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INHABITING GAUDÍ: INTEGRATING OBJECTIVE AND SUBJECTIVE ACOUSTIC EVALUATIONS FOR HUMAN COMFORT

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ABSTRACT

Inhabiting Gaudí: An Architecture and Engineering Approach to Human Comfort is an educational and research-based project that explores how interior spaces in a landmark Gaudí building affect users' subjective perception of sound and overall comfort. Now in its second completed edition, with a third planned, the program involves 17-year-old students in a dual-method approach. Participants carry out objective acoustic measurements using sound level meters to assess sound pressure levels in selected rooms and balconies. Simultaneously, they collect subjective data through questionnaires and short video reflections, offering insight into the auditory environment and perceived comfort or discomfort. This combination of objective and subjective methods provides a strong framework for examining how Gaudí's spatial design considered acoustic comfort. The project's iterative nature, repeated over multiple years, reinforces its educational value: students gain authentic, hands-on experience applying engineering and acoustic principles in a cultural heritage setting. At the same time, they contribute to a growing body of scientific knowledge. The findings underscore the relevance of integrating quantitative metrics with qualitative perceptions when defining comfort criteria—not only in historic buildings but also in contemporary architectural practice focused on human-centered design.

Keywords: Acoustic Comfort, Perception, Gaudí Architecture, Educational Research, Soundscape Evaluation

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1. INTRODUCTION

Architectural heritage is about form, structure, and visual aesthetics, but it is also a multisensory experience, where sound plays a critical role in shaping human perception of space and comfort [1]. The concept of acoustic comfort has gained relevance within building science and environmental psychology lately, particularly in spaces where reverberation, noise levels, and material properties converge to define the auditory quality of an environment, even if it is a historic building [2].

Historic buildings, in this regard, present a unique challenge. Designed without the benefit of modern acoustic simulation tools, they often exhibit sophisticated spatial solutions that naturally enable sound diffusion, intelligibility, or resonance, according to their original purpose. Among these, the architecture of Antoni Gaudí stands out for his innovative use of geometry, biomorphic forms, and locally sourced materials [3]. While Gaudí's work has been extensively analyzed from structural and symbolic perspectives, his attention to sound and the sensory dimension of space remains underexplored—despite a growing number of acoustic studies on his buildings [4–6].

The project *Inhabiting Gaudí* [7], within the framework of the *Barcelona International Youth Science Challenge* led by Fundació Catalunya-La Pedrera, addresses this gap by investigating the relationship between spatial design, interior acoustics, and users' subjective perception of comfort in one of Gaudí's landmark buildings. The project adopts a dual-method approach, combining quantitative acoustic measurements with qualitative data collection, to offer a holistic framework for studying human experience in architectural heritage. Importantly, the project integrates an educational innovation dimension. Developed over two consecutive editions—with a third

planned for this summer—it engages 17-year-old students in authentic, hands-on research, where they apply engineering and architectural principles in a real-world context. Alongside acoustic measurements, participants are also introduced to Gaudí's architectural logic—light modulation, structural fluidity, and the interplay of material and form—enriching their understanding of how spatial and sensory dimensions shape the built environment.

This paper is structured as follows. Section 2 details the theoretical framework we use to face the challenge of the acoustics of La Pedrera - Casa Milà. Section 3 explains the methodology used, assuming that it is an educational project and the measurement strategy that derivates from that. Section 4 details the results of the L_{eq} levels measured indoor the building and the subjective assessment conducted by the students and the researchers. Finally, Section 5 concludes with this first analysis and proposes future lines.

2. THEORETICAL FRAMEWORK

2.1 Acoustic Comfort and Multisensory Perception in Architecture

The concept of acoustic comfort defines how a space sound environment supports well-being, communication, and concentration without causing annoyance or stress to the people using it. While often overshadowed by visual design, the acoustic dimension of architecture is a critical factor in users' experience, especially when thinking of cultural heritage buildings, where reverberation, echo, and ambient noise can dramatically shape perception [1].

