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# A renewed perception of living environments after restrictions due to pandemic in Italy

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**Abstract:** The rapid habitual changes induced by the emergence of the COVID-19 pandemic first and the end of the most restrictive phase coinciding with the lock-down later resulted in significant changes, also occurred at an environmental level and, specifically, with regard to the perception of the soundscape in all European countries. The seek for knowledge underlying the research illustrated in this article concerned whether or not the perception of the soundscape following the almost normal resumption of daily activities had returned to that of the period before the restrictions came into force.
This article illustrates how an online questionnaire structured in 16 questions was designed and administered to a sample of Italian citizens, in order to understand whether and how the habits of the respondents had changed in the three reference time periods (before the pandemic spread, the period marked by lock-down or other restrictions in early 2020 and the period afterwards) and their perception of the perceived soundscape of the place where they spend most of their days. A total of around 70 questionnaires distributed throughout Italy were collected and analysed. The results obtained, through the use of descriptive statistical analyses and logistic models, are also presented in this article.

**Keywords:** soundscape perception, questionnaire, pre and post pandemic

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## 1 Introduction

The outbreak of the COVID-19 pandemic and the unprecedent actions taken by governments to restrict the spread of the virus had an enormous impact on people life and resulted in multiple environmental implications. Over the past three years, numerous studies have assessed the effects of COVID-19 pandemic consequences in terms of environmental pollution focusing on vehicular traffic, noise levels and air quality, to deepen our understanding of the far-reaching repercussion of the pandemic on people wellbeing and the environment.

Extensive monitoring and projects were activated to collect recordings and metadata of sounds in the COVID-19 scenario, such as the LYS (Locate Your Sound) project in Italy the UK Quiet Project and a N.Y.U. project, called SONYC [1]. The reduction of noise pollution was a positive unintended effect of the lockdown measures in several countries and many urban contexts. A significant sound level reduction has been reported in big cities around the world (Rio, Montreal, Lyon, Madrid, Milan, Girona and Paris) [2].

In Rome, during the lockdown period (March-May 2020) a consistent reduction of noise levels (8.7 dB(A)), with respect to the same period in 2019, was registered. Indeed, severe measures to tackle the pandemic reduced the private road vehicles traffic by 64.6%. Road traffic is considered as one of the main sources of noise pollution in the city [3]. Predictably, the number of people exposed to noise also significantly lowered. For example, in a pilot area of Milan, the reduction of the exposed people above the cut-off values was 61% for Lden and 55% for Lnight during the lockdown [4]. A recent meta-analysis has pointed out that average noise-level reduction registered is related to the stringency level of the confinement policies choices, as well as to urban morphology and main noise sources [5]. Generally, urban soundscape was positively affected by the contraction of the road traffic, however, in specific areas, other factors also had a significant impact such as the reduction of rail and ship traffic and international air traffic [6].

In addition, while a general significant decrease of noise levels during the COVID-19 containment measures was observed, a difference in the degree of noise reduction was found across space and different urban areas. For example, according to two assessments of acoustic scenarios carried out in as many big cities, Rio de Janeiro [7] and London [8], the more relevant reduction was not observed for the areas which have traffic as the dominant sound source, but rather for areas where the human activity - also combined with traffic - is the main contributor to the acoustic environment.

According to a study that analyzed urban traffic volumes and mapped noise emissions in Rome [3], noise emission reductions during restriction for COVID-19 containment compared to the pre-covid situation were considerably smaller in freeway than those observed for the urban road category. This may be explained by the fact that a significant reduction in traffic volumes over freeway links leads to high-speed regime.

Studies based on perceptual approaches and applying survey method have highlighted the impact of lockdown on the perceived sound environments. The analysis of an online distributed questionnaire in Italy shows a general reduction of annoying sounds during the lockdown period. In particular, a decrease in the perception of the transportation and mechanical sound sources and an increase in the natural sound sources have been reported [9]. Findings also show that the respondent was more inclined to give a positive judgement of the soundscape quality if he/she did not live alone during lockdown. Acoucité [10] found that the decrease in sound levels registered by sound monitoring stations in greater Lyon has corresponded to a perceived calm, pleasant, peaceful soundscape by the inhabitants that were asked to fill out an online questionnaire. People positive reaction to the outdoor new quieter conditions has been also demonstrated by the results of an international survey [11].

Since during lockdown phases home environment became the dominant place for daily activities, scholars have explored the perceived quality of indoor acoustic environment during confinement, confirming the multiplicity of factors that should be taken into consideration to study noise annoyance and perceived comfort at home. These factors encompass urban and building features, people noise sensitivity, sound typology (*e.g.*, the perceived dominance of neighbours' noises), and situational factors (*e.g.*, number of people at home) and call for applying a perceptual and multisensory perspective [12].

