



POST-COVID SOUNDSCAPES OF LIVING ENVIRONMENTS: INSIGHTS FROM A SURVEY IN ITALY

Chiara Bartalucci^{1*} Raffaella Bellomini¹ Sergio Luzzi¹
Paola Pulella¹ Giulia Iannuzzi¹ Giulia Torelli²

¹ Vie en.ro.se. Ingegneria S.r.l., Viale Belfiore 36, 50144 Firenze, Italy

² Department of Statistics, Computer Science, Applications "Giuseppe Parenti", University of Florence, Italy

ABSTRACT

COVID-19 pandemic and restrictions that forced people to stay at home profoundly impact people life and the environment also resulting in unprecedented changes in acoustic environments. While research on sounds was mainly focused on noise level assessments and their significant reduction during the lockdown period, soundscape research offers precious insights on the long-lasting and far-reaching impacts of the pandemic at the individual level. Specifically, the gradual returning to normal has brought about questions on the experienced "new normal" soundscapes and on how to capitalize on lessons learned. To explore if and to what extent the pandemic has engendered changes in the perception of living acoustic environments, we have conducted a study in Italy. A total of around 70 questionnaires distributed throughout Italy were collected and analysed. A comparison between pre/during and post-COVID highlighted a renewed perception of soundscape in the post-pandemic compared to period before COVID-19 spread. In this paper we also discuss the alteration of soundscapes as experienced by working people, a category that has attracted interest due to the implications of the shift to remote working as alternative or complement to the previous work models.

Keywords: *soundscape, online questionnaires, working people, statistical analyses, pandemic*

1. INTRODUCTION

Over the past three years, several studies have explored the impacts of COVID-19 pandemic on the environment focusing on vehicular traffic flows, noise levels and air quality to deepen the understanding of the far-reaching repercussions of the pandemic on people well-being and environmental pollution. As regards the impact on soundscape of governments' restrictions to control the spread of the virus (e.g., partial, and full lockdown), research was mainly focused on noise level assessments. Monitoring campaigns and projects were activated to collect recordings and metadata of sounds in the COVID-19 scenario [1]. Generally, urban soundscape was positively affected by the contraction of the road traffic. The decrease of rail and ship traffic and international air traffic also had a relevant impact [2]. Because of the reduced social and economic activity, significant sound level reduction was reported in big cities around the world and urban areas [3]. While a general decrease of noise levels during government restrictions and containment measures was observed, a difference in the degree of noise reduction was found across space and different urban areas. As an illustration, according to two assessments of acoustic environments carried out in many big cities, such as Rio de Janeiro [4] and London [5], the more relevant reduction was not observed for the areas where traffic is the dominant sound source, but rather for areas where the human activity, also combined with traffic, is the main contributor to the acoustic environment. However, according to a recent literature review [6], only 7% of the studies exploring the COVID-19 impacts on soundscapes have conducted both

*Corresponding author: chiara.bartalucci@vienrose.it

Copyright: ©2023 Chiara Bartalucci et al. This is an open-access article distributed under the terms of the Creative Commons Attribution 3.0 Unported License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

