brief description of the methodology used, as well as the main results are presented below.

The survey was designed by Acoucit and carried out through the internet and hosted on the Acoucit website (see Appendix). It was disseminated in the professional networks of the association, on social networks, and in the French written, radio and television press. For the conurbation of Paris (le-de-France), Bruitparif⁴ has promoted this survey among its network in order to gather the maximum number of respondents in le-de-France.

Between the 18th of March and the 11th of May 2020, 3242 questionnaires out of 3883 responses were validated in France (see Figure 1). These were voluntary respondents and not random sampling or based on the quota method. It should be noted that the method of dissemination of the survey may have a non-negligible influence on the responses obtained. Indeed, in Nantes, the Coceta (from French “Collectif des Citoyens Exposs au Trafic Arien rgion de Nantes”, meaning Collective of Citizens Exposed to Air Traffic in the Nantes Region) relayed the link of the on-line survey to their members, which may explain the fact that almost all respondents from Nantes are located in the communes close to the airport (or under the air corridor) as can be seen in Figure 2.

2.3 Impact on the noise exposure (Noise Maps) and health effects (DALY)

The observed reductions in noise levels (during the lockdown period) at measurement stations where the road noise is the dominating source were used to obtain estimated road noise maps for the lockdown period. This is done by applying a homogeneous reduction to the latest Strategic Noise Maps (Round 3) for the conurbations of Lyon and Grenoble. The lockdown maps are elaborated for two scenarios “–4 dB” and “–6dB” in order to fit with the range of reduction (average reduction for the whole lockdown period) observed at measurement station located within the relevant territories.

Sound levels computed at building faades were used to estimate the inhabitants noise exposure and the corresponding health impact that such reductions in noise levels would have if implemented over time (in terms of annoyance, sleep disturbance and ischemic heart disease).

³ **Coding of measured data:** Data coding consists in identifying events that could alter the reliability of the calculated indicators (sound levels). These portions may correspond to periods when the measurements are “non-compliant”, such as when weather conditions make the measurements unusable (e.g. wind speed too high), or to samples that could bias the comparison (e.g. holiday periods when it is necessary to obtain a “typical” indicator). This is subject to careful data control. Once the files have been coded, it is possible to remove these portions of the acoustic indicator calculation.

⁴ Bruitparif is a non-profit environmental organization responsible for monitoring the environmental noise in le-de-France. For more information, please visit their website <https://www.bruitparif.fr>

Figure 1: Geographical distribution of respondents. View of France

Figure 2: Geographical distribution of respondents. Detailed view of Metropolis of Nantes
The airport marked as • is located 47° 09'26.6"N 1° 36'22.4"W (more details in appendix p.29)

Figure 3: Reduction observed on the LDEN indicator for the 21 measuring stations. Difference between the average sound level in “normal situation” and the average sound level during lockdown

The methodology used for assessing the health impact is that recommended by the World Health Organization (WHO) in its recommendations guide based on the latest knowledge of the noise health effects, published in October 2018 [2]. The health impact is expressed in Disability Adjusted Life Years (DALY).

3 Results

3.1 Sound level variations

Figure 3 shows the overall reduction for all the measuring stations considered. This reduction corresponds to the difference between the average sound level (Lden) in “normal” situation and the average sound level during lockdown. A reduction of 4 dB to 6 dB is observed in most cases (*i.e.* 60% to 75% less sound energy). Larger reductions have been identified at stations where other sound sources contributes considerably to the sound environment in “normal” situation: Place Bellecour in Lyon, Allée Jean Jaurès in Toulouse and Place Victor Hugo in Grenoble (human

sounds such as voice, footsteps, shops...), and Rocade Sud in Grenoble conurbation (rail).

The observed reductions vary between weekends and working days (Figure 4). The differences can go up to 3 dB. For Grenoble, the reductions are generally more pronounced on working days. The opposite case is observed for the measuring stations in Lyon, Aix, Saint-Etienne and Toulouse.