Notably, the pandemic scenario has not resulted only in positive effects on noise annoyance. Indeed, studies have also revealed adverse consequences dealing with the reduced appropriateness for working and learning environments coupled with psychological responses to an unprecedent and unwanted situation e.g., an increase in perceived stress and mental health issues also linked to sleep disruption, reduced physical activity and changes in eating habits [13, 14]. Low-income or unemployed communities have been particularly affected [5]. With a special focus on remote working settings, results of an online questionnaire distributed in Italy in May 2020 show that 25% of workers recognize the noise generated by people as the main source of disturbance during remote working hours, causing a loss of concentration [15]. These findings are in line with the results of logistic regression models, whose analyses have been carried out on the data of the above-mentioned survey. The latter focuses on the soundscape perception before and during COVID-19 pandemic in Italy [9]. The results show that, as regards the perception of road traffic noise during the lockdown period compared with the pre-lockdown one, people with an age between 36 and 65 hear more traffic noise than younger ones and the neighbourhood noise has been more statistically significant for employed respondents. It is also worth noting that the results of a noise survey conducted in England show an increase in complaints by 54% between 2019/20 and 2020/21, being residential noise the main cause [16].

After the lifting of restrictions, noise levels did not return immediately to the ones prior to the lockdown period(s). In Monza (Italy), one month after the relaxing of restrictive measures (June 2020) noise levels had not yet returned to the ones prior to the lock down period [1]. This is explained by the progressive reopening of the activities and changing lifestyle habits, such as the spreading of remote working as a complement to previous work models. According to a study carried out in Spain, that has recorded the Global Positioning System (GPS) position of each respondent to an online questionnaire to correlate the recorded noise levels with the results of the survey, the perception of noise quality changed depending on the phase of de-escalation of restrictions, the type of property, and the outside noise [17].

Whilst very few studies are already available comparing traffic flows between the period before the pandemic spread (pre-2020), the period marked by lock-down or other restrictions (early 2020) and the period afterwards up to the current one, several studies report data comparing traffic flows in early 2020 with the same period in 2019.

Specifically, according to [18], during the first pandemic wave in 2020, in Poland the greatest decrease in traffic volume took place. This trend was in line with those registered in other countries around the world [19]. In details, a large decrease in traffic volume was recorded in France

during 2020 lockdown [20], resulted from both short-range and long-range population travel stopping by as much as 65%. In Greece, traffic volume decreased by more than 80% during the most serious period of the pandemic [21]. Also, a 65% decrease in traffic volume was recorded on non-urban roads in Spain [22]. The state-wide traffic volume in Florida decreased by 47.5% [23]. Meanwhile, a data analysis by Tom Tom of several major European cities confirmed that road traffic volume reduced in 2020 in comparison to 2019 [24]: the reduction ranges from the 54% registered in Moscow to the 11% registered in Detroit, with the majority of the European cities placed in between these two extremes.

Due to the unprecedent reduction in economic activities and the drop in traffic volumes during the lockdown events, benefits have been observed not only as regards the acoustic environment, but also concerning air quality of cities. $CO_2$ emissions dropped by 58% across Europe [25]. Significant declines in the population-weighted concentration of ground-level nitrogen dioxide released into the atmosphere by vehicles, power plants, and industrial facilities, and fine particulate matter was also found [26]. Concerning the concentration of nitrogen dioxide, in southern Europe strongest reductions of 40–50% were registered in the first stage of the lockdown, while, with the resume of regular activities in July and August 2020 the concentrations appeared to return to pre-covid levels (with a slower trend in large cities). These changes were also mapped by The Copernicus Sentinel-5P satellite, part of the European Copernicus Programme [27].

The aim of this paper is to explore if and how changes in terms of people's perception of the soundscape occurred, comparing the pre-covid scenario with the lockdown period and with the period subsequent to the moments of greatest restrictions to halt the spread of the pandemic.

The adopted instrument is an online questionnaire, designed and submitted to voluntary participants in Italy who were asked to compare the lockdown acoustic soundscape with the previous and the following ones. In the current paper the questionnaire structure and the obtained results, in terms of descriptive analysis and comparison of answers related to the different periods and of statistical models, are reported.

# 2 Methods

## 2.1 Questionnaire: design, distribution, and collection

The questionnaire is structured in two sections, as presented in Table 1. The section concerning personal information aims at characterizing the sample and the changes in participants' habits (nine questions). 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 11$^{th}$ of March 2020 - and the current period, which correspond to 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. The types of questions presented in the questionnaire are "*Select one*" - multiple-choice question with only one answer to be selected -, "*Geopoint*" - collection of GPS coordinates -, "*Question matrix*" - a group of questions displayed in a matrix form -, and "*Rating*" - ordering different options -. In Table 1, each question is associated with its question type. For questions whose answers had to be expressed by means of a rating scale, the typical Likert scale [28–30] was adopted.

Regarding questions related to the assessment of the soundscape, [31] has been considered as main reference for the selected attributes.