Acoustic comfort is always multidimensional, combining physical parameters—such as sound pressure levels, reverberation time, and frequency balance—with subjective responses, including comfort, clarity, annoyance, or even spiritual resonance. This dual nature of sound perception is increasingly acknowledged in contemporary research that incorporates both objective measurements and qualitative or affective feedback from users [8, 9].

2.2 Subjective vs. Objective Methodologies in Acoustic Evaluation

While objective metrics offer standardized ways to quantify sound properties, they often fail to capture the full richness of human perception. Studies have shown that perceived acoustic comfort may diverge significantly from what purely technical measurements suggest [10]. Therefore, a combined methodology is increasingly recommended, integrating psychoacoustic evaluation tools such as surveys, interviews, or soundscape-based protocols [11]. Built environments are not only evaluated for compliance with noise thresholds but for their capacity to support meaningful, pleasant, and identity-rich sonic experiences.

2.3 Gaudí and the Acoustics of Spatial Design

Although Antoni Gaudí is best known for his innovative geometry and organic forms in architecture, his buildings suggest he also had a profound sensitivity to the aural qualities of space. His use of vaulted ceilings, parabolic arches, and textured surfaces not only respond to structural needs and aesthetic principles, but also modulate intensively acoustic behaviour, enhancing clarity and reducing unwanted echo. Despite there is limited direct documentation of Gaudí's acoustic intentions, the experiential quality of his interiors—especially in buildings like Casa Milà, analyzed in this paper, and Palau Güell [4]—suggests a deliberate exploration of sound as an architectural medium. Investigating this dimension through both measurement of sound parameters and perception aligns with recent efforts in heritage acoustics to understand how historic spaces sound—and how they were meant to sound in the framework of their original use.

3. METHODOLOGY

3.1 Educational Context and Participants

The Inhabiting Gaudí project is structured as an educational research initiative, involving high school students (aged 17) participating in a ten-day intensive program. The project is part of the BIYSC – Barcelona International Youth Science Challenge–, coordinated by the Fundació Catalunya - La Pedrera, and aims to foster hands-on scientific engagement among highly motivated young students from diverse international backgrounds.

Participants are selected through a competitive call and work in teams, guided by a multidisciplinary research team including engineers, physicists, and architects. The students receive introductory training in acoustic theory, human perception of sound, and architectural heritage before initiating fieldwork, and they conduct several days of practise in specialized laboratories, as an anechoic and a reverberant chamber. The educational goal is twofold: to expose students to real-world scientific methodology, and to empower them to reflect critically on their own sensory experience within historical architecture.

3.2 Measurement Strategy and Data Selection for This Study

The project's methodology integrates audio recordings, a wide range of acoustic measurements, including reverberation time (T_{30} and T_{20}) and ambient noise levels (L_{eq} and L_{Aeq}, L_{max}, L_{min}), as well as subjective perception data gathered through questionnaires and reflective videos. These measurements are performed across different spatial typologies: enclosed rooms, circulation areas, and balconies, using Class 1 sound level meters and calibrated recording procedures (see several examples in Figure 1).

The present study focuses on a specific subset of this broader dataset. In particular, we analyze the following:

- Sound pressure level measurements (L_{eq}, L_{Aeq}) recorded in indoor rooms and balconies of La Pedrera, aiming to examine the impact of spatial transition on perceived acoustic comfort.
- Subjective perception data obtained through structured questionnaires completed by the 2023 edition of participants, which represents the most methodologically consistent dataset and is aligned with protocols used across other citizen science projects developed in parallel by the research team [12].

This combined quantitative–qualitative analysis allows us to reflect on how students perceive changes in acoustic environments when moving from the interior to the semi-exterior spaces of a historic building, and how these perceptions correlate with the real noise level readings.

By narrowing the focus to this coherent and internally validated data sample, we aim to draw conclusions that are both representative and transferable to future editions of the project and to comparable initiatives at the intersection of acoustics, education, and architectural heritage.