Figure 5 presents the reductions by period: Day (from 6h to 18h, in yellow), Evening (from 18h to 22h, in orange) and Night (from 22h to 6h, in purple). The reductions are generally fairly similar during the different periods of the day, with the exception of Place Bellecour in Lyon where the reduction observed for the night period (22h – 6h) is notably more pronounced than for the rest of the day and reaches a value of more than 10 dB (equivalent to a reduction of more than 90% of the sound energy).

Figure 6 shows the evolution of reductions over the 8 weeks of lockdown (Week 1 corresponds to the week of March 16th to 22nd 2020, Week 8 runs from May 4th to

Figure 4: Reduction observed for working days and weekends for the 21 measuring stations. Difference between the average sound level in “normal situation” and the average sound level during lockdown

Figure 5: Reduction observed by period of the day for the 21 measuring stations. Difference between the average sound level in “normal situation” and the average sound level during lockdown

Figure 6: Evolution of the reduction in terms of sound levels per week of lockdown. Difference between the average sound level in “normal situation” and the average sound level for each week of the lockdown period

Figure 7: Comparison between the sound level reduction observed during the lockdown period (green) and during the first two weeks after lockdown lifting (orange). For the case of Place Victor Hugo in Grenoble, this is not a reduction equal to 0 dB after lockdown lifting but an absence of data for this period

Table 1: Average noisiness depending on the nature of respondents' location

	Noisiness	Before lockdown	During lockdown	Decrease
	Overall	6.31	2.45	3.86
Nature of respondents' location	Urban	6.52	2.71	3.81
	Countryside	5.52	2.01	3.51
	Suburban	6.31	2.18	4.13
Main respondents' clusters	Métropole de Lyon (Lyon conurbation)	5.49	2.81	2.68
	Île-de-France (Paris conurbation)	6.35	2.58	3.78
	Nantes conurbation	7.75	1.58	6.17
Other respondents (outside the main clusters)	Overall	5.39	2.75	2.64

Figure 8: Traffic data from Cerema⁵ showing the evolution. The lockdown period is highlighted in grey

10th 2020). It is generally observed that the reductions are smaller during the last weeks of lockdown⁶.

Figure 7 shows a comparison between the sound reductions observed during the lockdown period (in green, averaged over the 8 weeks of lockdown) and those observed during the first two weeks after lockdown lifting (in orange, from May 11th to May 24th). It is observed that sound levels during the first two weeks after lockdown lifting have not yet returned to “normal” values (a return to

“normal” values would be represented by reductions close to 0 dB). This is consistent with the traffic trends provided by Cerema (see Figure 8).

3.2 Effects on the perception of the sound environment

3.2.1 Noisiness at home

Respondents were asked to rate the noisiness (perceived magnitude) in their homes before and during lockdown from all sources on a scale of 0 (not at all noisy) to 10 (excessively noisy).

The noisiness from all sources decreased by 3.9 points from an average of 6.3 points in “normal” situation to 2.4 points in lockdown condition.

Analysing the noisiness (average) as function on separately depending on the nature of respondents' location (Table 1), the greatest decrease takes place in suburban areas, almost as noisy as urban areas during “normal” times but much quieter during lockdown according to the respondents. A similar analysis is done by focusing on the main clusters of respondents (conurbations of Lyon, Paris and Nantes). One can notice that the decrease on noisiness varies significantly among main respondent clusters (from about 2.7 points in Lyon to about 6.2 points in Nantes).

Considering the decrease observed in Nantes, it is important to note that 96% of the respondents from Nantes declared that they live near an international or high-traffic airport (only 4% of respondents in the Lyon Metropolitan area live near an airport, 50% in the Île-de-France region).

⁵ <http://dataviz.cerema.fr/trafic-routier/>

⁶ There is also a smaller reduction for the first week of lockdown (compared to weeks after). This is explained by the fact that for week 1, travel restrictions only began on Tuesday at 12:00 noon. For the Monday of week 1, the measures put in place consist solely of school closures.

This is certainly related to the method of dissemination of the survey in Nantes (explained in Methods section). The risk of an “overrepresentation” effect cannot be dismissed from this cluster.