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 68 people living in Italy. The questionnaire "*Urban Sound during the pandemic: has COVID-19 changed our soundscape perception?*" was available in Italian language and it is fully enclosed in English language in Annex I.

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.

As initial starting point for any quantitative analysis of collected data, a descriptive statistical analysis has been carried out in order to classify and transform raw data into

**Table 1:** Contents of the questionnaire "Urban Sound during the pandemic: has COVID-19 changed our soundscape perception?".

| *Section* | *Question* | *Reference period* | *Question type* |
|---|---|---|---|
| 1) PERSONAL INFORMATION | 1: Age | - | *Select one* |
| | 2: Gender | - | *Select one* |
| | 3: Place of living | *Current situation* | *Geopoint* |
| | 4: Qualification | *Current situation* | *Select one* |
| | 5: Employment | *Current situation* | *Select one* |
| | 6: Comparison regarding sociality activities | • *Period before COVID-19 restrictions (before March 2020)*<br>• *Current situation* | *Question matrix* |
| | 7: Personal experience regarding fiduciary isolation or quarantine from COVID-19 | *Period between COVID-19 restrictions (from March 2020) and current situation* | *Select one* |
| | 8: Time spent at home | *Period between COVID-19 restrictions (from March 2020) and current situation* | *Select one* |
| | 9: Changes in job/student position | *Period between COVID-19 restrictions (from March 2020) and current situation* | *Select one* |
| 2) YOUR LIVING ENVIRONMENTS | 1: Places you spend more time in during the day | *Current situation* | *Rating* |
| | 2: Time spent in the most frequented living environment (*) | *Period before COVID-19 restrictions (before March 2020)* | *Select one* |
| | 3: Comparison regarding intensity and origin of sounds coming inside the most frequented living environment (*) | • *Period before COVID-19 restrictions (before March 2020)*<br>• *Current situation* | *Question matrix* |
| | 4: Level of agreement of soundscape with different statements (*) | *Current situation* | *Question matrix* |
| | 5: Assessment of soundscape (*) | *Current situation* | *Select one* |
| | 6: Pertinence of soundscape in relation to context | *Current situation* | *Select one* |
| | 7: Overall assessment of soundscape | *Current situation* | *Select one* |

(*) The question refers to the most frequented living environment, selected as first choice in Section 2 - Question 1.

a form that makes them easy to understand and manipulate in order to generate deeper information.

Moreover, for the current analysis, logistic regression models have been used since it was perceptive to associate a dichotomous character to the response variable. In fact, this type of models provides a powerful technique for analysing data involving binary responses and several explanatory variables and are characterized by an extremely flexible and easily used function. These models can be estimated via maximum likelihood estimation using numerical methods. The advantage of the approach is that it does not assume multivariate normality and equal covariance matrix [32]. Moreover, exponentiating the coefficients, you get adjusted odds ratios, which have a very intuitive interpretation.

### 2.2.1 Descriptive analysis concerning personal information

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 (Figure 2) and works as self-employed (40%) or attends university as professor/researcher (10%) or student (8%) (Figure 3). It can be stated that these particular 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 5). Moreover, the 72% of the subjects keeps the same job/student position from March 2020 (Figure 4) till the submission of the questionnaire and during this period a slightly higher per-

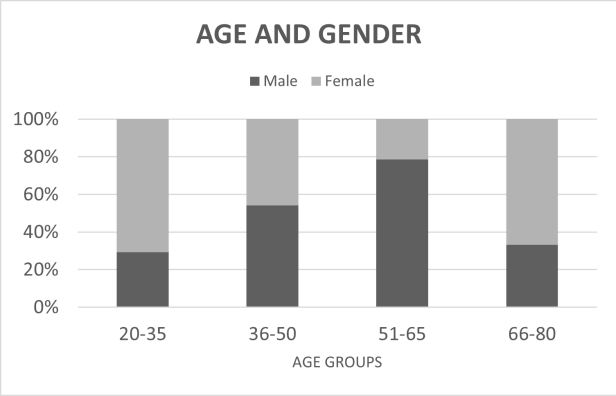


**Figure 1:** Frequency distribution of age and gender.

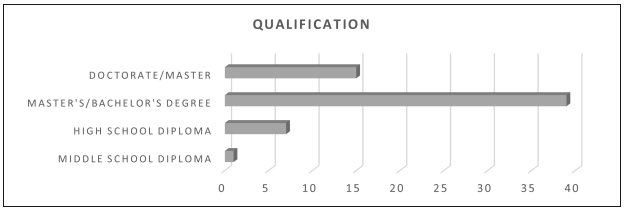


**Figure 2:** Frequency distribution of qualification.

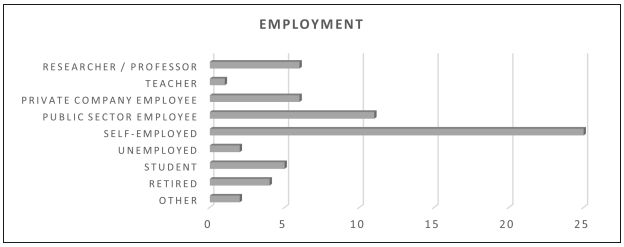


**Figure 3:** Frequency distribution of employment.

centage of subjects has experienced fiduciary isolation or quarantine (56%) compared to the people who were not personally involved in COVID-19 restrictions (Figure 6).

