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Indoor acoustic comfort for ASD people: from independent living to educational environments

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ABSTRACT

Autistic people, their families or caregivers need design processes capable of overcoming the difficulties of everyday life. In 2020, the Centre for Disease Control and Prevention reported that approximately 1 out of 54 children in the U.S. is diagnosed with an Autism Spectrum Disorder. Buildings are designed to provide a suitable living and learning environment for humans. Indoor comfort is necessary in different types of buildings, such as living, learning, working and healing environments. Good environmental quality is important as it affects health, comfort and productivity, significantly impacting on psychological and physiological aspects. The traditional reference could not be suitable in environments dedicated to individuals with special needs, since well-being strongly depends on individual differences in perception. It has been demonstrated that impaired individuals offer diverse responses to indoor environmental stimuli, in comparison with traditional users. Knowing this difference world would permit the realization of more inclusive spaces.

Thanks to the first results obtained, a comprehensive representative description of the peculiarities affecting these individuals' acoustic sensitivity has been obtained. Further developments have been focused on similar acoustic aspects on collective spaces, such as schools, defining which aspects most stress autistic people, as regards building and room acoustics issues.

1. INTRODUCTION

The comfort, safety and privacy of spaces dedicated to people on the autism spectrum is evolving towards the concept of inclusive design, i.e., capable of satisfy the needs of users, their relatives and caregivers, permitting to live as independently as possible and to receive adequate support.

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This design process has recently been developed: a network of smart sensors has been integrated in furniture specifically designed for autistic people; the obtained system permits to monitor indoor comfort conditions and to trigger an early warning system.

In order to fullfil the requirements of a UCD (user-centered design) approach, the environmental perception and preference of ASD individuals has been studied. This approach permits to define which aspects most stress autistic people, if they differ from conventional neurotypical users and study the possibility of introducing reference thresholds for each of these aspects.

An approach to investigate comfort issues of people with an altered perception of the environment was proposed, focusing on thermo-hygrometric, acoustic, visual and indoor air quality aspects.

The research has shown that acoustics comfort domain has the greatest impact on autistic people; indeed variations of spatial acoustic parameters can influence the sensitivities of each individual and the perceived stress is influenced by severity of autism, co-morbidities and age [1].

An initial analysis of indoor acoustical requirements for the living spaces of autistic persons with hearing impairment or sound hypersensitivity has resulted in a suitable range of values in terms of reverberation time reported in figure 1.

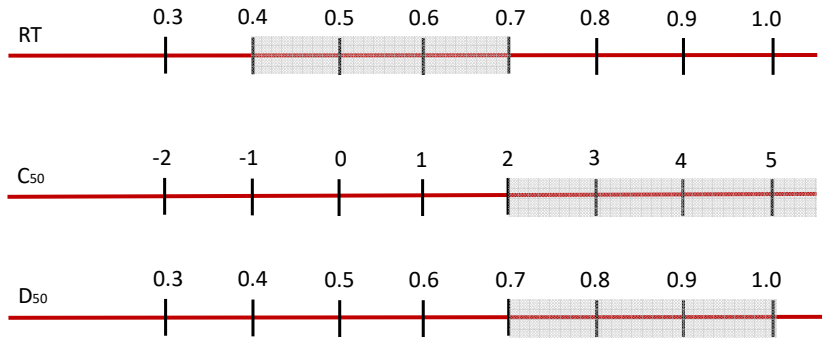

Figure 1: reverberation time, clarity and definition ranges identified for subjects particularly sensitive to auditory stimuli [from https://doi.org/10.3390/app11093942].

Investigating these people's comfort perception and their awareness to indoor environmental stimuli could help to better understand and manage this kind of issues.

