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ACOUSTIC DESIGN CASE STUDIES OF EDUCATIONAL SPACES FOR NEURODIVERGENT INDIVIDUALS

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ABSTRACT

The design of inclusive spaces is of primary importance, especially in public spaces characterised by sensory overstimulation (e.g. visual, olfactory and acoustic). Understanding what drives the perception of the environmental discomfort of people who are temporarily or permanently uncomfortable becomes a priority for designers of such spaces. For neurodivergent people, for example, the acoustic comfort of a space is related to the lesser or greater ability to tolerate unexpected acoustic events or the persistence of stressful noisy situations. This article provides examples of acoustic design of spaces in learning contexts (schools, museum spaces, etc.) adapting to different types of perceived environmental qualities, so that the environment itself can become a natural regulator of the perceived stress level.

Keywords: *educational spaces, neurodivergent people, inclusive spaces, sensory overstimulation.*

1. INTRODUCTION

People with hypersensitivity may be more prone to experiencing sensory overload, defined as "a condition in which sensory stimuli are received at an excessive rate or intensity". This overload can trigger physical, mental, or behavioral responses, manifesting as increased heart rate, blood pressure, respiration, anxiety, mental distress and irregular behavior [1].

The design of enclosed spaces can play a significant role in mitigating sensory overload by creating quiet, low-stimulus environments, such as silent spaces [2]. This approach is particularly useful in high-stimulus environments, where sensory overload is more likely to occur, such as noisy or highly reverberant spaces. Experimental studies have demonstrated improvements in behavioral temperament, mood, comfort, attention, academic performance, attendance and engagement in autistic students or dyspraxia through the reduction of reverberation and background noise [3, 4].

It is important to note that space does not necessarily need to be silent; rather, it should promote a mentally "calm" environment that encourages relaxation. A calm space should have low lighting, minimal noise levels, and be free from strong odors [5].

Additionally, recorded sounds can play a relevant role in facilitating relaxation and reducing environmental stress [6]. Implementing these principles in space designing can help create more inclusive environments that support psychological and physical well-being.

Sadia [7] reports that the top three settings where having calm spaces is considered "important" or "very important" are education, workplaces, and healthcare. The absence of sound is the most preferred soundscape for a calm space, followed by natural sounds (flowing water, rain, ocean waves, forest sounds, etc.) and music (soft, instrumental, classical). In this framework, here two examples of acoustic designing related to educational spaces and museums are here reported

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2. SENSORY RECOVERY SPACE IN A MUSEUM ENVIRONMENT

The results of the co-design workshops conducted with young adults on the autism spectrum as part of the Interreg project Besenshome [8] shed light on the challenges of navigating crowded public spaces. The workshop participants clearly articulated the benefits of having sensory rebalancing spaces within such environments. They expressed that knowing a dedicated space was available in locations such as waiting rooms, train stations and shopping centers would empower them to frequent these places rather than avoid them.

Building on this newly gathered insight, combined with findings from previous research on similar topics [9], we designed and implemented a sensory recovery space at the "Immaginario Scientifico", the science museum in Trieste, Italy. This museum, known for its interactive activities for children and adults, features large open areas and long corridors, which contribute to high background noise levels during peak hours.

For neurodivergent individuals with hyperacusis, maintaining focus on activities in such environments can be challenging. When background noise reaches high levels, all sounds become equally prominent, leading to sensory overload [10].

To address this issue and thanks to the strong awareness demonstrated by the museum's curator, we established a designated sensory rebalancing corner—a space where noise, lighting, and social interactions are significantly reduced, allowing individuals to recover from sensory overload.

The space features a wrap-around chair (Fig. 1) called "Alone-together sit" designed to accommodate a person in either a seated or curled-up position, or even an adult together with a child. The chair's structure envelops the head within an arch covered in sound-absorbing polyester fiber, thereby altering the auditory experience by modifying the surrounding sound field.