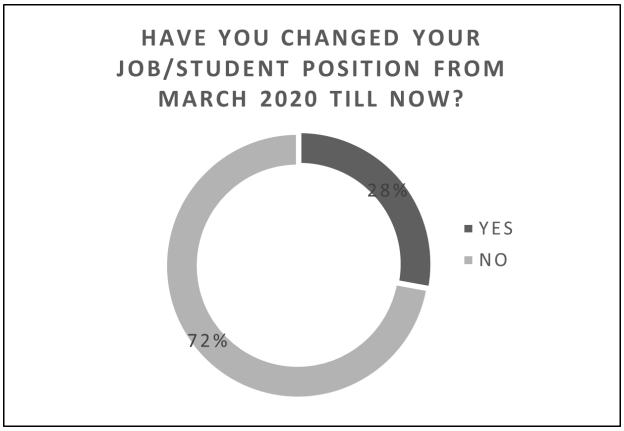


**Figure 4:** Circle chart of new job positions.

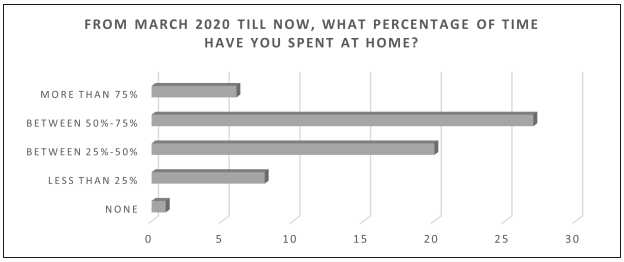


**Figure 5:** Frequency distribution of the time subjects spent at home, in the period between March 2020 and the current situation.

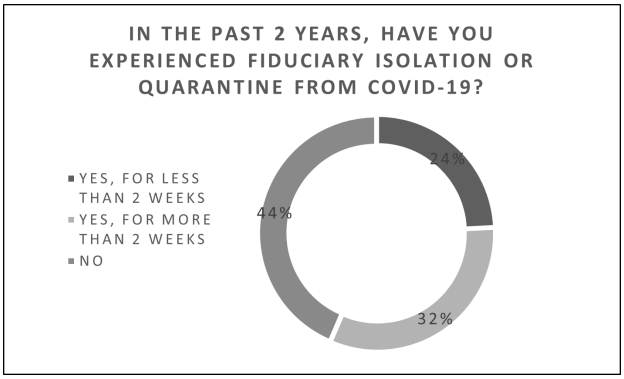


**Figure 6:** Circle chart of subjects' COVID-19 sickness.

In the two months of submission of the questionnaire (between the 6th of May and the 6th of 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) (Figure 7). 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%).

### 2.2.2 Comparison between the period before the DPCM 11/03/2020 and the period of the questionnaire's administration

Subjects were 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 COVID-19 restrictions and the administration of the questionnaire,

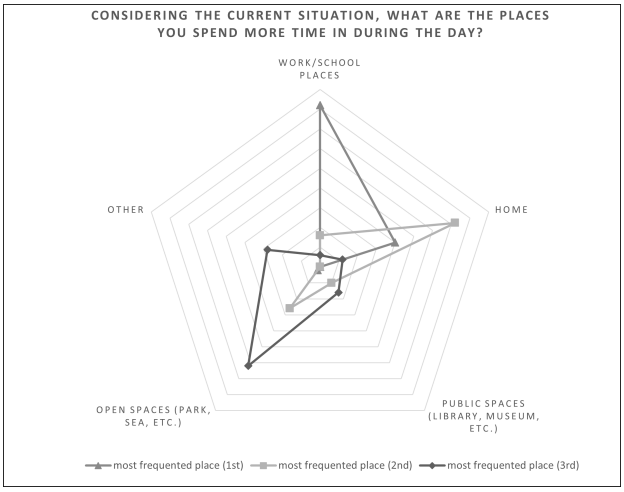


**Figure 7:** Typology and ranking of the most frequented places during the day, referring to the current situation.

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 (Figure 8).

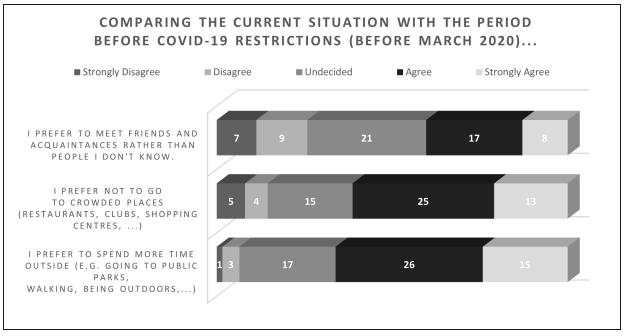


**Figure 8:** Comparison between the period before COVID-19 restrictions and the current situation, concerning personal habits.

