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A SURVEY METHODOLOGY FOR NOISE IN HOSPITAL WARDS

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ABSTRACT

Noise pollution is considered one of the most disturbing environmental factors, especially for vulnerable people, such as children, the elderly, people who are sick or who must live for a specific period in the hospital, in the latter case, for example, the excessive noise level can also negatively affect the recovery process.
Hospitals include a variety of different spaces with different requirements and levels of noise sensitivity, but also different activities and equipment that can cause disturbing noise levels. Several studies highlight how exposure to inadequate noise levels within hospital environments causes discomfort for all users (patients, staff, and visitors), leading to sleep disturbances, communication interference, aggression, annoyance, and stress. The paper proposes a survey methodology to be applied within hospital wards to investigate the most disturbing sources and users' perceptions of them, by acoustic characterization measurements, long-term measurements, and interviews and questionnaires aimed at patients and staff.

Keywords: *Acoustics, Hospital Environment, Acoustics Measures.*

1. INTRODUCTION

This research is part of a PhD program in Architecture Technology currently carried out at the University of Florence.

The literature regarding the acoustics of hospital environments is still very fragmented; although much research has dealt with noise levels within intensive care units, little has been done in general medical wards. A unified repeatable methodology for investigating noise disturbance in complex environments such as hospitals is still lacking. The complexity of hospitals is due to the simultaneous presence within the same environment of many functions and sources, and different user groups with different noise sensitivities, who often are at the same time both part of the problem and part of the solution.
For this study, we relied on evidence from the literature to define a methodology for investigating noise in hospitals. As this is a vast topic, the survey will be performed with reference only to general medical wards within which double rooms with bathrooms are located. This chosen room type, with external facing on one side and corridor access on the other, is currently the most common in European hospitals, however, single rooms are becoming more common in recent years [1].

1.1 Acoustics in Hospital Environment

According to the World Health Organization, noise pollution is one of the most disturbing environmental factors, causing many problems to health and cognitive activities, such as sleep disturbance, annoyance, cardiovascular disease, and problems with perception, concentration, and learning [2]. The greatest attention should be paid to the design of environments intended for vulnerable users, such as children, the elderly, and those who are ill or hospitalized; particularly for patients, acoustics is a key parameter, as well as all environmental parameters, which is able to directly influence the healing process [3,4].
Regulatory references on hospital room acoustics in different countries are varied [5]. In Italy, the Ministerial Decree DM 23/06/2022 "*Minimum Environmental Criteria for the award of design services and works for*

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the new construction, renovation, and maintenance of public buildings" [6] indicates acoustic comfort as a mandatory condition to be verified for public buildings, including hospitals. The decree refers to the UNI 11532 series of standards on room acoustics, Part 4 of which, specific to hospital environments, has not yet been published [7].

Hospitals include a variety of different spaces with different requirements and varying degrees of noise sensitivity, but also different activities and disturbing equipment; we can define it as a complex sound environment characterized by the presence of multiple sound sources. In addition, the spectrum of hospital users is composed of different dimensions that follow one another, with varying degrees of sensitivity to noise. In particular, hospital is a healthcare personnel's workplace, within which they spend moments of ordinary daily life; in this case, prolonged noise pollution over time within the workplace can cause annoyance, aggression, or negative effects on productivity, or worse, increase the occurrence of errors [8]. On the other hand, patients are the most vulnerable users; specifically, they spend extraordinary moments of their lives within hospital environments (as well as visiting relatives), often experiencing pain, anxiety, or fear. For patients, high noise levels can directly affect stress, sleep, or the recovery process [2].

Since hospitals represent a complex environment to analyze, the parameters used in the literature to quantify noise disturbance within this scenario are various.

Most studies use the A-weighted equivalent sound pressure level (LAeq), Lmax, or Lmin, and the statistical indices such as L5, L10, L50, L90, and L95, and less common ones such as L1, L70, L30, or L33; moreover, some studies also performed frequency analyses [9].

Scientific studies that focus on healthcare personnel consider parameters such as LAeq, Lmin, and L90; on the other hand, parameters such as SEL, LAmax, L10, the number of individual disturbance events per hour, or the analysis of the frequencies of the noises that most characterize the detected noise climate, are more suitable for the study of night disturbance for patients [2, 9].

During the night, it is advisable to have an indoor equivalent sound pressure level (LAeq-Night) not exceeding 30 dB(A), to be maintained also during the day inside hospitalizations (LAeq-Day/Evening), and a maximum sound pressure level (LAmax) no higher than 40 dB for all those anomalous or impulsive events, which can wake up patients, who instead need peace and rest for the regular course of hospitalization; the sound pressure level should generally not exceed 35 dB(A) in all areas frequented by patients [2].

Table 1. Values from Table 1 "Guideline values for community noise in specific environment" [2].

