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ACOUSTIC CHARACTERIZATION AND NOISE ASSESSMENT IN ITALIAN HOSPITALS: A PRELIMINARY STUDY

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Abstract

Acoustic comfort in hospitals is vital for staff performance and patient safety, yet it remains a critical challenge in healthcare design. This paper presents the preliminary results of the BRIC INAIL 2024 project (ID07), aimed at defining a standardized protocol to assess the extra-auditory effects of noise on healthcare workers. The study characterizes the acoustic environment of selected Italian public and private hospitals through an observational approach involving three levels of depth: preliminary noise monitoring, room acoustic characterization, and integrated environmental-biomedical assessment. Preliminary measurements reveal that sound pressure levels significantly exceed WHO recommendations, with high sound dynamics ($\Delta L \approx 13$ dBA) and excessive reverberation times. Based on these findings, specific intervention strategies—including the installation of high-efficiency sound-absorbing materials—were designed and simulated. The results demonstrate a substantial predicted reduction in reverberation.

Keywords: *acoustic comfort, healthcare environments, reverberation, noise assessment, staff well-being*

1. Introduction

This protocol is part of the research activities of the BRIC INAIL 2024 project (ID07). The objective is to define a standardized procedure to evaluate the potential extra-auditory effects of noise on healthcare staff, their performance, and safety. The results obtained from these investigations will serve as the basis for drafting the INAIL Guidelines for noise control in healthcare settings and for the refinement of the UNI 11532-4 standard regarding the acoustic characteristics of healthcare environments.

Noise pollution represents a critical factor for human health, especially in vulnerable contexts such as hospitals [1], [2]. While research often focuses on patients, noise heavily impacts healthcare personnel, leading to stress, chronic fatigue, and headaches [3], [4]. High sound levels compromise concentration and effective communication, hindering the delivery of compassionate care and increasing clinical risk, particularly in critical situations [5]. Despite WHO guidelines recommending strict limits (35 dB(A) during the day and 30 dB(A) at night), hospitals consistently show higher and increasing levels [6]. Previous studies by the Department of Architecture of the University of Florence highlight that such noise primarily stems from activities and conversations within the ward, emphasizing the urgency of design centered on operator well-being [7], [8].

Based on literature evidence, the research included a preliminary phase in which sound levels in typical environments of two Italian hospitals were analyzed. Subsequently, critical environments were selected for acoustic improvement interventions and ante- and post-intervention field surveys. This article explains the investigation protocol and presents the preliminary phase and the study of intervention strategies in the first case study

2. Research protocol

This observational study aims to evaluate parameters influencing the working hours of healthcare staff. Given

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the complexity of the hospital context, the approach involves both objective (environmental) and subjective (personal) analyses. The field activities include:

- Preliminary analysis: Short-term monitoring (2-hour sound levels and spectra) to obtain an overview of the acoustic context.
- Instrumental measurements: Assessment of room acoustic performance and building elements.
- Environmental monitoring: Continuous monitoring of environmental parameters for at least one week using multi-sensors.
- Surveys: Administration of questionnaires and interviews.
- Personal exposure assessment: Evaluation of noise disturbance and biomedical parameters through wearable devices during working hours.

3. Case studies selection criteria

Three healthcare facilities are currently involved: one public University Hospital and two private accredited structures. The choice of scenarios was based on:

- High noise levels reported in literature.
- Representativeness of the hospital context.
- Opportunity/complexity of the specific site.

Availability of the scenarios within the specific case study. The identified representative scenarios include:

- low and medium-high intensity care wards.
- automated analysis laboratories.
- rehabilitation gyms.
- reception areas.
- sterilization centers,
- plaster rooms.
- switchboards.

4. Preliminary measurements results

Preliminary measurements in Case Study 1 show that levels are significantly above the WHO-recommended limits in terms of A-weighted equivalent sound pressure level (LAeq). Furthermore, these environments exhibit high sound dynamics, with a difference between L10 and L90 of approximately 13 dBA. High reverberation times contribute to increased sound reflections and higher overall noise levels.

At the time of writing, preliminary measurements have been conducted across two of the participating hospitals. While the monitoring phase involved both facilities, this paper focuses on the results and the subsequent acoustic strategies developed for Case Study 1.

Within this case study, based on these results, the rehabilitation gym, the nursing station in high-intensity care, and the reception area were selected for acoustic interventions.