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 the 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

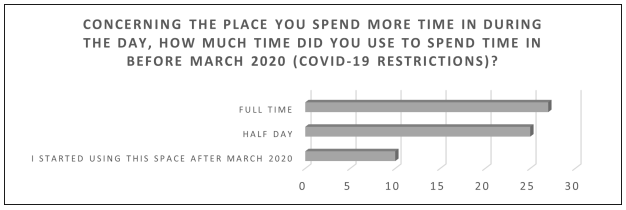


**Figure 9:** Time subjects used to spend in the most frequented place in the period before COVID-19 restrictions.

sound intensity. In particular, the rank of sound sources which are defined as unaltered compared to the period before COVID-19 restrictions are rail traffic (89%), road traffic (65%), nature sounds and neighbourhood sounds from the same building tied (61%), and mechanical/electrical sounds (60%) (Figure 10).

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 11).

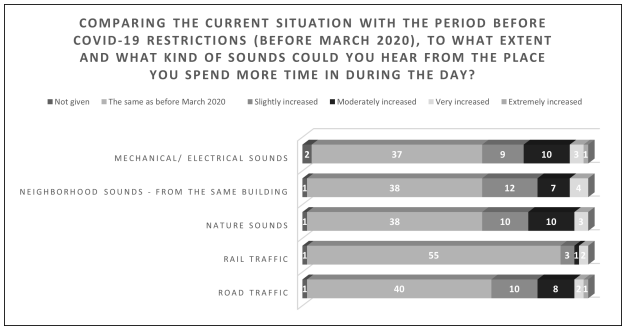


**Figure 10:** Type and intensity of sounds heard from home, comparing the current situation with the period before COVID-19 restrictions.

In general, the soundscape has been assessed as "acceptable" by the majority of the sample (34%). 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, it is considered as "moder-

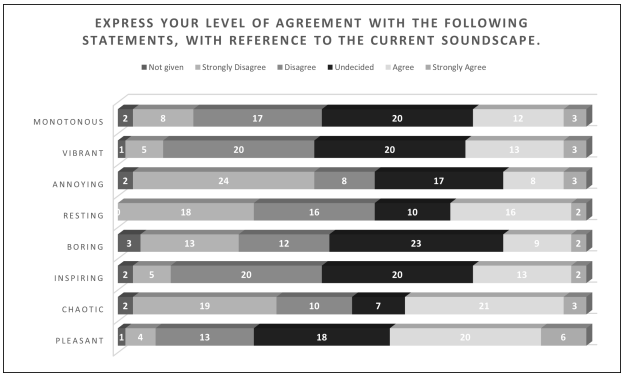


**Figure 11:** Definition of the soundscape in the current situation.

ately" appropriate to the context by almost half of the subjects (48%) followed by the 32% who defined it as "very" pertinent (Figure 12).

Considering the environment (Figure 13), it is mainly assessed as "good" (37%) and "acceptable" (37%). A significant number of subjects defined it as "poor" (20%).

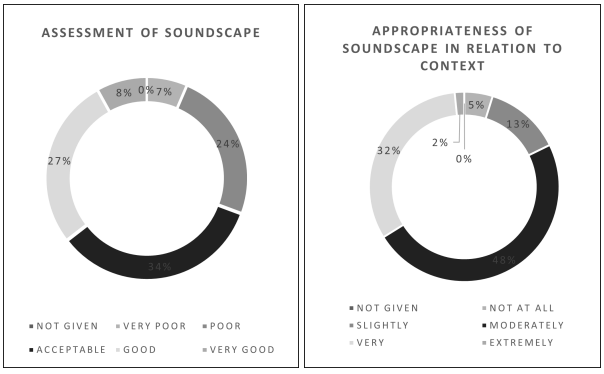


**Figure 12:** Assessment and appropriateness of the soundscape in the current situation.

In Figure 14, the locations of the respondents are marked with coloured spots. It shows that 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 coloured spot, otherwise it means it was filled in by only one person.