perceptual and noise level assessments and most of the perceptual changes of auditory sensations were evaluated by research participants or volunteers. According to our previous study conducted to explore perceptual evaluation of pandemic soundscapes in Italy during the lockdown period (March - May 2020), using a survey method, the unexpected and peculiar lockdown scenario altered indoor acoustic environments [7]. The quality of the perceived soundscape improved: the soundscape was evaluated as “good” or “very good” by 47% of the respondents in the period before COVID-19 emergency versus 73% during the lockdown period. The composition of soundscape and the relative importance of different sound sources (e.g., road traffic, rail traffic, nature sounds neighborhood sounds) also changed. Particularly, data analysis shows an overall increase of perception of nature sounds, a lower perception of road traffic, rail traffic, overflights, and mechanical/electrical sounds. These findings have confirmed the expectation of a general reduction of the perception of annoying sounds. However, a deeper investigation, made using logistic regression models, shows that people aged between 36 and 65 years that correspond to the “working category”, have witnessed a worsening in the perception of the traffic noise in terms of annoyance and of the noise produced by neighborhood, compared to younger respondents. The category of workers has attracted interest during the pandemic considering the implications of the shift to remote working as alternative (especially during lockdown) or complement (during the gradual returning to normal lives) to previous work models. On this point, it is worth noting that several studies have shown that the pandemic scenario has not resulted only in positive effects on noise annoyance; adverse consequences dealing with the reduced appropriateness for working and learning environments, coupled with psychological responses to an unprecedented and unwanted situation have been also pointed out. During the pandemic it was observed an increase in perceived stress and mental health issues also linked to sleep disruption, reduced physical activity and changes in eating habits [8]. The general picture of the changes triggered by the pandemic has been reported and described by several studies. Specifically, a growing body of research has highlighted the new challenges faced by indoor environments and houses which had to host new social functions (e.g., remote working, home schooling, socializing) [9]. The returning to the new normality brings about questions on the implications of the alteration of social context and environmental/sound pollution during the unprecedented situation we lived on the “new” soundscape. This aspect is of key importance considering that soundscape is of major impact to people perception of

environmental quality, also involving people health and well-being. The aim of this paper is to contribute and explore the “new-normal” soundscapes in living environments. Particularly, adopting a survey method, we have investigated if and how changes in soundscape occurred, comparing the pre-covid scenario with the lockdown period and with the period after strict restrictions. In this paper, the results and analysis presented in [10] will be enriched by specific insights on soundscape as perceived by workers.

2. METHODS

2.1 Questionnaire: design and distribution

The questionnaire is structured in two sections. The first section concerning personal information aims at characterizing the sample and the changes in participants’ habits. The second section focuses on the soundscape perception related to the most attended living environment during the day. A comparison between the recollection of the soundscape before the spread of pandemic - before the 11th of March 2020 - and the period of distribution of the questionnaire - between 06/05/2022 and 06/07/2022 - is investigated. This latter section consists of seven questions, mainly divided in two types: multiple-choice and matrix questions [11-12]. The questionnaire has been distributed using a free and open-source software for collecting and managing data online (Kobo toolbox). The sample of voluntary participants who filled-in the questionnaire is composed of sixty-eight people living in Italy. Sixty-two submitted questionnaires were analysed, as the remaining six questionnaires were considered invalid for a small number of data entered.

2.2 Data analysis

The collected data have been subject to two typologies of statistical analysis: descriptive analysis and logistic regression models. For the latter a dichotomous character has been used and associated to the response variable. In fact, logistic regression models provide a powerful technique for analysing data involving binary responses and several explanatory variables. They are characterized by an extremely flexible and easily used function. The response variable assumes two values: “0” when the answer can be considered negative (very bad, bad, and mediocre) and “1” otherwise (discrete, good, and very good). As regards age, the variable has been dichotomized by dividing those who work (both in public and private companies) by those who

do not work (retired, students and unemployed). Taking into account the age variability of the sample, four age categories (20- 35, 36-50, 51-65 and 66-80) have been defined. Finally, for the other used explanatory variables, the answer has been dichotomized with the same strategy as the response variable. So, the answer that can be considered negative (very bad, bad, mediocre, total disagreement and disagreement) have value “0”, instead the variables take on value “1” in the opposite case. For the analysis it has been deemed appropriate to use the logistic regression model. For the quality of the sound environment, the logit model is:

$$\text{logit}(y_{\text{genv}}) = \alpha_i + \beta_1 \text{emp}_i + \beta_2 \text{quar}_i + \beta_3 \text{rest}_i + \beta_4 \text{appr}_i + \beta_5 \text{comp}_i \quad (1)$$

where α_i is the constant term, emp_i is a vector that represents the employment position of the respondent, the variable quar_i indicated if the subject has experienced quarantine, rest_i and appr_i indicate if the environment is considered restful and appropriate. Finally, the covariate comp_i indicates how the whole environment is considered.