Specific environment: Hospital ward rooms, indoor			
Critical health effects	LAeq [dB(A)]	Time base [h]	LAmax fast [dB]
Sleep disturbance (N)	**30**	**8**	**40**
Sleep disturbance (D/E)	**30**	**30**	**-**

In the literature, a clear correlation emerges between noise level, number and frequency of noise events, and disturbance on users (both in patients, during night hours, and in medical personnel, during working hours). For this reason, many studies place the subjective user response alongside the objective measurement data, by analyzing psychoacoustic parameters [10], generally used in soundscape analyses [11, 12] combined with quantitative surveys, based on questionnaires or qualitative surveys, using post-hospitalization interviews, [13-18]. Since studies are conducted in various ways, there is a need for a more comprehensive standardization strategy to balance noise measurement procedures in indoor hospital environments [9]. A greater focus on the users and their behaviors and needs, flanking objective data with subjective data, could be an effective survey methodology.

1.2 Sleep Disturbance in Hospital Environment

Sleep is an essential physiological phenomenon for maintaining health, relieving stress and anxiety, and helping the body recover, which is why some studies suggest that the sleep quality of hospitalized patients be considered part of routine medical assessment [19]. Sudden environmental changes, such as those caused by noise, can fragment sleep, reducing the continuity and thus the total time of rest [20, 21]. In inpatient rooms, noise is reported to be the most significant factor interfering with patient sleep [22, 23].

Despite this, the soundscape of general wards is still poorly investigated today [24], most studies on hospital noise associated with sleep disturbance have focused on machine noise in intensive care units [25]. In the few studies conducted in general wards, the common sources of nighttime noise reported by patients were medical interruptions, conversations by staff or other patients, alarms, and medical equipment [26-29], and there is also

evidence that sleep disruption following hospitalization can persist for up to a year after discharge [30].
Noise-related sleep disturbance is studied using existing questionnaires adapted to the hospital setting, such as Pittsburgh Sleep Quality Index (PSQI), Leeds Sleep Evaluation Questionnaire [31], or Richard Campbel Sleep Questionnaire [32, 33]. These questionnaire typologies were created to investigate sleep disturbance related to the last month in people with insomnia who are not hospitalized. In addition, they are very long and do not include specific questions to investigate environmental acoustic quality.
Therefore, to understand patients' opinions of their sleep experience, identify sources of disturbance, and accurately measure noise levels in the ward environment, a subjective survey methodology is proposed to support acoustic measurements. Specifically, this method involves the administration of appropriately structured questionnaires and interviews to acquire data through quantitative and qualitative surveys.

2. METHOD PROPOSED

Based on the evidence, the overall item of this study is to investigate the acoustic quality of general medicine inpatient wards, highlight the current existing critical issues, and propose an appropriate survey methodology. The research design is based on a strong interdisciplinary set-up. In particular, the purpose of the investigation is to find the point of contact between the measurable physical data and the subjective experience of the users. Therefore, adopting a mixed method becomes necessary: field observation will be complemented by qualitative surveys (conducted through in-depth interviews) and quantitative surveys (conducted through questionaries).
This analysis will require experimental acoustic measurements within selected double-roomed inpatient wards; quantitative and qualitative surveys will be conducted within these rooms by administering appropriately structured questionnaires and interviews with healthcare staff and patients. Subsequently, based on the survey results, intervention strategies will be hypothesized to improve the acoustic quality of hospital ward environments.
The research consists of the following steps:
1. Literature review;
2. A survey methodology;
3. Objective data acquisition: In situ measurements;
4. Subjective data acquisition: Questionnaires and in-depth interviews;
5. Data analysis and validation of the methodology;
6. Guidelines for the improvement of acoustic quality in hospital wards.

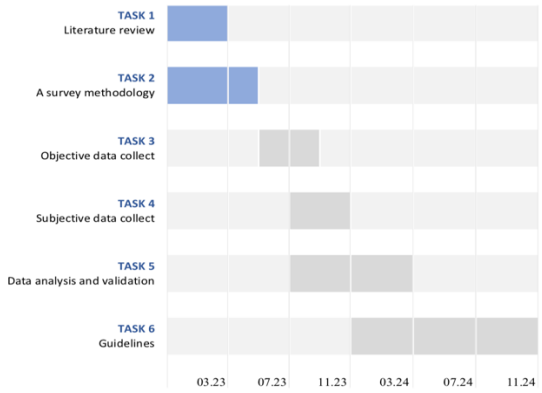

Figure 1. Currently research status Gantt: Task 2.