4. RESULTS

4.1 Objective Acoustic Measurements: Sound Pressure Levels

The objective data obtained during the 2023 edition of *Inhabiting Gaudí* includes measurements of sound pressure levels (L_{Aeq}) across five locations within La Pedrera. On the fourth floor, three indoor rooms were analysed: an office facing Carrer de Provença, a living room overlooking the interior block courtyard (*pati d'illa*), and

Figure 1. Pictures of Inhabiting Gaudi 2023 project. (a) Gaudí's La Pedrera building, (b) Recording the soundscape from the Principal's Balcony, (c) Recording the soundscape from the ceiling, (d) measurements in a rear balcony

a small room with a window facing the Provença courtyard. On the main floor, which is dedicated to exhibitions, two semi-open areas were studied: a balcony facing Passeig de Gràcia and a window overlooking the Passeig de Gràcia courtyard.

As shown in Figure 2, average L_{Aeq} values ranged from 40 dBA in the living room and small room, up to 50 dBA in the Gràcia courtyard. The office (47 dBA) and the Gràcia balcony (43 dBA) occupy intermediate positions. These variations reflect both architectural characteristics found in the rooms (e.g., enclosure, insulation, openings) and proximity to external urban noise sources, which affect the final soundscape. The courtyard, though visually enclosed, behaves acoustically as a semi-exterior space, receiving more airborne noise from the surrounding streets.

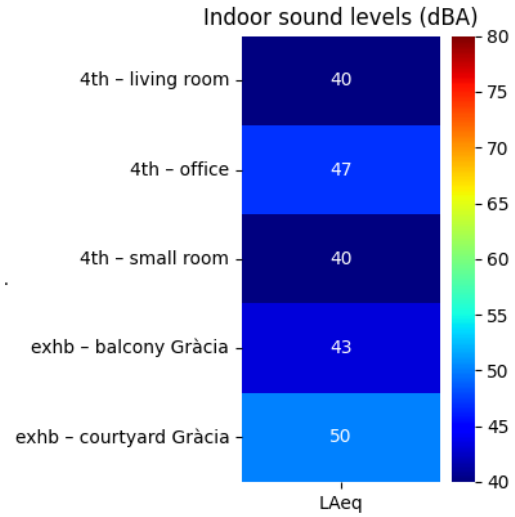

Figure 2. Indoor L_{Aeq} sound levels measured across different spaces of the fourth (4th) and exhibitions (exhb) floors.

These results confirm that indoor rooms offer quieter and more acoustically stable conditions, while the semi-exterior areas are more exposed to fluctuating ambient soundscapes, which may influence perceived comfort, speech intelligibility, and usability for activities.

4.2 Subjective Assessment: Perceptual Attributes and Global Ratings

In parallel with physical measurements, students completed a structured questionnaire evaluating each space using the perceptual attributes defined by the ISO 12913-2 for soundscapes evaluation [13]: pleasant, calm, vibrant, eventful, chaotic, annoying, monotonous, and uneventful. Each attribute was rated on a 5-point Likert scale [14] and averaged across participants.

The radar charts (Figures 3.a and 3.b) show that indoor rooms were generally perceived as calmer and more uneventful, whereas the balcony and courtyard scored slightly higher in eventfulness and vibrancy. These semi-open areas did not report an increase in perceived chaos or annoyance, and the ratings remained within positive or neutral ranges.

