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EFFECTS AND COSTS OF LEISURE NIGHT NOISE ON RESIDENTS' SLEEP: A PROTOCOL FOR AN INTERDISCIPLINARY EXPERIMENT IN TURIN

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ABSTRACT

European city centres are experiencing a particular type of noise pollution originated by night-time recreational activities mainly located in the city centers, the so called "Movida". It is a complex phenomenon with contradictory effects: benefits due to the commercial activities and interactions, but also threats related to the impacts of alcohol abuse, foulness, vandalism, criminality and, of course, noise disturbance depriving people of sleep. Social behaviors, economic activities, physical conditions of space and noise, individual propensities and health conditions all contribute to the pace and likelihood of these threats and the related social and economic costs. For instance, tensions between residents and nightlife users due to recreational noise are frequent in "Movida" neighborhoods and have led to legal class actions against the local administration.
This study develops an interdisciplinary experimental protocol to investigate, from a health and economic perspective, the impacts of leisure noise on the sleep quality of the residents of three "Movida" neighborhoods in Turin (Italy): San Salvario, Vanchiglia, Piazza Vittorio. The experiment under this protocol will quantify, via a counterfactual approach, the neurological and economic impacts of night noise, and look for the correlation between the individual metrics of sleep quality and the physical conditions of noise and noise diffusion.

Keywords: *recreational noise, Movida, night economy, sleep disorders, quality of life, inter-disciplinary research.*

1. INTRODUCTION

European city centres are experiencing a particular type of noise pollution originated by night-time recreational activities mainly located in the city centers, the so called "Movida". This study acknowledges the complexity of the night economy as a relevant research and policy issue which is to be approached by the means a truly interdisciplinary approach to investigate its impact. It is, in fact, a multidimensional phenomenon whose contradictory effects generate impacts at the individual and the social level, and from different perspectives (health, quality of life, society, economy). In many cities, the night economy determines increased revenues, social relationships, attractiveness etc. Nevertheless, night-time activities are also problematic when associated with increased alcohol abuse, foulness and vandalism, violence-related episodes and crime, such as money laundry, drug dealing and excessive noise.
Namely, the disturbance caused by night-time recreational noise is one of the most frequent causes of protests and

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tensions among residents. This problem is particularly evident in urban areas affected by gentrification and "Movida" (Ottoz et al., 2023). Nonetheless, tensions provoked by recreational noise may also occur among single blocks or residential buildings hosting noisy night activities such as bars, clubs or discos (Campolongo, 2020).

From the point of view of a local urban authority, the presence of groups of residents subjected to chronic sleep deprivation because of recreational noise has gained more and more centrality as a health, social and economic problem. Sleep disruption has proved to be associated with reduced mental abilities (such as concentration), depression, anxiety and a number of adverse health effects from weight gain to a weakened immune system (Berglund, Lindvall, and Schwela, 1999, Basner and McGuire, 2018).

Disturbed and insufficient sleep puts the physical health at risk determining the need for diagnosis and treatments that are largely at the expense of the Public Health System. Moreover, it has thus proved to be an economic burden for the public administration compelled to pay for acoustic tests and controls, investigations, lawsuits and legal practices, sanctions (Ottoz et al., 2018).
In Italian cities, the detection of a condition of sleep disturbance among residents is usually certified by the local authority that asks a public/third-party technical authority for the acoustic measurement of the noise levels respect to a range of tolerability established by law (Campolongo, 2000). This methodology, however, has a high probability of ineffectiveness since:

- it focuses on the intensity of the noise only, whereas also its rhythm, frequency and band levels contribute to sleep disturbance or instability (Araújo Alves, 2020; Myllyntausta et al., 2020; Debellemanière, 2022; Gantt, 2023; Scarratt et al., 2023).
- it does not consider the effects of the vibrations the noise determines in the building structures such as walls, floors, windows, etc. (Berglund, Lindvall, Schwela, 1999).
- it does not account for individual noise receptivity and existing sleep disorders influencing the levels of sleep stress induced by the noise.