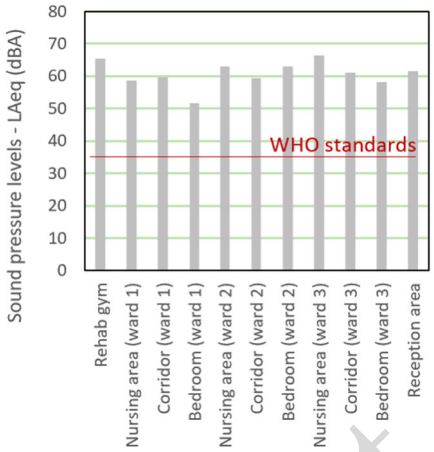

Figure 1. Preliminary results in Case Study 1 - Sound pressure levels (LAeq) measured in the analyzed environments. Results are compared with WHO reference standards of 35 dBA (indicated in red).

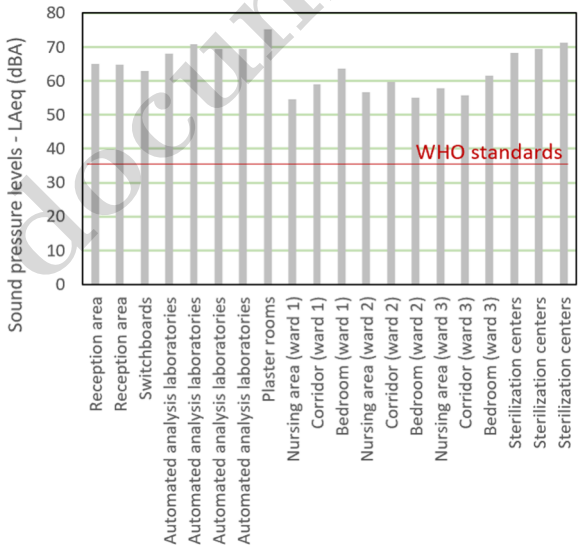

Figure 2. Preliminary results in Case Study 2 - Sound pressure levels (LAeq) measured in the analyzed environments. Results are compared with WHO reference standards of 35 dBA (indicated in red).

Table 1. Sound pressure levels in the three selected scenarios.

Scenario	LAeq (dBA)	LAFmax (dBA)	L10 (dBA)	L90 (dBA)	L10-90 (dBA)
Rehab gym	65.5	84.3	70.5	60.4	10.0
Nursing area	66.5	85.1	71.3	52.3	19.0
Reception area	61.5	77.0	65.2	52.6	5.9

5. Simulation of the acoustic improvements

5.1 Design strategies

The acoustic improvement interventions were designed using high-density mineral wool sound-absorbing materials, specifically selected to meet the stringent hygiene and fire safety standards required for healthcare environments.

The selection included diverse product typologies: one suitable for suspended ceiling structures and another specifically designed for glue-on applications on both ceilings and walls. The strategies for acoustic improvement include:

- Uniform reduction of reverberation time by replacing non-absorbent ceilings.
- Integration of sound-absorbing wall panels (at heights > 1.80 m for durability and hygiene).
- Application of sound-absorbing material to existing plasterboard ceilings.

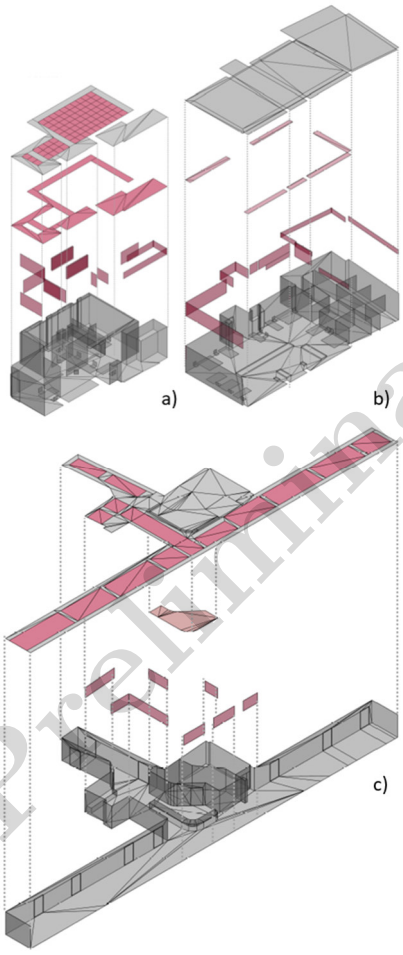

Figure 3. Schematic representation of the acoustic interventions in the three selected scenarios. From top left: a) reception area, b) rehabilitation gym, and c) nursing station.