### 2.2.3 Logistic regression models

On the basis of the collected answers, regression models have been used for observing the possible relationship between the perceived quality of the sound environment (response variable) and a set of explanatory variables. Regression methods have become an integral component of

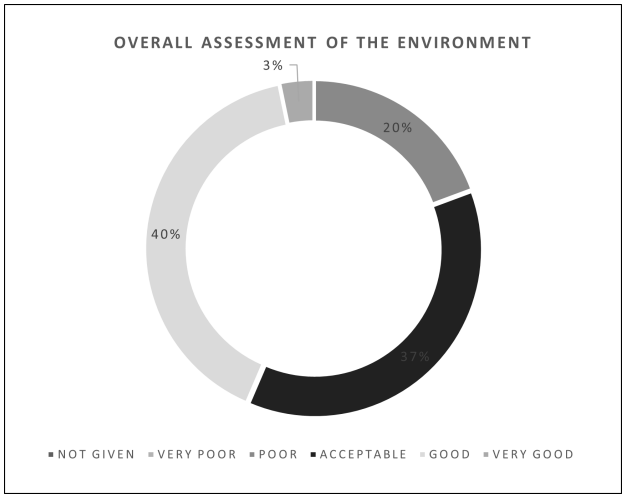


**Figure 13:** Overall assessment of the environment in the current situation.


**Figure 14:** Distribution of people who filled in the questionnaire.

any data analysis concerned with describing the relationship between a response variable and one or more explanatory variables. Specifically, logistic regression models have been used, therefore the outcome variable is binary or dichotomous.

In order to use logistic models, dependent variables have been dichotomized. 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.

In statistics, the logistic model (or logit model) defines the probability of an event taking place by having the log-odds for the event be a linear combination of one or more independent variables. In regression analession [33] (or logit regression) estimates the parameters of a logistic model (the coefficients in the linear combination). Formally, in binary logistic regression there is a single binary dependent variable, coded by an indicator variable, where the two values are labelled "0" and "1", while the independent varbinary variable (two classes, coded by an indicator variable) or a continuous varie). In general, the model that link the probability with a set of covariates is the linear probability model:

$$\pi_i = x_i^{'}\boldsymbol{\beta}$$

where $\boldsymbol{\beta}$ is a vector of regression coefficients. One problem with this model is that the probability $\pi_i$ on the left-hand-side has to be between zero and one, but the linear predictor $x_i^{'}\boldsymbol{\beta}$ on the right-hand-side can take any real value, so there is no guarantee that the predicted values will be in the correct range unless complex restrictions are imposed on the coefficients. A simple solution to this problem is to transform the probability to remove the range restrictions and to model the transformation as a linear function of the covariates. To do this is firstly necessary to move from the probability $\pi_i$ to the odds:

$$odds_i = \frac{\pi_i}{1-\pi_i}$$

defined as the ratio of the probability to its complement, or the ratio of favorable to unfavorable cases. Then the logarithm of this form is taken:

$$\eta_i = logit\,(\pi_i) = log\frac{\pi_i}{1-\pi_i}$$

which has the effect of removing the floor restriction. Suppose that we have k independent observations $y_1, \ldots, y_k$, and that the i-th observation can be treated as a realization of a random variable $Y_i$ . It is assumed that $Y_i$ has a binomial distribution:

$$Y_i \sim B(n_i,\ \pi_i)$$

with binomial denominator $n_i$ and probability $\pi_i$. This defines the stochastic structure of the model. Suppose further that the logit of the underlying probability $\pi_i$ is a linear function of the predictors:

$$logit\,(\pi_i) = x_i^{'}\boldsymbol{\beta}$$

where $\mathbf{x}_i$ is a vector of covariates and $\boldsymbol{\beta}$ is a vector of regression coefficients. This defines the systematic structure of the model that we use for our analysis.

For the quality of the sound environment, the resulting logit model is:

$$\begin{aligned} logit\,(y_{qenv}) =& \alpha_i + \beta_1 emp_i + \beta_2 quar_i + \beta_3 rest_i + \beta_4 appr_i \\ &+ \beta_2 comp_i \end{aligned}$$

where $\alpha_i$ 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 in more 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:

$$logit\,(y_{traffic}) = \alpha_i + \beta_1 room_i + \beta_2 livel_i + \beta_3 mono_i$$

where $\alpha_i$ 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:

$$\begin{aligned} logit\,(y_{nature}) =& \alpha_i + \beta_1 age_i + \beta_2 sex_i + \beta_3 emp_i \\ &+ \beta_4 Thouse_i + \beta_5 enjoy_i \end{aligned}$$

where $\alpha_i$ 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

According to the collected data, the results that come to light in the logistic regression models are presented.

In this paragraph, the results of the three models mentioned in paragraph 2.2.3 are presented.

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≤ 0.1, ** 0.01<p≤ 0.05, *** p≤ 0.01).

In the coefficienTable 2ts of the model, considering environmental quality as dependent variable, are reported.

**Table 2:** 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 as a whole, also provide a positive answer to the soundscape.

The coefficients of the two models that measure the relationship between some covariates and the perception of traffic noise and natural sounds are respectively shown in Table 3 and in Table 4.

**Table 3:** 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 |

**Table 4:** 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 between the period before COVID-19 restrictions and 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 a review published in October 2022 [5], only the 7% of the studies exploring the COVID-19 impacts on soundscapes have conducted both perceptual and noise level assessments and most of the perceptual changes of

auditory sensations were evaluated by research participants or volunteers, while some of the studies employed authors' intensive evaluations or assessments based on the surrounding observations.