In order to analyse the sound environment of the respondents more in detail, two other logistic models, that consider the perception of traffic noise and nature sounds in the surrounding environment as a dependent variable, have been carried out.

For traffic noise, the resulting model is:

$$\text{logit}(y_{\text{traffic}}) = \alpha_i + \beta_1 \text{room}_i + \beta_2 \text{livel}_i + \beta_3 \text{mono}_i \quad (2)$$

where α_i is the constant term, room_i indicates the perception of the sounds coming from other rooms of the same building. livel_i and mono_i indicate if the environment is considered lively or monotonous.

For the nature sounds, the resulting model is:

$$\text{logit}(y_{\text{nature}}) = \alpha_i + \beta_1 \text{age}_i + \beta_2 \text{sex}_i + \beta_3 \text{emp}_i + \beta_4 \text{Thouse}_i + \beta_5 \text{enjoy}_i \quad (3)$$

where α_i and emp_i are the constant terms and a vector indicating the employment is represented by the individual. The covariates age_i and sex_i respectively indicate the age and the gender of the respondent. The covariate Thouse_i is a vector that indicate the time spent in the house, and enjoy_i indicates if the environment is assessed as enjoyable.

3. RESULTS

3.1 Descriptive analysis

In the following diagrams, the frequency distribution of the answers referred to the personal information is shown. The sample of citizens who submitted the questionnaire is over 20 years old and equally distributed between male and female (Figure 1), with a slightly higher percentage of women (52% versus 48%). Most of the participants got degrees or higher education and works as self-employed (40%) or attends university as professor/researcher (10%) or student (8%) (Figure 2). It can be stated that these categories of workers have a more independent management of work. It is notable that the most part of the sample spent at home a considerable period of time (Figure 3). Moreover, the 72% of the subjects keeps the same job/student position from March 2020 till the submission of the questionnaire and during this period a slightly higher percentage of subjects has experienced fiduciary isolation or quarantine (56%) compared to the people who were not personally involved in COVID-19 restrictions.

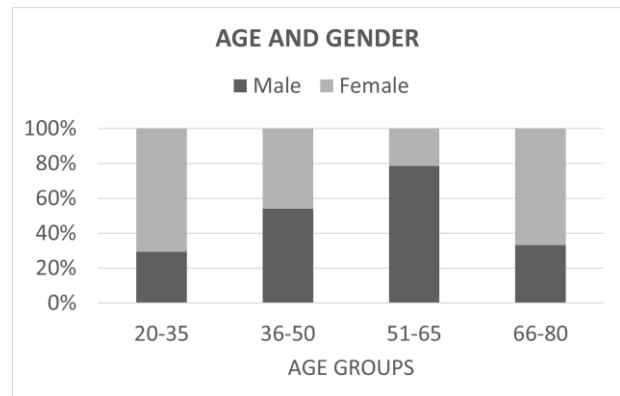


Figure 1. Frequency distribution of age and gender.

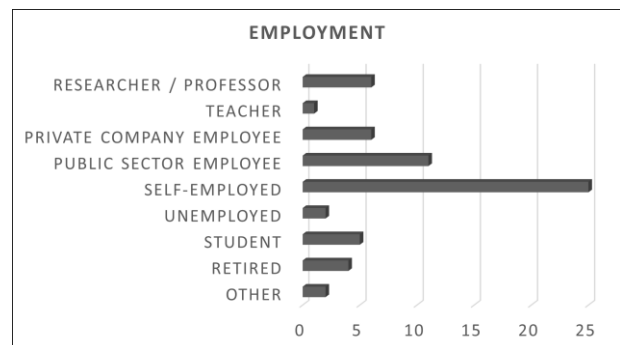


Figure 2. Frequency distribution of employment.