2. INDOOR ACOUSTIC REQUIREMENT FOR ASD INDIVIDUALS

2.1 GENERAL INDOOR ENVIRONMENTS

The user-centered design focused on ASD individuals has to consider the following issues: a "too quiet" environment implies to give absence of input to a hyposensitive subject, who could need to increase her/his sensory experience, for example by tapping his fingers insistently; on the contrary, planning a "too noisy" environment may force the ASD individuals to make continuous use of anti-noise headphones in order to protect themselves from this sensory stimulation [3].

In case of critic situations, the noise caused directly by some people with ASD (such as shouting or breaking objects) requires additional sound insulation for the neighbors, but often also for those who live in the rooms of the same apartment. It should not be forgotten, for example, that some people can be particularly active at nighttime and turn on sound sources such as TV or stereo, or use showers or water services that can create noise in neighboring rooms [4].

Therefore, every autistic person should be considered according to his/her profile and individual needs. The diversity of neurological conditions means that the design of an intelligent home or intelligent space cannot be guessed, but must respond precisely to the needs and wishes of the person who will use the environment [5]. Therefore, for best results, it is strongly recommended that more attention is paid for such acoustic issues [6].

Mostafa [7, 8] identifies the acoustic conditions of the indoor and outdoor environment as the principal aspects to be considered in this context. The necessary solutions includes more performing external partitions (walls and windows) where the environmental acoustic conditions are

characterized by noisy sources (traffic, railways, etc.). If the studied space is a volume which requires high acoustic quality, such as a bedroom or speech therapy room, it may be preferable to reduce the number and size of openings. The use double or triple glazing, outer flaps and heavy curtains (velvet or thick gauzy cotton) is strongly encouraged. Internal walls and ceilings with good sound insulation values in the frequencies 125-4000 Hz are required.
The guidelines [9] for the design of spaces for people with cognitive disabilities such as autism demonstrate how important is the need to have simple and relaxing spaces: linear and well-proportioned geometries are positively evaluated, which guarantee good sound reverberation and good acoustics, without sources of noise that may cause distraction or discomfort.
People with autism are extremely sensitive to stimuli and because of the difficulty of filtering foreground and background information are often able to perceive details that others could not notice. The fundamental concept of "simplicity" for living spaces leads to a reduction to a minimum of the furnishing accessories in the rooms [10 - 13] and, above all, it is important to avoid the insertion of suspended sound absorbing elements (buffers etc.).
Rooms with long reverberation times, with acoustically highly reflective surfaces (i.e. those with large volumes and hard surfaces), are particularly unsuitable for many types of ASD children's needs. Children with hearing problems may also find the noise painful because it is amplified by their hearing aids.
Overall we can conclude that the internal acoustic qualities of the room must be provided by the finishes of the walls, floors and ceilings [14]. The walls can be covered with sound-absorbing panels, taking care not to alter the continuity of the wall itself. It is necessary to avoid creating elements that capture the eye and attention. Alternatively, furnishing accessories with sound absorbing elements on certain strategic points can be considered.

2.2 FOCUS ON SCHOOLS

Since it is not possible at present to provide definitive acoustic requirements for ASD individuals in schools, it is appropriate to consider the requirements published by specialized organizations or literature reviews on this topic.
Specific studies carried out on school environments with autistic children have shown that the application of interventions aimed at reducing noise coming from outside the classroom (from corridors, or neighbouring classrooms), has permitted to reduce behavioural temperaments (self-stimulatory behaviour) such as obsessive behaviour, specific for each child, including head-banging, biting hands and rocking [3]. Inclusive environments should be designed considering acoustic aspects, in accordance with these specific needs.
Thus, ranges for hearing impaired individuals could be found, but neither research related to indoor sound field distribution is available, focused on individuals, nor procedures or approaches explaining how and where to select speakers and listeners' positions.
In this view, studies not directly related to ASD individuals are available so far and may be used as reference. The American Speech Language Hearing Association]15] recommend 0.4 s as reverberation time for unoccupied rooms for children with hearing loss and children with auditory learning difficulties, or hearing disabilities. The UK Building Bulletin 102 [9] contains the maximum mid-frequency reverberation time requirements for newly built environment and refurbishment. For spaces intended for users with special hearing or communication needs, the recommended reverberation time is $RT \leq 0.4$ s averaged from 125 Hz to 4 kHz octave bands. American National Standards Institute [16] recommend reverberation time $RT < 0.7$ s for schools in the octave frequency band of 500Hz, 1000 Hz and 2000 Hz. For the healthcare sector, Braam [17] suggested RT values in the range between 250 Hz and 2000 Hz between 0.4 and 0.7 s.