3.2.2 Perceived sound source variability

Lockdown is accompanied by a perception of a large decrease in transport-related noise sources. The perceived reduction is very large for road and air transport, and less so for rail transport. As transport noise has decreased significantly, respondents note an increase in natural sounds (more than 50%). As for neighbourhood sounds, their presence is unchanged for most respondents but increased for about a quarter of them.

3.2.3 Adjectives used for describing the perception of the sound environment during lockdown

Negative adjectives all score less than 3%. The sound environment is overwhelmingly perceived as pleasant, peaceful or quiet when on lockdown.

3.3 Impact on noise exposure (Noise Maps) and health effects (DALY)

The lockdown maps corresponding to the scenarios “-4 dB” and “-6dB” are presented in Figure 9 and Figure 10.

Figure 11 provide the estimated change in Disability Adjusted Life Years (DALYs) for the two agglomerations studied, based on an average individual over a lifetime. The estimated gains go up to 55% (*i.e.* 3.7 months gained) for the Metropolitan Area of Lyon and 70% (*i.e.* 3.5 months gained) for the Metropolitan Area of Grenoble with the “-6 dB” scenario (for the indicators L_{den} road and L_n road).

4 Discussion

A significant decrease in sound levels was observed at all the monitoring stations during lockdown. The decrease in sound levels goes from 4 dB to 6 dB for stations where the predominant sound source is road traffic. More significant decreases (up to 10 dB(A)) were identified on 4 measuring stations. This is due to the fact that other sources contribute to the sound environment of these sites in “normal situation”: the strong human presence (Place Bellecour in

Figure 9: Road noise maps for the usual situation (left) and the scenarios “-4 dB” (middle) and “-6 dB” (right) for the Metropolis of Lyon (1.4 million inhabitants)

Figure 10: Road noise maps for the usual situation (left) and the scenarios “-4 dB” (middle) and “-6 dB” (right) for the Metropolis of Grenoble-Alpes (0.4 million inhabitants)

Figure 11: Estimated variations in Disability Adjusted Life Year due to road noise within the metropolises of Lyon and Grenoble for two road noise reduction scenarios corresponding to what was observed during the lockdown period

Lyon, Allée Jean Jaurès in Toulouse and Place Victor Hugo in Grenoble) and rail traffic (Rocade Sud in Grenoble).

It should be noted that a 4 to 6 dB reduction in sound level corresponds to a 60% to 75% reduction in terms of sound energy. These orders of magnitude are consistent with the decreases observed in terms of road traffic, as well as the associated air quality indicators (nitrogen oxides, NO_x).

Decreases in physical levels are also well perceived by residents. Indeed, the results of the perception survey show that, on a scale of 0 to 10, the noisiness from all sources decreases from an average of 6.3 points to 2.4 points. This is a highly significant drop of 3.9 points. The decrease in perceived intensity differs between territories and reaches 2.7 points for respondents in the Lyon metropolitan area, 3.8 points for respondents in the Île-de-France region and 6.2 points in Nantes (where 96% of respondents indicated living nearby). The airport near Nantes suspended all commercial flights and closed its facilities for customers from March 30th to May 11th (<https://www.nantes.aeroport.fr/fr/coronavirus-covid-19>).

In addition to the impact identified in terms of sound levels, the sound environment in the city is profoundly modified in its composition and the hierarchy of sound sources is reversed. Sounds that were previously masked by the dominant presence of transport noise and sounds related to other human activities (deliveries, shops, terraces, voices, etc.) are now receding, giving way to sounds that were already present but were still barely perceivable. Because of the lockdown, people are forced to stay at home almost 24/7 and therefore paying more attention to their surrounding soundscape. The low background noise caused by the reduction of vehicles allowed to perceive weaker sounds from longer distances than usual. The re-

sults of the perception survey clearly show how sounds of natural origin have become predominant during lockdown.

This change in the sound environment is accompanied by positive adjectives (calm, pleasant, peaceful) chosen by the respondents. This can also be found in the comments detailing the respondents' perception: sleep regained thanks to the absence of traffic, rediscovery of natural sounds, etc.