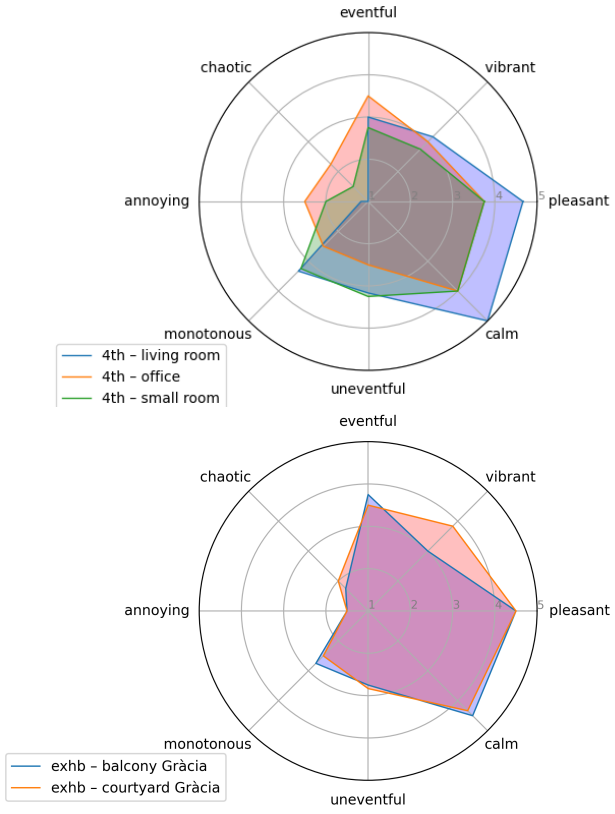

Figure 3. Radar chart of indoor attributes for fourth floor (top) and exhibition flat (bottom).

An important observation is that the Gràcia courtyard, despite presenting the highest noise level (50 dBA), received high subjective ratings for cleanliness, aesthetics, and overall valuation, as well as favorable ratings for the soundscape (see Figure 4). This example illustrates that the equivalent sound level is not the sole factor influenc-

ing perceptions of pleasantness. It suggests that acoustic comfort is not strictly correlated with absolute sound levels, and that contextual and visual elements may enhance the perception of an otherwise noisy space.

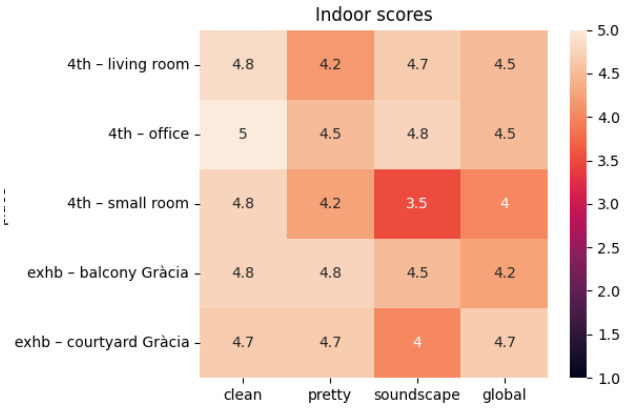

Figure 4. Indoor scores evaluation.

Conversely, the small room, despite low noise levels, received the lowest soundscape score (3.5/5), suggesting that a highly enclosed or acoustically dull space may feel less engaging or even oppressive. This aligns with findings in soundscape research indicating that both sensory richness and moderate stimulation contribute to positive perceptions.

4.3 Educational and Methodological Insights

The results underscore the importance of combining objective and subjective data to develop a nuanced understanding of comfort in heritage spaces. While sound level meters provide reliable quantitative insight, only through perception-based data can we evaluate how users emotionally and cognitively experience the space.

The project also confirms that teenage participants can meaningfully engage in scientific acoustic inquiry, successfully collecting, analyzing, and interpreting both quantitative and qualitative data. This reaffirms the pedagogical value of Inhabiting Gaudí and supports the expansion of citizen science frameworks in architectural and environmental studies.

5. CONCLUSIONS

Inhabiting Gaudí demonstrates the value of combining objective acoustic measurements with subjective perception data to assess comfort in heritage architecture. The results show that sound levels alone do not determine user experience: semi-exterior spaces like the Gràcia courtyard, though noisier, were still perceived as pleasant, while quieter rooms could feel less engaging.

The project also highlights the potential of educational citizen science: students not only contribute valid data but gain meaningful experience in acoustic research. This dual benefit—scientific and pedagogical—makes the initiative a strong model for future studies in architectural acoustics and comfort.

With a third edition planned, the project will soon offer longitudinal insights, and could be extended to other historic sites to further explore how spatial design, sound, and perception interact.

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