CHI: G: Design and Assessment of Hoomie, a Small Multisensory Space for Autistic Children in Primary Schools

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ABSTRACT

While Multisensory Environments (MSEs) are thought to be useful in addressing autistic children's sensory processing dysfunction, there is a lack of solutions tailored to schools that address students' anxiety while meeting the needs of support teachers. We describe the iterative design process that resulted in the creation of Hoomie, a small relaxing MSE, as well as the 2-week exploratory study that involved six classes in a primary school. We present the findings of the study alongside the overall contribution of the research project.

ACM Reference Format:
Irene Zanardi. 2023. CHI: G: Design and Assessment of Hoomie, a Small Multisensory Space for Autistic Children in Primary Schools. In *Proceedings of ACM Conference (Conference'17).* ACM, New York, NY, USA, 5 pages. https://doi.org/10.1145/nnnnnnn.nnnnnnn

1 TERMINOLOGY

In this paper, I follow the guidelines proposed by the Autistic Self-Advocacy Network (ASAN) [7]. Instead of *children with autism*, I will talk about *autistic children*. By using identity-first language, we can recognize and validate the individual's identity and accept the condition as a part of their being.

2 PROBLEM AND MOTIVATION

Sensory processing dysfunction is one of the characteristics of Autism Spectrum Disorder (ASD), which can cause a variety of issues [32, 33]. Autistic students may experience a range of detrimental effects as a result of the abundance of uncontrolled sensory stimuli present in schools, including difficulty focusing, difficulty processing auditory stimuli, and painful sensory overload [3, 19]. The inadequate sensory accessibility of schools poses a significant challenge to the socialization and education of students with neurodevelopmental disorders (NDDs), including ASD, which can adversely affect their well-being [32]. Unfortunately, support teachers, who can play a critical role in facilitating inclusion and learning, often face neglect and a lack of resources [12].

Given the increasing number of autism cases, there is a growing demand for technological solutions that can address the needs of autistic people [23]. Due to their controllability, predictability, and flexibility, multisensory environments (MSEs) have gained popularity as valuable tools for addressing sensory accessibility in ASD [15]. While there are full-room solutions like Snoezelen, Magika, and Mediate and smaller MSEs like Ahù that can turn any space into a multisensory one, none of them are specifically designed for the school context and at the same time propose relaxing activities that promote well-being [5, 16, 17, 28]. Therefore, this study aims to explore how a small MSE can promote personal and social experiences for primary school autistic students, making schools more accessible, comfortable and welcoming for students that experience sensory overload. By gathering support teachers' perceptions and observing children's behaviors, the study envisions the possibility of designing a flexible and efficient tool that can improve the students' well-being while addressing the needs of teachers.

3 BACKGROUND AND RELATED WORK

3.1 ASD, Sensory Processing and School

ASD is a NDD characterized by deficits in social communication and interaction, as well as by the presence of repetitive behavioral patterns and restrictive interests [4]. While the DSM-V does not include sensory dysfunction as a criterion for diagnosis, research has shown that up to 95% of autistic children exhibit some degree of atypical sensory processing [33], which can have a significant impact on social functioning [32] and interaction with the environment [10]. The heterogeneity of sensory processing dysfunction in ASD led to the development of several theories. According to the Intense World Theory [26], hyper-functioning of neural circuits can lead to hyper-perception, hyper-attention, hyper-memory, and hyper-emotionality. On the other hand, the Weak Central Coherence theory [14] suggests that autistic individuals tend to focus on local details rather than the global meaning derived from multisensory integration. Finally, the Temporal Binding Hypothesis [6] proposes that impairment of the temporal binding mechanism leads to difficulties in integrating information and interpreting objects as a whole.

Schools are a vital place for socialization, but they can be particularly challenging for autistic children [20]. More than 1 in 6 autistic children are victims of bullying from primary school to high school [34]. The social and communicative skill deficits coupled with peer unawareness of ASD and reduced willingness to accept differences affect negatively the interaction quality, limit the circle of friends, and increase bullying and rejection [21]. Aside from bullying, school is also a source of anxiety. Anxiety is highly prevalent in autistic students, with generalized anxiety reported in up to 27% of cases and social anxiety in 14% of cases [1]. Teachers and parents report that anxiety influences the amount of support the student

Conference'17, July 2017, Washington, DC, USA

ACM ISBN 978-x-xxxx-xxxx-x/YY/MM…$15.00
https://doi.org/10.1145/nnnnnnn.nnnnnnn

needs [31], and the school environment can be a significant cause of anxiety in autistic students [30].