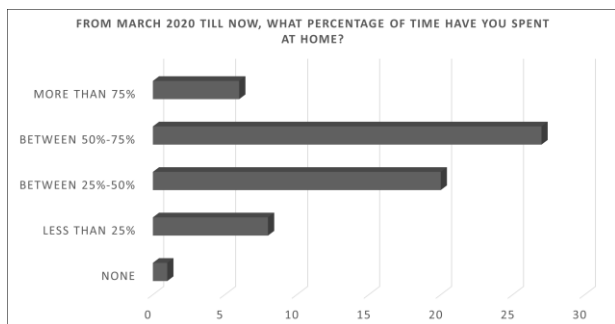


Figure 3. Frequency distribution of the time subjects spent at home, in the period between March 2020 and the current situation.

In the two months of submission of the questionnaire (between 6th May and 6th July 2022), the investigated sample states that the place he/she frequented the most is the one where he/she works or studies, followed by his/her house and as last ranked, open places such as parks (ranked as third most frequented place by 50% of the sample). This provides a framework in which people mainly attend indoor environments. According to the question related to the time spent in the currently most frequented place, most of the people (52 out of 62) started using that space before COVID-19 restrictions and use it full time (44%) or half time (40%). Subjects were also asked to define how their personal habits and the perception of soundscape have changed in comparison with the period before the restriction due to COVID-19. For a comparison between the period before restrictions and the administration of the questionnaire, questions related to sound perception and changes in subjects' habits have been analysed.

Most of the sample (40%) shows a preference in meeting friends and acquaintances rather than unknown people, whereas the 34% doesn't declare a sharp preference and define that it is irrelevant whether they are known people or strangers. 61% of the subjects prefers not to go to crowded places, such as restaurants, clubs, and shopping centres, and spend more time outside (66%), for example going to public parks. In the light of the time spent in the most frequented place from the period prior to COVID-19 restrictions, the comparison of the type and intensity of sounds is of particular interest in terms of change in personal perception of spaces. For all the investigated sound sources, most of the subjects states that no difference has been noted between the period prior to COVID-19

restrictions and the one of administration of the questionnaire in terms of sound intensity. However, a not negligible 35% of respondents reported an increase (ranging from "slight" to "extreme" increase) of perceived mechanical/electric sounds, 37% of neighborhood sounds and nature sounds. Similarly, 33% of the interviewees reported an increase of road traffic sounds (Figure 4).

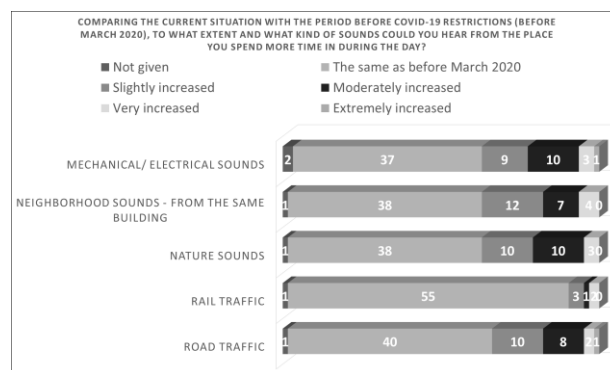


Figure 4. Type and intensity of sounds heard from home.

The soundscape, as it is perceived in the most frequented place during the administration of the questionnaire, is mainly defined as pleasant (26 out of 62 "agree" and "strongly agree" with this statement) and not resting (34 out of 62 "disagree" and "strongly disagree" using the term "resting") nor annoying (32 out of 62). Moreover, the adjective "chaotic" has been debated: it has been used by 24 out of 62, whereas the soundscape was defined as non-chaotic by 29 of the subjects.

A significant number of subjects was undecided in defining the features of the soundscape: a percentage between 11% (for the term "chaotic") to 37% (for the term "boring") did not clarified its accordance with the given adjectives (Figure 5).