3. USER-CENTERED APPROACH: SOME PRACTICAL EXAMPLES

The best approach is not to "standardize" acoustic characteristics but rather to use "user-centered design" approaches]18].
The acoustics of a living space can be controlled by the insertion of sound absorbing elements of various types, but in the case of autistic users, literature suggests that it is necessary to follow the fundamental concept of “simplicity”. Therefore, available solutions have to be sorted in order to meet autistic individuals’ needs and attitudes, avoiding conventional choices and carefully analyzing acoustic interventions.
Alternatively, furnishing with sound absorbing elements on dedicated areas can be considered. Some furniture elements like beds, cushions, armchairs and sofas are all intrinsically sound absorbing. This property will depend on their geometries and thicknesses.
The possible inclusion of all these elements in the indoor environment should therefore be studied in advance, in order to optimize the indoor acoustic characteristics of the room and to define the possible addition of sound absorbing units.
A real application case study has been possible thank to “ProgettoautismoFVG Foundation”: a daycare facility specifically design for young and adult autistic activities. Specifically, one of the rooms included in the facility houses the auditorium for the music project wherein autistic guests play music (Fig. 2). Because of this high reverberation time, discomfort was perceived not only from autistic user, but also from most of the people who work there. In order to solve this, a design process involving the participation of all the users (namely caregivers and autistics users) was used.
To obtain a better spatial distribution of the internal reverberation, it was necessary to insert sound absorbing ceiling and sound absorbing panels on the walls. Their sound absorption coefficient is reported in figure 2.

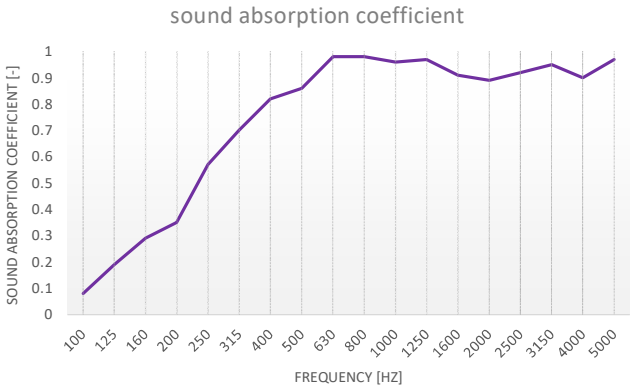

Figure 2: panels sound absorption coefficient.

For the ceiling, users chose sound absorbing panels with soft colors (grey and light blue), to be arranged in an orderly manner and featuring a chequered pattern (Figg. 3 and 4).

Figure 3: Auditorium of ProgettoautismoFVG daily care facilities.

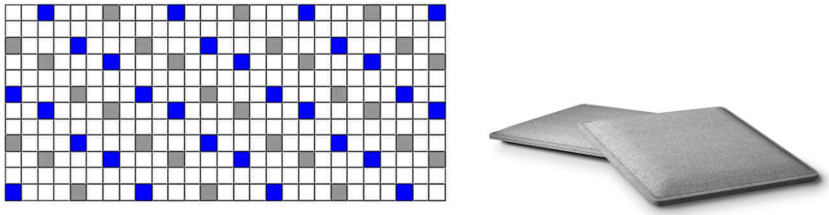

Figure 4: scheme and colors choose for the sound absorbing ceiling elements

The choice of the sound absorbing panels for the walls provided a new interesting point of view: various options were shown to them, namely panels with white color, with colors of all kinds, in various shapes and dimensions. However, they only show some interest when the possibility of customize the panels was proposed. ASD individuals and teachers agreed to use the images of their own paintings printed on the sound absorbing panels. It is here useful to specify that these paintings were drawn by the autistic individuals. Thus, they chose familiar pictures in order to personalize their space (Fig. 5).