The location for this sensory space was deliberately chosen in a relatively quiet yet visible corner of the museum (Fig. 2), optimizing both accessibility and usability. Informational panels, designed in the same style as the museum's educational materials, were printed on sound-absorbing polyester fiber to further enhance acoustic comfort (Fig. 3). The same unfinished polyester fiber material was also used to create additional visible installations, either wall-mounted or self-standing.

Figure 1. Alone-together sit inside the "Immaginario Scientifico" museum in Trieste (IT)

Figure 2. Sensory rebalancing corner at the "Immaginario Scientifico" museum in Trieste (IT)

Figure 3. Example of informational panels printed on sound-absorbing polyester fiber

3. SENSORY RECOVERY SPACE IN PRIMARY SCHOOL ENVIRONMENTS

Thanks to the dissertation conducted by an architecture student who is also a primary school teacher with experience in working with vulnerable students and neurodiversity, it was possible to analyze certain school environments. These environments, by their very nature, tend to be overly "rigid" and often unsuitable for accommodating different learning styles. The difficulties are frequently related to the multitude of sensory stimuli present in school settings. Therefore, new ideas for school architecture have been proposed to address these challenges.

The primary goal was to put architecture at the service of schools and disability, particularly intellectual disability, by rethinking school environments with a dual perspective: addressing both the educational needs of the most vulnerable students and the sensory and well-being requirements of daily school life. Recent scientific evidence demonstrates that a welcoming environment with controlled stimuli contributes to the overall well-being of vulnerable individuals, the teachers working with them, and the entire classroom community [11]. The proposed model is designed to be replicable in other educational institutions.

In school settings, the occurrence of a crisis can make simple daily activities—such as the ringing of the bell, eating in the cafeteria, sitting at a desk, remaining silent for extended periods, transitioning back to class after recess, or stopping play—particularly challenging for individuals who are highly sensitive to external stimuli. In the event of a crisis, it is essential to ensure both the child's freedom of movement and the possibility of supervision, containment and safety.

To develop an adequate architectural project, school spaces must be reorganized to include a dedicated classroom for welcoming autistic students and areas for desensitization and relaxation, aiming to prevent potential behavioural crises. The entire school should be made "resilient," meaning adaptable to different sensitivities and vulnerabilities through targeted interventions that transform the school environment into an accessible, inclusive, and multisensory space.

The schools analyzed in this paper presented several opportunities for sensory-based interventions, particularly in terms of acoustics. Observations revealed that all school buildings have an unused computer lab due to recent educational reforms in this subject area. Unlike other classrooms of similar size within the same buildings, these labs are equipped with suspended ceilings for cable routing, which significantly improves internal sound reverberation (Fig. 4). Prioritizing these rooms for classes that include neurodivergent students with diagnosed hyperacusis would be a significant improvement.

Further observations were conducted in common areas such as entrance halls and cafeterias, which, in some cases, overlap. The large volumes of these spaces and the noise associated with social interactions often make them practically inaccessible for some vulnerable individuals, leading to avoidance and isolation. Therefore, design hypotheses were formulated by means of 3D acoustic simulation (pyramid tracing) to incorporate sound-absorbing materials for overall acoustic improvement and to create internal islands that enhance the near sound field. These islands were designed using dedicated sound-absorbing furniture. The resulting improvements tested on a room dedicated for computer teaching (ICT) compared to an other classroom without sound absorbing elements

benefit not only neurodivergent students, but also all students, teachers and school staff (Figs. 5 and 6).
Lastly, consideration was given to the possibility of introducing a multisensory classroom based on the Snoezelen method in all schools to promote both exploration and relaxation. Individuals with cognitive disabilities often tend to live in their own world, but within these environments, they are encouraged to explore and engage more with their surroundings. Each piece of furniture is designed to stimulate one of the five senses in a controlled manner, helping students develop sensory awareness and a general sense of well-being and calm. The acoustic design of such a space requires significant considerations for both internal sound absorption and sound insulation. The achievement of appropriate reverberation values is crucial for internal well-being [12]. Therefore, strategic placement within the school building is crucial, along with the necessary architectural measures to achieve the intended objectives.