In general, the soundscape has been assessed as "acceptable" by most of the sample (34%) (Figure 7). However, the distribution of the answers takes the form of a Gaussian curve: a comparable number of subjects evaluates the soundscape as "poor" (24%) and "good" (27%). Relating the soundscape to the context, the first is considered as "moderately" appropriate to the context by almost half of the subjects (48%) followed by the 32% who defined it as "very" pertinent (Figure 6).

As shown in Figure 8, questionnaires have been mainly filled-in in North and Central Italy. In the most significant cities, the number of collected questionnaires is displayed

within the colored spot, otherwise it means it was filled in by only one person.

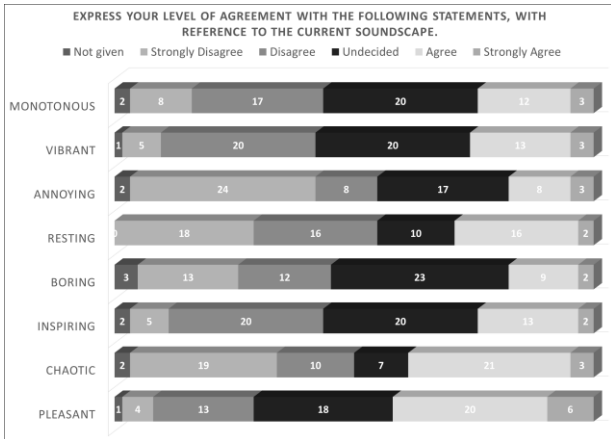


Figure 5. Definition of the soundscape in the current situation

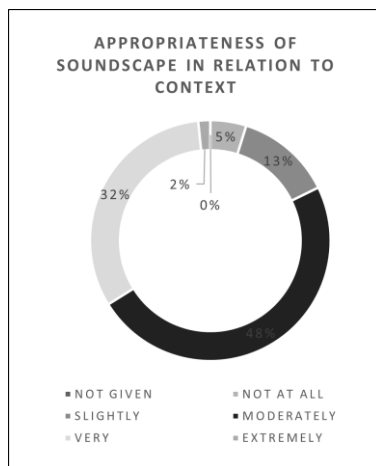


Figure 6. Assessment of the appropriateness of the soundscape in the current situation

As shown in Figure 7, environment is mainly assessed as “good” (37%) and “acceptable” (37%). A significant number of subjects defined it as “poor” (20%).

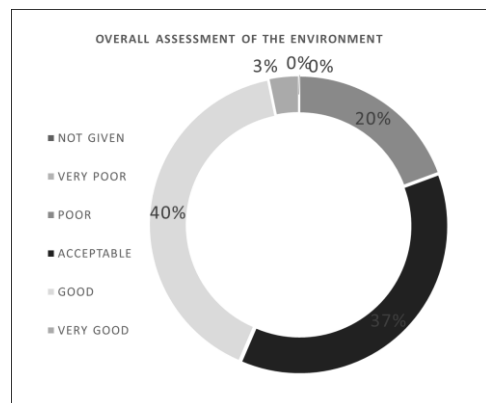
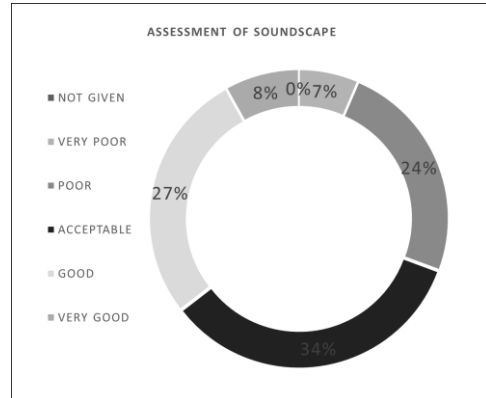


Figure 7. Assessment of the soundscape and the environment in the current situation



Figure 8. Distribution of the respondents

3.2 Logistic regression models

According to the collected data, the results of the logistic regression models are presented. In this paragraph, the results of the three models mentioned in paragraph 2.2 are displayed. All the models, even the not reported ones, include missing categories of the covariates.