In Italy, the education system strives for the inclusion of primary school students with disabilities by placing them in mainstream classes, accompanied by a support teacher who aims to achieve individualized educational goals [2]. While this approach values social integration, creating an accessible environment, especially in terms of sensory needs, remains a challenge [27]. Furthermore, support teachers often feel overlooked and helpless in their roles [12], and nearly half of them lack specialized training [27], highlighting the need for more resources and support for both students and their teachers.

3.2 Multisensory Environments and Autism

Technology is used more and more to engage autistic people in various contexts and with various supports [23]. This is not surprising, as technology has several advantages that make it easy to address the heterogeneity of their needs: it is predictable, as its behavior is constant, and controllable, allowing for diversified sensory feedback and multiple interaction modalities [15, 23].

One promising technology is the MSE [23]. One of the earliest examples of MSEs was the Snoezelen [18], which originated in the Netherlands in the 1970s. Snoezelens typically include a variety of objects and elements that can be used to promote relaxation and improve sensory processing. Mediate [28] allows autistic children to express themselves freely without imposing any goals or demands. The Responsive Dome Environment (RDE) [8] provides muted and calm sensory information to promote relaxation and a meaningful sensory experience. Magika [16] was designed for the school setting and focuses on interaction and multimodality. Lastly, Ahù [17] is a nomadic solution designed for schools, that proposes collaborative activities for learning.

Both Magika and Ahù were designed with schools in mind; the first offers more interaction modalities but has more installation challenges, while the latter offers more flexibility but little control over the undesirable sensory stimuli of the environment. Neither of them was intended to deal with sensory overload or to propose relaxing activities. On the other hand, RDE and Mediate do suggest stress-relieving activities, but because they were not created for use in classrooms, they do not take teachers' needs into account. Therefore, there is a need for an MSE that is easy to install, capable of limiting sensory information in the environment, provides unstructured relaxation activities, and considers teachers as users.

4 UNIQUENESS OF THE APPROACH

4.1 Iterative Design for a Hedonic Perspective

There are two ways to accomplish the goal of enhancing the well-being of autistic students in the classroom. While the eudaimonic perspective assists children in finding their own fulfillment [22], the hedonic approach fosters pleasant experiences that meet children's desires for stability and a sense of belonging [13]. We applied a hedonic perspective, which emphasizes happiness and meets the security and sense of community demands of autistic students. To lessen anxiety, we recognize the value of creating a comfortable atmosphere that accommodates their sensory needs and offers control over sensory stimulation. We also recognize the value of enhancing relationships with teachers and other students. To do this, the system should provide, in a safe environment, small-group activities that promote relaxation and self-expression without attempting to impart any particular knowledge or skills. Every stakeholder was given the opportunity to participate throughout the project's various iterations. These iterations informed the design choices [Table 1].

Hoomie is a system that consists of a space called Tana and an application. The primary users are children and their teachers, who plan activities and use the space to relax and socialize. Parents and therapists are also involved by providing knowledge via the application. The Tana's shape resembles a little house, and it can be closed when not in use [Fig. 1]. Pillows and a soft white carpet make the space welcoming and encourage tactile exploration. The teacher can control the activity from inside using five hidden buttons: emergency stop, start, pause, and volume control. The interactive panel on the front wall is made up of cells with LEDs and proximity sensors to allow multiple interaction modalities, with or without physical touch, and with or without mediating tools. Each lateral wall can have four removable tactile modules to increase the possible interaction modalities and allow a wider range of tactile stimulations. Tactile panels can be detached or changed according to the activity the teacher wants to carry out. Activities can be structured-interactive, unstructured-interactive, or non-interactive, and can involve tactile, auditory, and visual stimuli. Teachers can control the Tana through the application, where parents and therapists can share information about the child's sensory profile. By adjusting various settings, including color, animation, sound, panels, and actions, teachers can design activities [Fig. 2 - A]. The app notifies the teacher and issues warnings and suggestions if any chosen setting conflicts with the child's sensory profile [Fig. 2 - B].