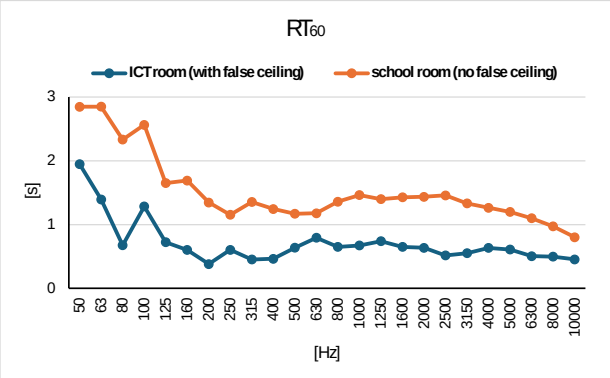

Figure 4. Comparison of reverberation time of classrooms of the same volume with and without false ceiling.

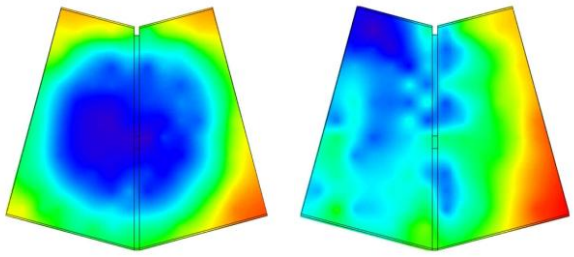

Figure 5. Comparison of the reverberation time at 1000 Hz of a school canteen before and after the insertion of sound-absorbing treatments (values between 1.8 and 2 seconds pre-treatment, to values between 0.7 and 0.8 seconds post-treatment)

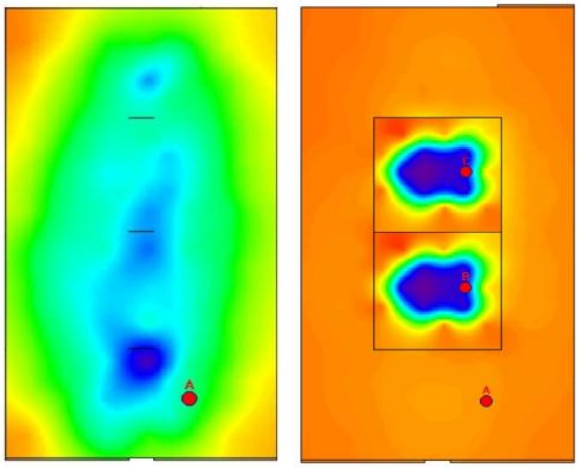

Figure 6. Comparison of the reverberation time at 1000 Hz of a school atrium before and after the insertion of sound-absorbing treatments and realization of internal islands (values between 2.1 and 2.4 seconds pre-treatment, to values between 0.6 and 1.2 seconds post-treatment).

4. CONCLUSIONS

The findings presented in this study highlight the crucial role of acoustic design in shaping inclusive educational spaces for neurodivergent individuals. By addressing sensory overstimulation through targeted architectural interventions, it is possible to create environments that not only accommodate diverse learning needs but also promote well-being for students, educators, and the broader school community.
The case studies explored in both museum and primary school settings demonstrate that strategic modifications—such as the use of sound-absorbing materials, designated sensory recovery spaces, and adaptive classroom designs—can significantly enhance the comfort and usability of these spaces for neurodivergent individuals.
Moreover, the implementation of multisensory environments, such as the Snoezelen room concept, reinforces the importance of controlled stimuli in reducing stress and fostering engagement. Future research should further explore the long-term impact of these interventions, as well as investigate their applicability in other public settings such as workplaces and healthcare facilities.
Overall, this study underscores the need for an interdisciplinary approach in designing educational spaces

that prioritize inclusivity, ensuring that every individual, regardless of their sensory sensitivities, can fully participate in learning and social activities.

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