5.2 Simulation method and results

Scenario's three models were analyzed using Ramsete® software (pyramid-tracing method), calibrated with on-site measurements.

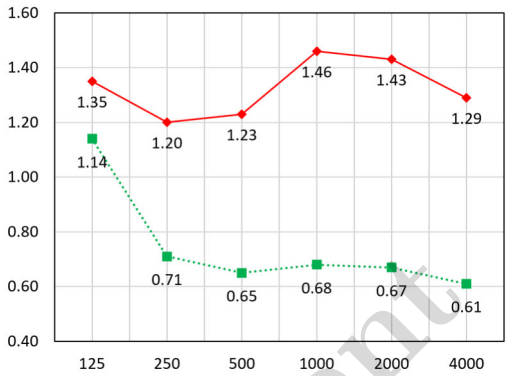

Figure 4. Rehab gym – After (in green) and Before (in red) intervention simulation. The x-axis represents time (s), and the y-axis represents frequency (Hz).

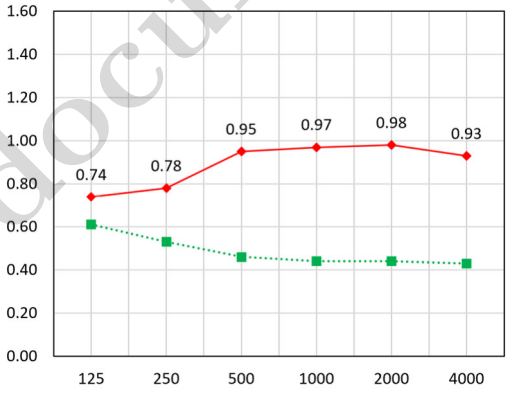

Figure 5. Nursing area – After (in green) and Before (in red) intervention simulation. The x-axis represents time (s), and the y-axis represents frequency (Hz).

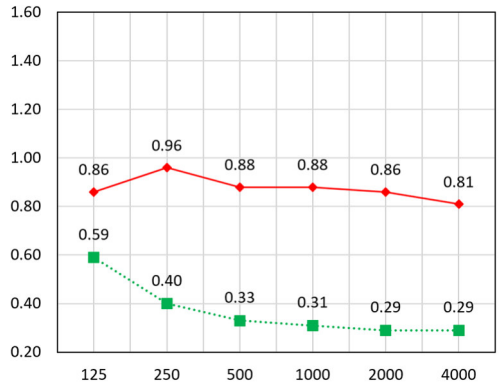

Figure 6. Reception area – After (in green) and Before (in red) intervention simulation. The x-axis represents time (s), and the y-axis represents frequency (Hz).

Simulations predict significant effectiveness in terms of maximum attenuation in the reverberant field across

all selected scenarios (Nursing area, Rehab Gym, and Reception).

Table 2. Improvement effectiveness within the three scenarios, in terms of maximum attenuation in the reverberant field (dB).

Scenarios	Frequencies					
	125	250	500	1000	2000	4000
Rehab gym	0.7	2.3	2.8	3.3	3.3	3.3
Nursing area	1.1	2.4	3.3	3.4	3.5	3.4
Reception area	1.6	3.8	4.3	4.5	4.7	4.5

6. Conclusions

The analysis of the preliminary measurement campaign confirms the critical noise levels within the examined hospital environments. The findings highlight that the primary sources of disturbance for staff are alarm systems, medical equipment, and anthropogenic noise (conversations and activities). These high sound pressure levels, combined with excessive reverberation times, create an acoustic environment that may compromise both the well-being of healthcare workers and the safety of clinical procedures.

At the current stage of the research, the preliminary phase of the defined protocol is being applied within two case studies. Informational meetings with staff and department heads have been completed. In the coming months, the full-scale field phase will be activated, providing the first integrated results correlating objective environmental parameters with the subjective physiological and psychological effects of noise on the personnel. These outcomes will be instrumental in validating the proposed acoustic interventions and will provide a scientific foundation for the upcoming INAIL Guidelines and the UNI 11532-4 standard, ultimately promoting a "healing architecture" approach that prioritizes the acoustic health of healthcare staff.

7. Acknowledgments

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