An inter-disciplinary approach, including both physic, medical and socio-economic data, in order to detect the overall healthcare, welfare and social costs of the sleep disturbance caused by night-time activities looks appropriate (Garbarino et al., 2016).
Our intent is to design a protocol for a pilot experiment. In the first phase, tracker bracelets will be supplied to a sample of residents living in areas affected by night recreational noise in the districts of San Salvario, Centro and Vanchiglia and in other areas of the city of Turin not affected by the night recreational noise (the control sample). The data of participants' sleep disturbances will be then used to calculate an indicator of sleep quality and correlated with the features of the environmental noise and its physical transmission (i.e. vibrations; see: Piorecky et al., 2021).

2. STUDYING NOISE IMPACTS VIA A AN INTER-DISCIPLINARY APPROACH

The paper develops a protocol of research based on the inter-disciplinary collaboration of researchers from the University of Turin - Department of Physics, the Department of Neurosciences "Levi Montalcini", and the Department of Economics and Statistics "Cognetti de Martiis"- and from the Italian National Research Council. Crossing disciplinary borders between the physical, medical and social science is crucial to cope with the complex issue of the quantification of the impacts determined on individuals and societies by the night recreational noise. Disciplinary cross-fertilization can help to reconfigure the problems, open new perspectives and find solutions coherent with the different contexts of policy implementation. Currently, most of the environmental and societal challenges we face (e.g., climate change or sustainability) need more interdisciplinary approaches and techniques. However, genuinely inter-disciplinary research remains a hard task to fulfill (O'Sullivan, 2004; Stock, Burton, 2011; Sella et al., forthcoming) as it implies the overcoming of several practical problems such as:

- the lack of shared labeling, common terminology and well-established understanding (Stock, Burton, 2011);
- poor reciprocal knowledge and acquaintance among the researchers (Li Vigni, 2020);
- researchers' unwillingness in overcoming their disciplinary boundaries (also because of the lack of academic recognition of inter-disciplinary research) and the lack of researchers trained in inter-disciplinary research;
- the fact that inter-disciplinarity is rarely the main aim of the study.

In this study, the diverse research groups first adopted a method based on regular meetings, brainstorming and the sharing of literature from different disciplines. Secondly, they all recognized the necessity of preparing an interdisciplinary case study protocol, designing the main

questions of the study itself and identifying - before starting - the main environmental parameters of the experiment. Thirdly, all the participants agreed on the opportunity to turn the protocol into a scientific instrument at the disposal of the local public authority for the assessment and the economic quantification of the impacts of noise on health.

3. A RESEARCH PROTOCOL TO QUANTIFY THE EFFECTS AND COSTS OF LEISURE NOISE ON RESIDENTS' SLEEP QUALITY

3.1 Motivation

Traditionally, the literature investigating the effects of noise exposure on sleep tends to focus on traffic sources rather than recreational ones (Knottnerus, 2004). Also, most of the studies are laboratory experiments under highly controlled environmental conditions (e.g., simulations and polysomnographic experiments in laboratories run by Piorecky et al., 2021; Debellemanière, 2022; Gantt, 2023).
Differently from this literature, our aim is to run a real-world experiment by measuring noise and its effects on the quality of sleep, directly in the homes and neighborhood where residents live.
In order to do that, a preliminary step is the identification of the borders of the experiment itself, i.e.:

- the range of the metrics under investigation and the presence of disturbing/confounding factors such as the vibrations due to the physical characteristics of the buildings and streets;
- the presence of environmental sources of noise different from night-time recreational activities;
- the technical potentialities of the different instruments and devices available for the measurement of noise and sleep quality.

The protocol described in this section contains both the description of the preliminary tests (3.2) and the design of the overall experiment (3.3 based on a mixed-method study aims at measuring both noise metrics and sleep quality metrics.