Moreover, referring to some case studies, the research has the following specific objectives:
1. Identify the main noise sources, through field observation and noise monitoring;
2. Assess the acoustic quality of inpatient wards, through acoustic measurements of standard parameters;
3. Assess the sleep quality of patients, through the in-depth interviews and (on a larger scale) through the use of questionaries;
4. Assess the quality of staff work, through the in-depth interviews and (on a larger scale) through the use of questionaries;
5. Examine existing associations between noise levels and disturbance in users, identifying which physically measurable parameter best describes the actual disturbance perceived by different types of users.

2.1 Acoustic Measurements

Based on the results obtained from previous research [29], the acoustic quality within the selected inpatient rooms will be investigated by reverberation time and insulation measurements of vertical partitions using the MLS technique; in addition, long-term monitoring of 48 hours will be conducted.
The following parameters will be measured: LAeqT [dB(A)], LAmax [dB(A)] in Fast, L10, L90, and the

number of hourly peaks with LAmax above 45 [dB(A)] and Psychoacoustic parameters.
Since, according to the World Health Organization, LAsmax = 40 dB is the level that can wake people up during sleep [2], the number of hourly night events greater than 40 dB will be detected through a trigger function of the acoustic analysis software.

2.2 User Survey

In-depth interviews will be conducted with patients and staff to highlight the subjective experiences of different user groups within a typical ward. To investigate the perceptions of health care staff, the interview will address macro thematic areas such as the most frequented places in the ward, activities during the day, mood during work, and overall comfort. Instead, to investigate patients' perceptions, the interview will address macro thematic areas such as their room, activities during the day, sleep during the night, and overall comfort.
Subsequently, we will administer an appropriately structured questionnaire to investigate noise disturbance in both patients and staff on large scale. The questionnaires for both user groups, in an anonymous form and lasting about 25 minutes, consist of the following sections:

1. General items;
2. Soundscape items;
3. Global environmental items;
4. Noise disturbance items.

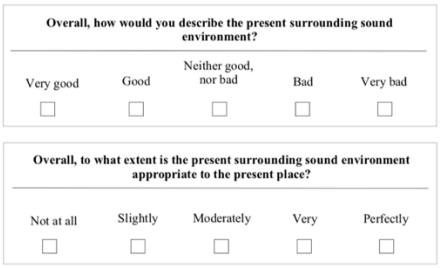

Figure 2. Some examples of soundscape items; these questions are common for both patient and staff questionnaires.

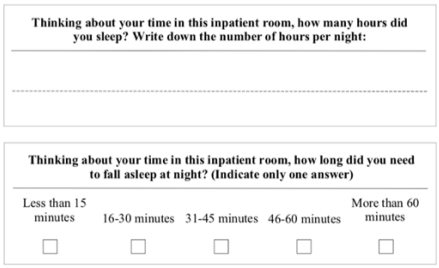

Figure 3. Some examples of items on sleep disturbance: patient questionnaires.

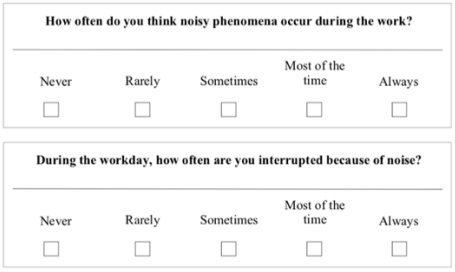

Figure 4. Some examples of items on disturbance during work: staff questionnaires.

Items for section 2 (soundscape) refer to Part. 2 of BS ISO 12913-2 [12] standard usually used to investigate the outdoor environment (Figure 2); these items have been simplified and adapted to the hospital context and different user groups. The items in section 4 (noise disturbance) are also adapted to the hospital context and different user groups: in the protocol for patients there are questions to analyze their sleep disturbance [34] (Figure 3) while in the one for the staff, there are questions related to their working hours (Figure 4).

3. DISCUSSION & CONCLUSION

The research shown is part of a PhD program in Architecture Technology currently carried out at the University of Florence, that aims to determine an appropriate survey methodology to study noise within hospital environments.
In this paper, some considerations are made about the state of the art of research on acoustics in general medical wards. First, the evidence found in the literature shows that the study of noise in hospital environments is still very fragmented; second, there are few studies involving general medical wards; and finally, a unified

repeatable methodology for investigating noise disturbance in hospitals is still lacking, probably due to the complexity of these environments.
This preliminary study allowed the structuring of an investigation protocol. Despite the complexity of the hospital environment due to the different types of spaces, functions, and users, the proposed method involves the study of the indoor acoustic quality of patient rooms using objective and subjective surveys.
In this paper, we report the most appropriate acoustic parameters to describe the indoor acoustic quality of inpatient wards. Furthermore, we propose using appropriately constructed questionnaires to study the users' subjective experience; in particular, we structured several items to investigate noise perception in patients and staff.

This procedure will be tested in the coming months in some Italian hospitals, that will participate in the study.
Field experimentation will enable us to validate or revise the method; moreover, the results of this experimentation will be the subject of future publications.

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