In the following tables, the p-values determine which variables are significant in the regression model (* $p \leq 0.1$, ** $0.01 < p \leq 0.05$, *** $p \leq 0.01$).

In Table 1 the coefficients of the model, considering environmental quality as dependent variable, are reported.

Table 1. Coefficients of the model for environmental quality

Env. Quality	Coef.	Std. Err.	P> z
Occupation	-4.156**	1.821	0.022
Quarantine	-2.944***	1.178	0.012
Restful	4.531***	1.503	0.003
Appropriate	2.698*	1.460	0.065
Complex	2.602*	1.575	0.099
Intercept	0.706	1.969	0.720

The model measures the relationship between the environmental quality dependent variable and some covariates. People who work tend to perceive a lower quality of the soundscape than those who do not work. Furthermore, respondents who have experienced quarantine appear to have a lower perception of the environment than those who have not experienced it. Moreover, people who consider the environment as restful and appropriate tend to assess the soundscape better than the others. Finally, subjects who positively assess the environment, also provide a positive answer to the soundscape.

Table 2. Coefficients of the model for traffic noise

Traffic	Coef.	Std. Err.
Rooms	5.168***	1.574
Lively	3.595***	1.304
Monotone	-2.42**	1.225
Intercept	-4.315***	1.378

The coefficients of two models that measure the relationship between some covariates and the perception of traffic noise and natural sounds are respectively shown in Table 2 and in Table 3.

Table 3. Coefficients of the model for nature sounds

Nature	Coef.	Std. Err.
Age		
36-50	-2.566*	1.519
51-65	-4.723**	2.007
66-80	0.276	1.482
Sex (Woman)	-2.577**	1.121
Occupation	3.067**	1.615
Time at home	2.401***	0.890
Enjoyable	1.724*	1.154
Intercept	-2.535*	1.507

The first model concerns the perception of traffic noise during the administration of the questionnaire, compared to the period before COVID-19 restrictions. It emerges that subjects who state an increase in the perception of noise coming from other rooms of the same building also highlight it in the perception of road traffic noise. People who find their surroundings lively tend to hear more noises in the period that followed the COVID-19 restrictions. On the other hand, those who consider the environment “monotonous” tend to perceive a decrease in traffic noise during the second period.

The model concerning nature sounds shows a correlation between the perception of nature sounds and the age of the respondents. In fact, compared to the reference category (20-35 years) people who are between 36 and 65 years old tend to perceive a decrease in the sounds coming from the nature if comparing the period before COVID-19 restrictions with the period of administration of the questionnaire. Regarding gender, women, compared to men, register a decrease in the perception of the nature sounds between the two periods. Furthermore, subjects who work and those who spend a higher percentage of time at home experience an increase in the perception of the sounds coming from the nature. Finally, people who assess the environment as “pleasant” tend to have a higher perception of the sounds of nature in the period of administration of the questionnaire rather than in the period before COVID-19 restrictions.

4. DISCUSSION

According to the results presented in section 3.1, the perception of soundscape in the post-pandemic situation is generally unaltered compared to the period prior to the restrictions. This is consistent with an urban soundscape where sound events seem to have reacquired the same characteristics that had before pandemic restrictions, because of the resumption of social and economic activities. Nevertheless, it is worth noting that a not negligible number of respondents reported an increase of perceived mechanical/electric sounds, of neighborhood and nature sounds as well as road traffic sounds. Considering that a significant majority of the respondents has returned to the places that frequented the most before the pandemic, these results suggest that people may have increased attentive listening of everyday predominant sound sources after experiencing lockdown and pandemic crisis. This is corroborated by the results of the logistic regression model that consider traffic noise perception as dependent variable: subjects who stated an increase in the perception of neighborhood sounds compared to the pre-covid situation also reported an increase in road traffic noise.