3.2 Noise measurements

For the pre-test it is not necessary to have a noise measurement campaign hosted in different homes/places. In order to define the borders of the experiment it will be sufficient to make a h-24 registration in a noisy area of the selected neighborhoods during the night period, because in this scenario the frequency and its range are the most valuable parameters. Indeed, the boundary conditions are the most challenging also for the devices which will be exploited, since a clear definition of the complete frequency spectrum is still not available for indoor measurements, especially in the low frequency region. Data for outdoor measurements of recreational noise (Cerniglia et al, 2016) could suggest exploring the low frequency region up to 160 Hz and the medium frequency range between 400 Hz and 1250 Hz.
The main parameters we plan to measure with an adequate precision are, thus, the noise intensity and the frequency.
The instrumentation which can be used is quite various and ranges from microphones based on micro electro-mechanical systems technology (MEMS) to more complete and standard sound metering systems. Interesting opportunities come from some miniaturized acoustic transducers available on the market; for instance, MEMS microphones with their development boards can be a low-cost solution, but with the drawback of presenting significant variations of the sensitivity in the frequency range of interest. For this solution, the data acquisition program has to be specifically developed, in order to acquire the measurement data with the proper sampling rate, and to store them, e.g. on an SD memory card, for further analysis and post-processing. On the other hand, sound level meters and analyzers are available as well on the market as well. They have the capability to measure and monitor the environmental noise in a quite wide range of frequencies and sound pressure levels, enabling to save and export data in some of the standard formats for further analysis.
The final choice of the instrument which will be implied in the measurement depends on the frequency spectrum we identify to be investigated in the pre-test campaign.
Another opportunity might be the use of smartphones already at the availability of the residents involved in the experiment. For instance, Rozzi et al. (2022) developed a smartphone-based participatory experiment to measure indoor noise level measurements and subjective comfort. This solution has undoubtedly the advantage of being easy to use and cheap. In our study, however, we decided not to use smartphones as sound level monitoring systems because of the lack of information about their accuracy and reliability.
Expected results of this test are a clear definition of the frequency spectral range, which determines the choice of the instrumentation which will be exploited in the experiment. Moreover, we plan to have a complete working package which will be able to deliver the time stamp needed to connect the noise measurement with the information coming from the actigraphs.

3.3 The design of the overall experiment

As to the noise we will use oscillators to physically measure the noise, as to the measurement of the disturbance of sleep we will use (fit-bit type) tracker bracelets with actigraphy function to a sample of residents living in areas affected by night recreational noise in the districts of San Salvario Centro and Vanchiglia and in other areas of the city of Turin not affected by the night recreational noise (the control sample). Actigraphy (activity-based monitoring) is a recognized and validated tool capable of diagnosing circadian rhythm sleep disorders and providing affordable estimation of sleep duration and stability.
A sleep questionnaire will be used to select and enroll only subjects without previous sleep disorders due to other common causes, such as severe pain, nocturia, sleep apnea, REM behavior disorders, restless legs syndrome, periodic limb movements during sleep.
Once the proper instrumentation is defined, the noise measurements will be performed simultaneously with the actigraphy ones. Each measurement will be correlated to a time stamp.
The information coming from the noise measurement and from the actigraphs will be merged together by means of time stamps, previously calibrated. The combination of both sleep signals and noise will allow to recognize if the sleep quality and its periods of instability depends and how on certain frequencies and intensities. If such a correlation will become evident, we will have the possibility to study the source of the problem and eventually propose solutions in order to increase the sleep quality of exposed people.

4. THE ESTIMATION OF NOISE ECONOMIC IMPACT

The high costs of sleep disorders have already been quantified in the literature. For instance, the Australian Sleep Health Foundation commissioned Deloitte Access Economics (a nation-based company) to analyze the direct and indirect costs of sleep disorders for the year 2010 and the reported estimates describe the magnitude of the problem. "The estimated costs associated with the three commonest sleep disorders (OSAS, primary insomnia, and RLS) were $818 million per year, including $274 million for sleep disorders and $544 million for associated conditions. About $248 million were the costs for OSAS and $409 million for related healthcare conditions such as hypertension, cardiovascular diseases, and depression. The indirect financial and non-financial costs were estimated to be above $4.3 billion, of which OSAS accounted for 61% ($2.6 billion), primary insomnia 36% ($1.5 billion) and RLS 3% ($115 million). Impaired quality of life due to sleep disorders and related conditions was estimated to a total non-financial cost of up to $31.4 billion" (Garbarini et al., 2016). The aim of the experiment is to quantify the costs determined by sleep disturbance for residents (health and depreciation of residential property prices; Ottoz et al., 2023), for the National Health Service, for public administrations in the attempt to measure and address the phenomenon of leisure noise at night. In addition, the costs of compensating citizens for legal actions must be added, as it recently happened in Turin.

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