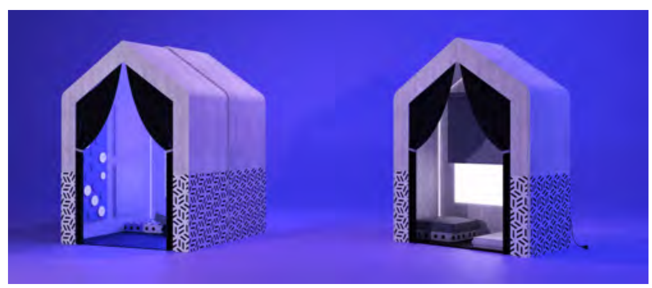

Figure 1: The design of Hoomie.

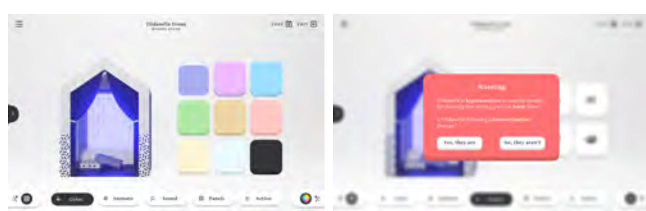

Figure 2: Hoomie application. (A) Selection screen of LEDs colors. (B) Warning pop-up of incompatible stimulus with child's sensory needs.

Table 1: Steps of the design process and main insights (Te = Teacher; Th = Therapist; P = Parent; A = Autistic person; nTC = neuroTypical Child; nDC = neuroDivergent Child)

Sessions	Participants	Main insights
Surveys	65 Te, 16 Th, 30 P, 30 A	**Every stakeholder** should be involved; Hoomie should create an environment that is **dynamic and stimulating**; it is crucial to plan activities that **promote empathy**.
Digital Ethnography	129 P, 92 A	Schools should have a **place where students can unwind**; **information on students' sensory needs** should be provided to teachers.
Interviews	14 Te, 4 P	Hoomie should consider **small-group activities** to encourage inclusion; the planning of such activities should not take away from time that could be spent with the child.
Focus Group	12 Th	The therapists' role in the system should require the least amount of time as possible; the app should allow teachers to **create their activities**, but the process should be **as automated as possible**.
Codesign Session	38 nTC	**Small houses, tents, caves, and treehouses** are portrayed as welcoming and comfortable spaces with **natural sounds and music**; these spaces also have **relaxing and play items** like pillows, stuffed animals, and technological gadgets inside.
First prototype	18 nDC	Children should be able to **move around freely** and **lie down** in a small MSE; some stereotypies can prevent play, so **multimodality** is crucial to enabling them to interact.
Second prototype	248 nTC, 11 nDC	It is critical to demonstrate cause-and-effect relationships by placing **feedback close to the location of interaction**; **delocalizing interaction** to a well-known controller, like a tablet, can make it challenging to distinguish between game activities carried out at home and in MSEs; to avoid tumult, group activities should involve around two children.
Third prototype	38 nTC	According to the preference of the children, there should be both **playthings and relaxing items available** to accommodate their personal inclinations.
Codesign Session	6 Te	Activities should last about **15 minutes** to capture the child's attention and provide educational opportunities; **unstructured activities** are essential because their goal can be adjusted based on the child's engagement; small MSEs should be **affordable** in order to have **multiple small spaces**, allowing for more children to be accommodated at the same time and greater sensory customization.

4.2 Exploratory Study and Hoomie Prototype

In the latest design iteration, which came after the nine steps presented above [Table 1], we looked into how children interact within a small MSE in school to determine which factors should be considered to improve its inclusiveness.

At an Italian primary school, we conducted an exploratory study that lasted two weeks and involved six classes, 129 neurotypical children, 11 children with NDDs, including 4 autistic children, aged between 6 and 8 years old, and 11 support teachers. The school provided the ethical approval to conduct the study. Objectives, activities, and the technique of data collection and storage were all explained to the parents, who were requested to sign the participation consent form. Children had complete control over whether they entered the small MSE and when to quit the activity. Support teachers' presence was essential to ensuring children felt at ease at all times. The sessions were designed to focus on children's interactions with the MSE as well as their social interactions with their teachers and peers. We recorded the types of interaction and their duration, children's emotional reactions, and the time spent inside for each session. Activities were created based on the insights gathered during the design process, as well as existing activities proposed in the literature. Following the activities, we solicited input from support teachers on the session.