Also, the fact that subjects who have experienced quarantine have a lower perception of the environmental quality than those who have not experienced it may be due to the circumstance that quarantine, as an obligatory imposed period to spend at home, leads individuals to perceive the noise of the surrounding environment as more negative than what they would normally have perceived. On the other hand, as expected, a strong relationship is highlighted between the positive perception of the soundscape and the overall good evaluation of the environment. If we focus on the category of people who work, the results of the model in which nature sounds is included as a dependent variable show that this category experienced an increase in the perception of the sounds coming from nature. It can be asserted that the pandemic might be a reference point for the identification of positive sounds that were missing or were predominant during that unique historical phase. Indeed, referring to the findings of the previous work [7], during the lockdown period, a general increase in the perception of nature and neighborhood sounds was observed and, at the same time, a reduction in terms of annoyance was declared. In particular, people aged between 36 and 65 years, that correspond to the “working category”, have witnessed a reduction in the perception of traffic noise and have been more sensitive to the noise produced by neighborhood, compared to younger respondents, during restrictions. Additionally, results of the survey have shown that people who work tend to perceive a

lower quality of the soundscape than those who do not work. These main findings confirm that to support indoor activities (such as remote work) and improve health, well-being, and quality of life of buildings’ occupants, a perception-based approach that does not only consider objective data (acoustic measurements) should be applied. This is particularly urgent in a context where there seems to be a renovated sensibility to different type of sounds of everyday life and, particularly, considering a shift to remote working solutions as complement of more traditional models of work. Indeed, this shift has put challenges on indoor environments (e.g., houses) that have not been designed to accommodate this type of social activity and resulting new lifestyles. In this line, the results of a study conducted during the COVID-19 lockdown in London has suggested that spaces considered more appropriate for remote working are those perceived comfortable (with no annoying sounds) and guaranteeing privacy [9].

As regards social habits, results show that people currently prefer not to go to crowded spaces (e.g., restaurants, shopping centers). It is also confirmed that, as a result of the COVID-19 pandemic, the willingness to spend time in outdoor places has significantly raised. Therefore, in line with previous research, the present study suggests that there is an increasing need to easily and safely access green spaces located not only in open country areas, but also within urban centers.

5. CONCLUDING REMARKS

COVID-19 pandemic has offered a unique opportunity to test soundscapes and assess how the outdoor and indoor living environments change under extreme circumstances. The gradual return to normality provides interesting insights on the long-lasting and far-reaching impacts of the pandemic on soundscape perception, that have been partly assessed by the authors and illustrated in this article, further developing the previous research work [7-10]. The present paper aims at contributing and directing a broader discussion concerning the desired features for future cities and living environments in terms of improving public and indoor spaces.

Results on social habits and soundscape perception suggest and confirm to city planners, public administrations, acoustics experts and soundscape designers that the proper maintenance and enhancement of outdoor public spaces is a key turning point. It ensures the well-being of citizens, also in the light of the impacts of pandemic restrictions experience. Indeed, a good correlation was found between the perception of soundscape and natural sounds with the

subjective assessment of environmental quality. This is a result that confirms the findings of previous studies and highlights the relevance of nature sounds on the positive evaluation of living environments. Concurrently, the worsening perception of the soundscape inside buildings emphasizes how crucial the role of the acoustic design is. Specifically, the increasingly widespread practice of remote working and the need of rethinking indoor spaces accordingly have turned the spotlight on the importance of ensuring the correct criteria for sound insulation and comfort in buildings. As the most restrictive period related to pandemic containment measures seems to be over in most EU countries, a further development of the study might be spread in other countries for a wider evaluation of the data, adapting the questionnaire to local characteristics of buildings and habits of people and communities. Moreover, further research might focus on comparing long-term measurements campaigns referred to the different periods and related restrictions, in order to be able to correlate subjective data with objective ones.