Figure 5: personalization of the wall sound absorbing panels

The combination of the two sound absorption approaches made the internal reverberation considerably decreased as reported in figure 6. As could be seen, indoor sound field also feature a very homogeneous distribution in frequency.

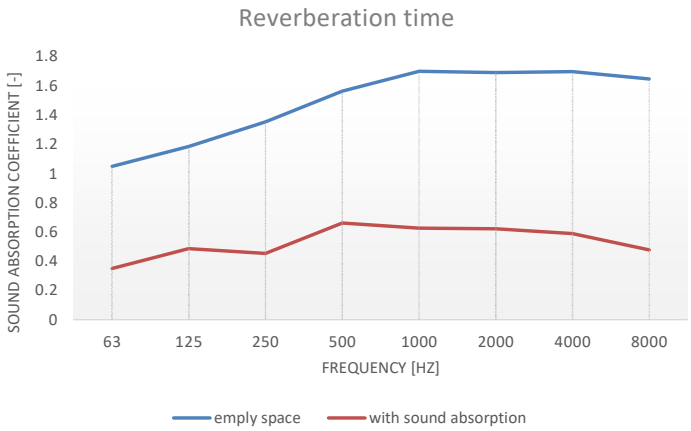

Figure 6: measured reverberation time in frequency, before and after refurbishment

This effect provided (i) a good indoor acoustic and (ii) very good feedbacks from users. Thus, the concept of customization was more important than simplicity as previously expected.
A further example of user-centered design approach was applied during the design of inclusive classrooms, in which special spaces were provided for the reduction of sensory stimuli for autistic students. For this reason, in order to help ASD individuals with a "safe" and "private" place always available to host them and usable as "shell" against too hard situations, some small houses placed close to the back walls of a classroom were designed, also serving as a play space for all children (Figg. 7-8). The small fake houses were realized using sound-absorbing panels characterized by a sound absorption reported in figure 2.