Moreover, only a few of those studies aimed at a comparison between pre and during/post COVID-19 situations. As an overall outcome, the COVID-19 measures and pandemic situations positively influenced outdoor soundscapes by reducing external anthropogenic noise sources, while negatively affected indoor and surrounding soundscapes.

According to results reported in paragraph 3, it can be noted that the perception of soundscape is generally unaltered compared to the period prior the COVID-19 restrictions. The alterations to the social context, which took place after the 11$^{th}$ of March 2020 and were formally defined in the national restrictions (34), did not influence the personal analysis of soundscape, which is mainly determined by the social restoration of the current not pandemic conditions. The period of administration of the questionnaire defines a picture of the latter: it can be stated that the willing of spending more time outside has significantly raised. Almost 40% of the sample showed indecision in the characterisation of the soundscape using adjectives. In the light of that aspect, increasing people attentive listening and analysis of the perceived sounds is a starting point for living in acoustically better environments.

The soundscape has been assessed as "acceptable" by the majority of the sample. Therefore, a further investigation might be oriented towards the sounds that people would like to listen in order to improve their living soundscapes. It can be noted that the lockdown period, despite the strong negative impact on people, might be a reference point for the identification of positive sounds that were missing or predominant during that unique historical phase. In particular, referring to the results of (9), during the lookdown period, an overall increase in the perception of nature and neighbourhood sounds was observed and, at the same time, a reduction in terms of annoyance was declared.

According to the logistic regression models, some considerations and interpretations of results are hereafter reported.

First of all, considering the model in which environmental quality is included as dependent variable, the fact that subjects who have experienced quarantine have a lower perception of the environment than those who have not experienced may be due to the circumstance that quarantine, as an obligatory period to spend at home, leads individuals to perceive the noises of the surrounding environment as more negative than what they would normally have perceived. Moreover, as expected, a strong relationship is highlighted between the positive perception of the soundscape and the overall good evaluation of the environment as a whole.

According to the second model, it is confirmed that citizens strictly relate the perception of noise mainly to road traffic with respect to other main noise sources.

Finally, from the last model, it can be asserted that in the post-covid period there is still a predominance of nature sounds compared to the period before the start of the pandemic, according to the respondents.

According to the outcomes of the research illustrated in the current paper, it can be concluded that they are overall in line with the few similar studies that are currently available.

Moreover, the highlighted evidence confirms that, on the one hand, as a result of the Covid-19 pandemic, there is an increasing need for people to be able to easily and safely access green spaces located not only in open country areas, but also within urban centres themselves.

On the other hand, the fact that a large part of the European population has been forced, perhaps even for limited periods of time, to spend most of their time at home, but also the increasingly widespread practice of smart working, has turned the spotlight on the need to ensure the correct criteria for sound insulation and comfort in buildings.

# 5 Conclusions

The outbreak of the COVID-19 pandemic at the beginning of 2020 caused an enormous impact on people life in terms of restrictions and multiple environmental implications, including modifications to the soundscape of everyday life. The gradual return to normality, while still requiring certain precautions and care, offers some interesting research insights that have been partly developed by the authors and illustrated in this article, further developing the work already presented in [9].

Thanks to the results of the new online survey presented in this paper, it has been possible to investigate the perception of soundscape in the places people spend most of the time during the day, comparing the current situation with the period before the entry into force of the DPCM 11 March 2020 [34] and lockdown period. In terms of habits, obtained results have shown that, currently, people prefer not to go to crowded places, such as restaurants, clubs,

and shopping centres, and prefer to spend more time outside, for example going to public parks, than before.

This result suggests and confirms to city planners, public administrations and acoustics experts and soundscape designers that the proper maintenance and enhancement of outdoor public spaces is definitely a key turning point for the well-being of citizens, also in the light of the experience of the pandemic restrictions.

In fact, the concept of holistic design of spaces comes into play in this issue, taking into account the 360-degree perception of spaces that affects all five of our senses of users. To this end, the design of noise mitigation measures, in particular those due to road traffic in accordance with the results of the questionnaire, and the enhancement of natural sounds or those deemed appropriate to the context assume a central role. This evidence is also in line with the recent Italian Ministry of Ecological Transition Decree for the Definition of Modalities for the Identification and Management of Agglomeration and Open Country Quiet Zones.

Moreover, concerning sound perception, for all the investigated sound sources, most of the subjects does not envisage significant differences between the period prior to COVID-19 restrictions and the one of administration of the questionnaire, in terms of sound intensity. This suggests that, for the interviewed sample, there is a substantial 'return to normality' with regard to the intensity of perceived sounds.

A deepened investigation has been made using the logistic regression models from which it is possible to deduce that indeed the COVID-19 pandemic had an important impact on the perception of the soundscape. In particular, the quarantine obligation seems to have negatively influenced the perception of the soundscape, while, as a confirmation of the previous study [9], a good correlation was found between the perception of the soundscape and natural sounds with that of the environment as a whole.