6. ACKNOWLEDGMENTS

The authors would like to express many thanks to the Acoustical Society of Italy (AIA) and to Giovanni Brambilla, for supervising the questionnaire and encouraging and promoting the collection of the data.

7. REFERENCES

- [1] C. Bartalucci, F. Borchi, M. Carfagni: “Noise monitoring in Monza (Italy) during COVID-19 pandemic by means of the smart network of sensors developed in the LIFE MONZA project”, *Noise Mapping*, vol. 7, no. 1, pp. 199–211, 2020.
- [2] K. Vogiatzis, V. Zafiropoulou, G. Gerolymatou, D. Dimitriou, B. Halkias, A. Papadimitriou et al.: “The noise climate at the time of SARS CoV-2 VIRUS/COVID-19 disease in Athens – Greece: The case of Athens International Airport and the Athens Ring Road (Attiki Odos)”, *Noise Mapping*, vol. 7, no. 1, pp. 154–70, 2020.
- [3] P. Aumond, A. Can, M. Lagrange, F. Gontier, C. Lavandier: “Multidimensional analyses of the noise impacts of COVID-19 lockdown”, *The Journal of the Acoustical Society of America*, vol. 151, no. 2, pp. 911–23, 2022.
- [4] N. Gevú, B. Carvalho, G.C. Fagerlande, M.L. Niemeyer, M.M. Cortês, J.C. Torres: “Rio de Janeiro noise mapping during the COVID-19 pandemic period”, *Noise Mapping*, vol. 8, no.1, pp.162–71, 2021.
- [5] F. Aletta, S. Brinchi, S. Carrese, A. Gemma, C. Guattari, L. Mannini et al.: “Analysing urban traffic volumes and mapping noise emissions in Rome (Italy) in the context of containment measures for the COVID-19 disease”, *Noise Mapping*, vol.7, no.1, pp.114–2, 2020.
- [6] Y. Hasegawa, S.K. Lau: “A qualitative and quantitative synthesis of the impacts of COVID-19 on soundscapes: A systematic review and meta-analysis.” *Science of the Total Environment* 844:157223, 2022.
- [7] C. Bartalucci, R. Bellomini, S. Luzzi, P. Pulella, G. Torelli: “A survey on the soundscape perception before and during the COVID-19 pandemic in Italy.” *Noise Mapping*, vol. 8, no.1, pp. 65–88, 2021.
- [8] E. Caroppo, M. Mazza, A. Sannella, G. Marano, C. Avallone, A.E. Claro, et al.: “Will Nothing Be the Same Again?: Changes in Lifestyle during COVID-19 Pandemic and Consequences on Mental Health.” *International Journal of Environmental Research and Public Health*, Vvol. 18, no. 16, pp. 843, 2021.
- [9] S. Torresin, R. Albatici, F. Aletta, F. Babich, T. Oberman, A.E. Stawinoga, et al.: “Indoor soundscapes at home during the COVID-19 lockdown in London - Part I: associations between the perception of the acoustic environment, occupant activity and well-being”, *Applied Acoustics*, 183:10830.
- [10] C. Bartalucci, R. Bellomini, S. Luzzi, P. Pulella, G. Iannuzzi and G. Torelli: “A renewed perception of living environments after restrictions due to pandemic in Italy.”, *Noise Mapping*, vol. 9, no. 1, pp. 189-203, 2022.
- [11] T.J. Cox, B.M. Shield: “Audience Questionnaire Survey of the Acoustics of the Royal Festival Hall, London, England”, *Acta Acustica*; vol.85, pp. 547–59, 1999.
- [12] Ö. Axelsson, M. E. Nilsson, B. Berglund: “A principal components model of soundscape perception.”, *The Journal of the Acoustical Society of America*, vol. 128, no. 5, pp. 2836-2846, 2010.