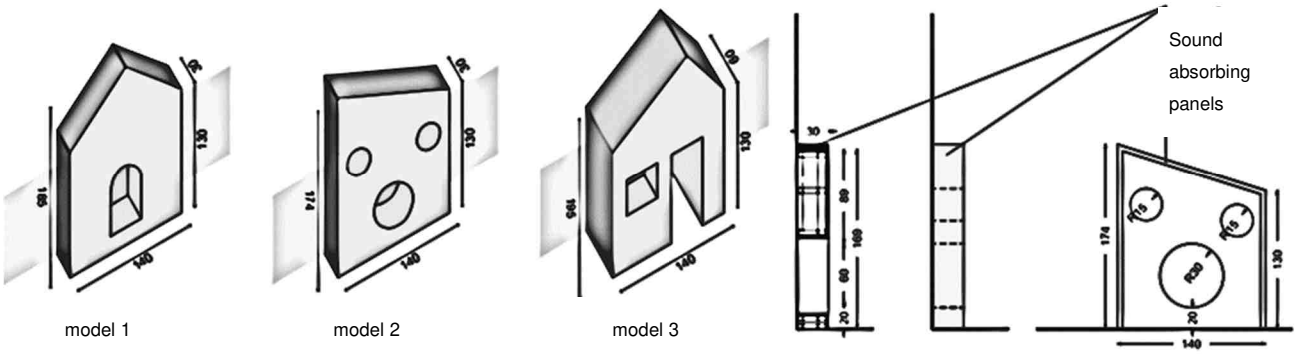

Figure 7: classrooms equipment: spaces for sensory stimuli reduction

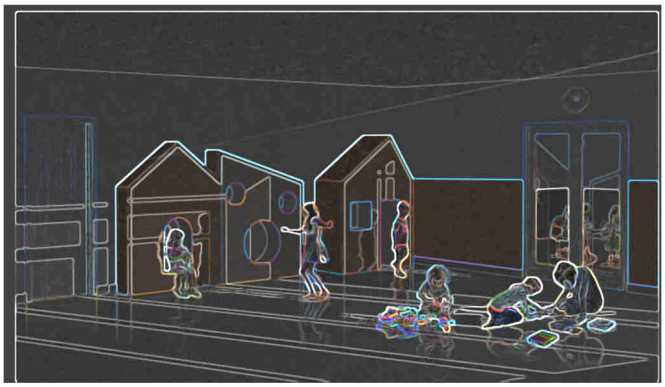

Figure 8: rendering of the fake houses placed inside classroom

With this solution is possible to obtain a twofold objective: (i) create a niche inside which the background noise is effectively reduced thanks to the sound-absorbing capacity of the structure and at the same time (i) ensure that the sound-absorbing surface of the fake houses contributed to reduce the indoor reverberation of the classroom.
In order to predict the final sound field caused by the insertion of these elements, a simulation was performed using a pyramid-tracing software. It shows how the internal reverberation time of the classroom can reach clearly very good results (figure 9), also featuring a good sound field distribution.

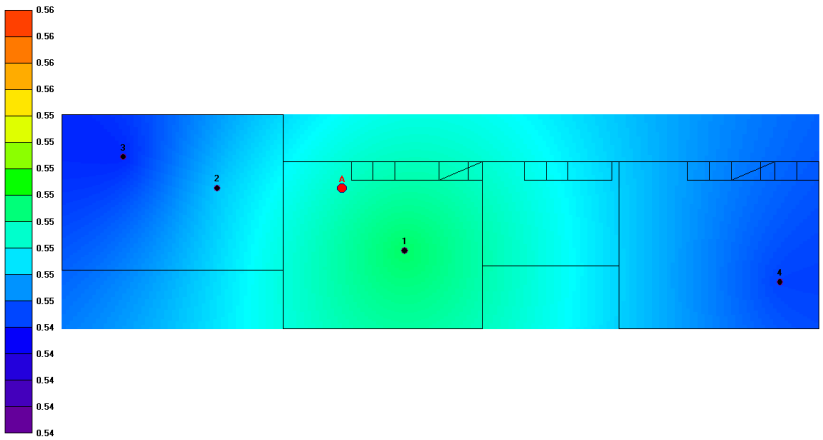

Figure 9: simulated reverberation time at 1000 Hz, obtainable inside a classroom

4. CONCLUSIONS

In this work, results inherent to the following themes are identified:
- importance of indoor acoustic comfort condition of an environment arranged to accommodate autistic persons with auditory hypersensitivity;
- importance of the user-centered design approach for the acoustic personalization of spaces designed for autistic individuals.
This research includes an overview of the literature related to the discussed issues and two dedicated case studies, used to represent examples of possible approach to integrated acoustic design in a user-centered approach for autistic individuals' spaces. Interestingly, the paramount importance of the "simplicity" several time addressed in literature showed not to be consistent with our case study, since once the users where asked to participate in the design phase, they preferred the customization rather than the simplicity. This means that user-centered design for acoustic could be an opportunity to both fit ASD occupants' needs and to design more inclusive spaces. The second case study, applied to classroom, demonstrated how, by the insertion of dedicated fake houses made of sound absorbing materials in a school environment, one ASD pupil could use them as a quiet place to stay; furthermore, they consistently contribute to decrease the indoor reverberation time.

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