Analysis of the measurement data from the first two weeks after lockdown shows that sound levels are not yet "back to normal" by this time.

In terms of health impact, the estimated gains in terms of DALY for the studied scenarios are significant (reduction of up to 55% for the Metropolitan Area of Lyon and up to 70% for the Metropolitan Area of Grenoble). It is to notice that this gain does not correspond to the effect of 8 weeks of reduction of noise exposure due to lockdown but to a hypothetical scenario where such reductions in noise levels are implemented over time. However, this estimation makes sense in view of the fact that reductions in the order of 4 to 6 dB are achievable (not without huge efforts) through technical actions and transport policy orientation (not only through lockdown measures leading to a drastic reduction in traffic volume). Indeed, studies conducted by Acoucity have shown that results comparable to those of the -4 dB scenario (in terms of population exposure and associated health impact) are possible by combining the silent motorization of all vehicles and a 3dB reduction in the rolling noise of light vehicles (corresponding to the combination of actions such as the generalization of silent tires, reduction of traffic speeds and the laying of acoustically efficient road surfaces). These types of action, combined with a more conscious use of motor vehicles (by favoring soft modes of transport and limiting the uncivil behavior of some drivers of two-wheelers or sports cars) could lead to results equivalent to those of the -6 dB scenarios.

5 Conclusions

Faced with the exceptional settings created by the lockdown, Acoucity carried out a study of the induced impact on noise environment, particularly with regard to road noise. The multi-dimensional approach that was chosen made it possible to examine the effects from different angles.

Firstly, the metrological approach made it possible to quantify the reduction in terms of sound pressure levels.

The variations found are in line with the variations observed in road traffic volume.

Secondly, the perception survey has led to gather important information on how residents felt about the changes experienced in their soundscape during this period. The reduction of sound intensity was clearly perceived by the respondents. But changes were not only related to the magnitude of sound that took place. In fact, the composition of the noise environment changed and this was well expressed by the inhabitants who noticed a strong decrease in transport noise which gave rise to a greater presence of natural sounds, such as birdsong or the sound of the wind in the foliage of trees. Those changes were perceived favorably and described as pleasant, calm and peaceful.

Finally, the mapping approach made it possible to evaluate in macroscopic form the impact in terms of noise exposure of the population in two conurbations in the south of France. The results of computations were used to study the health impact that would be obtained if similar reductions were to take place in the long-term.

It should be noted that previous studies carried out by Acoucity has shown that the effects observed during lockdown (sound exposure reduction) can also be achieved by combining technical solutions and a more reasoned use of motor vehicles by favoring soft modes of transport and limiting the uncivil behavior of some of two-wheelers or sports cars drivers.

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Conflict of Interests: The authors declare no conflict of interest regarding the publication of this paper.

References

- [1] Vincent B., Olney X., Vallet J., Philip T., Anselme C., Halbwachs Y., *Enjeux des observatoires de l'environnement sonore des agglomérations*, 2016, 2039-2045
- [2] World Health Organization, *Environmental Noise Guidelines for the European Region*, 2018

APPENDIX: The structure of the on-line questionnaire

How do you feel about noise environment during the lockdown?

What is your perception of the soundscape during the lockdown?

The purpose of this short questionnaire is to assess your feelings about the changes in your noise environment since lockdown in your country.

This questionnaire is anonymous and will only be used for research purposes.

Questionnaire made by

*(Non profit organisation)
There are 19 questions in this survey.*

In order to be able to answer this questionnaire you must know the noise environment of your lockdown area

If you answer NO, you may choose to:

- stop (thank you for your visit)
- Fill in the questionnaire to display the statistics but your answers might not be saved.