Evidence of the worsening perception of the soundscape inside buildings emphasises how crucial the role of the acoustic and building comfort designer is.

Finally, the fact that natural sounds are perceived more in the post-covid period leaves us with the hope that a lesson may have been learnt regarding the value to be placed on the landscape, both visual and sound, that surrounds us.

As the most restrictive period related to pandemic containment measures seems to be over in most EU countries, a further development of the study for future outlook might provide to spread it in other countries for a wider evaluation of the data, translating the questionnaire in English and in native languages of interested areas of the world and adapting, as far as possible, to local characteristics of buildings and habits of people and communities. Moreover, it could be very interesting to be able to compare long-term measurements campaigns referred to the different time (and related restrictions) periods, in order to be able to correlate subjective data with objective ones.

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# Annex I – Questionnaire's template

## Urban Sound during the pandemic: has COVID-19 changed our soundscape perception?

Welcome to our research project concerning Soundscape!
During these two years our lives have changed significantly as a consequence of the measures of containment and management of the COVID-19 epidemiological emergency. During the pandemic, the sound environment has changed as well: the cities, at first hectic and crowded, emptied out during the months of lockdown, have consequently found a new balance between social distancing and in-person and remote work.
The questionnaire investigates the perception of soundscape in the places you spend most of the time during the day and aims to compare the current situation with the period before COVID-19.
Two years ago, we administered a questionnaire entitled "Noise perception before and during COVID-19 pandemic".
If you had answered the questionnaire or if you are interested in the results, you may find the related paper at the following link: https://www.degruyter.com/document/doi/10.1515/noise-2021-0005/pdf
The questionnaire is promoted by the Acoustical Society of Italy (AIA), in collaboration with Vie en.ro.se Ingegneria.
We invite you to answer all the questions in the order in which they are listed, following the indications provided.
This survey collects your data anonymously.
We inform you that the processing will in any case be confidential and the subsequent publication of the results will be carried out in such a way as to make it impossible to trace the answers given by the interviewed person.

**PERSONAL INFORMATION**

Question n.1 - Age

< 20

20-35

36-50

51-65

66-80

> 80

Question n.2 - Gender

Female

Male

Non-Binary

Question n.3 - Enter your location: enter your address in the "search for place or address" space and then click on the corresponding point on the map, so that the geographical coordinates of your location appear.

latitude (x.y°)

longitude (x.y°)

altitude (m)

accuracy (m)

Question n.4 – Qualification

Primary school diploma Middle school diploma High school diploma

Bachelor/Master's Degree

Doctorate/Master

Question n.5 - Employment

Self-employed

Public sector employee

Private company employee Manual/factory worker

Shop keeper

Teacher

Researcher / Professor Student

Retired

Unemployed Other

Question n.6 -

Comparing the current situation with the period before COVID-19 restrictions (before March 2020)

Question n.7 – In the past 2 years, have you experienced fiduciary isolation or quarantine from COVID-19?

Yes, for less than 2 weeks

Yes, for more than 2 weeks

No

Question n.8 – From March 2020 till now, what percentage of time have you spent at home?

None

Less than 25%

Between 25%-50%

Between 50%-75%

More than 75%

Question n.9 – Have you changed your job/student position during this period?

Yes

No

**YOUR LIVING ENVIRONMENTS**

Question n.1 – Considering the current situation, what are the places you spend more time in during the day? Please order from the most used to the rarely used. (Please specify "Other")

Work/school places

Home

Public spaces (library, museum, etc.)

Open spaces (park, sea, etc.)

Other …

Please answer to the following questions in relation to the place you spend more time in during the day, as indicated in Question n.1:

Question n.2 – Concerning your first choice of Question 1, how much time did you use to spend in before March 2020 (COVID-19 restrictions)?

I started using this space after March 2020

Half day

Full time

Question n.3 – Comparing the current situation with the period before COVID-19 restrictions (before March 2020), to what extent and what kind of sounds could you hear from the place you spend more time in during the day? Select the option you consider as the most appropriate.

Question n.4 – Express your level of agreements with the following statements, with reference to the current soundscape. For each adjective select the option you consider as the most appropriate.

Question n.5 - How do you assess the quality of sound environment around the place you spend more time in during the day? (Select the option you consider as the most appropriate)

Very Poor

Poor

Acceptable Good

Very good

Question n.6 - Do you think that the sound environment around you is appropriate to the context of the place you spend more time in during the day? (Select the option you consider as the most appropriate)

Not at all Slightly

Moderately Very

Extremely

Question n.7 - How do you overall assess (sound, vision, safety, etc.) the environment you perceived around the place you spend more time in during the day? (Select the option you consider as the most appropriate)

Very Poor Poor

Acceptable Good

Very good

Thank you for taking the time to complete this survey.

Eng. Chiara Bartalucci, Eng. Arch. Paola Pulella and Eng. Giovanni Brambilla collaborated in the survey design.