☐ I know my lockdown location well enough in normal times to be able to compare it with the current period.*

Please choose **only one** of the following:

- Yes
- No

☐ Your lockdown place corresponds to your: *

Please choose **only one** of the following:

- Main home
- Second home
- Other

[[Your lockdown place is *

Please choose **only one** of the following:

- Urban area
- Rural area
- Peri-urban area

Description of the audible sound sources around your lockdown area.**[[Check when applicable****[[Close to a road**

Please choose **all** that apply:

- Highway
- Usually high-traffic road
- Usually low-traffic road
- Does not apply

[[Close to a railroad

Please choose **all** that apply:

- High-speed railroad
- High-traffic railroad
- Low-traffic railroad
- Does not apply

[[Close to an airport

Please choose **all** that apply:

- National or international airport
- Local airport
- Does not apply

[[Close to a lively area

Please choose **all** that apply:

- Lively area (bars, restaurants, shops)
- Commercial (mall, supermarkets, etc.)
- Industrial
- Education area (campus, schools, etc.)
- Construction work
- Does not apply
- Other:

[] Close to a natural areaPlease choose **all** that apply:

- Countryside, mountain,
- Seaside, riverbank
- Forest, park
- Does not apply
- Other:

How do you perceive changes in your sound environment (outside your home) since lockdown?**[] During the lockdown period, compared to the “normal” situation you would say that the presence of sound sources of these types has:**

Please choose the appropriate response for each item:

	Strongly decreased	Slightly decreased	Remain the same	Slightly increased	Strongly increased	I don't know
Road transportation vehicles (cars, trucks, motorbikes, etc.)	☐	☐	☐	☐	☐	☐
Rail transportation vehicles (trains, tramway, etc.)	☐	☐	☐	☐	☐	☐
Air transportation vehicles (planes, helicopters, etc.)	☐	☐	☐	☐	☐	☐
Nature (bird songs, pets, farm animals, fountains, rivers, etc.)	☐	☐	☐	☐	☐	☐
Neighbourhood (voice, music, footsteps, television, cooking, etc.)	☐	☐	☐	☐	☐	☐

Assess the noise level of your lockdown location**Could you rate, from 0 to 10 (0 being very quiet, 10 being very noisy) your sound environment as it was before lockdown? ***

Your answer must be between 0 and 10

Only an integer value may be entered in this field.

Please write your answer here:

Could you rate, from 0 to 10 (0 being very quiet, 10 being very noisy) your sound environment since the lockdown? *

Your answer must be between 0 and 10

Only an integer value may be entered in this field.

Please write your answer here:

Could you rank the sounds you heard before lockdown (from the most dominant to the least dominant)?

All your answers must be different and you must rank in order.

Please number each item in order of preference from 1 to 6

Vehicles
Trains etc.
Airplanes
Activities (bars, shops, industries, construction work)
Nature (songbirds, pets, water...)
Neighbourhood (voices, footsteps, music, etc.)

Could you rank the sounds you hear since lockdown (from the most dominant to the least dominant)?

All your answers must be different and you must rank in order.

Please number each item in order of preference from 1 to 6

Vehicles
Trains etc.
Airplanes
Activities (bars, shops, industries, construction work)
Nature (songbirds, pets, water...)
Neighbourhood (voices, footsteps, music, etc.)

Would you say that change in the sound environment since lockdown is (multiple choices):

Please choose **all** that apply:

- Pleasant
- Unpleasant
- Peaceful
- Irritating
- Exciting
- Calm
- Agitated
- Monotonous
- Other:

[] Before lockdown, you were spending your day:

Please choose **only one** of the following:

- At home
- In another place

[] How old are you?

Only numbers may be entered in this field.

Please write your answer here:

[]In which country do you live?

Please write your answer here:

[]Where do you live? (city)

Please write your answer here:

[]Do you wish to add anything?

Please write your answer here:

Questionnaire made by

(Non profit organisation)

Click the picture if you wish to know more about it.

Thank you for completing this survey.

Nantes Aéroport

Noise perimeter (Plan de Gêne Sonore) around the Nantes Atlantique airport:

As a reminder, the noise perimeter is not matching the planes trajectories and air corridors may vary.
Standard Instrument Departure for this airport: https://storage.ivao.fr/lfr_public/MANEX/MANEX_LFRS.pdf