The first three days involved *relaxation sessions* based on music listening activities [9], which aimed to create a safe environment and investigate children's responses to it. During these sessions, children were alone in the tent and free to explore for five minutes while a soothing animation played on the LED panel and eight tactile modules were present. We observed whether they felt comfortable enough to stay in the space, which modules caught their attention and how they interacted with them. The following two days involved an unstructured *expression activity* inspired by Mediate [28], during which children played together with their teachers by touching the interactive panel to play sounds and light up the cells. We observed whether they created rules and how their teachers responded to them during the ten-minute sessions. During the second week, children played with their classmates in the structured *game activity*. Also in this case, the interactive panel was the focus of the game, in which both children had to touch two lit cells at the same time, while upbeat music played. We observed whether children interacted with their peers and whether they participated in the game.

To conduct the study, we created a prototype with the main interaction features and activities of Hoomie in order to respond to the research objectives. The interactive panel is made up of fifty cells, each with six LEDs and a proximity sensor, allowing for various interaction modalities and a wide range of possible activities. There are four removable tactile panels on each lateral wall. To provide enough variety to observe their preferences, selected materials can be interacted with through various gestures, such as grabbing, pressing, and stroking. On the floor, there are pillows and a soft rug that not only act as additional tactile items but also create a warm and welcoming atmosphere. Finally, two colored lights enhance the overall illumination.

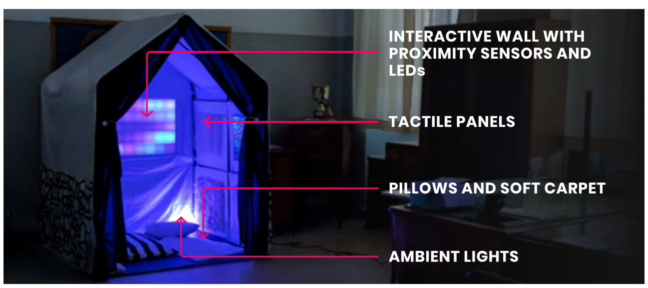

Figure 3: Hoomie prototype inside the school.

5 RESULTS AND CONTRIBUTIONS

5.1 Interacting within Hoomie

Regarding the first activity, nine out of eleven children completed all three relaxation sessions, with the other two missing one session due to illness. During the first session, most of the students looked for their teachers, who were located outside the tent. In subsequent sessions, they gradually became more comfortable, and many lay down to rest. The most interesting tactile element was the carpet, followed by the wool panel and the panel with small mirrors attached to several threads. Surprisingly, those tactile elements were the ones that best to be grabbed due to their position and composition. Their gaze was mainly directed to the LED panel and towards the carpet. Two children had different relationships with Hoomie. One child with a non-specific NDD was particularly drawn to the tactile panels. Rather than just touching them, they preferred to tear the materials off and manipulate them on the floor. The teacher noted that this level of active participation was surprising compared to typical school activities. Another noteworthy case involved an autistic student who was uncomfortable, especially during the second session. According to the teacher, the child displayed atypical behavior, so the activity was cut short. For the third session, the teacher remained inside the tent. With the teacher present and the observer out of sight, the child relaxed and interacted with the space, eventually even lying down to rest.

Regarding the *expression activity*, the first session included all of the children, but due to illness, only seven were able to attend the second. Like the relaxation session, despite the range of diagnoses and their severity, the experiences were similar across the group. The children explored the wall with their hands and the handles provided, then created and followed their own game logic. Two children even communicated the rules to their teachers. The majority of them tapped and swiped on the panel, with only a few preferring only one of the two options. Only three children stopped interacting with the panel after a few minutes, whereas the others interacted with the panel throughout the session. Some teachers joined in and incorporated small educational moments into the game, such as counting, naming colors, or challenging the students to make particular movements. Other teachers chose not to participate and instead stood aside in the space. Interestingly, the child who interacted the least with the *expression activity* was the one who was most engaged by the tactile panels in the relaxation session. The teacher was able to engage them for short periods, but they were more drawn to the pillows, which were more satisfying to the touch.

The *game activity* involved 68 couples, with 7 consisting of a neurotypical child and a neurodivergent child. Four of the eleven children were absent due to illness. Almost every couple with a neurodivergent child actively participated in the game. Some of them understood the rules through verbal instructions, while others needed help from their classmates. Some teachers were taken aback by the positive behavior of some children who had previously struggled with social interaction. Furthermore, teachers observed positive effects for neurotypical children: because the game did not require verbal communication, which can be a barrier for students learning the language, it allowed foreign children to interact with Italian students.

5.2 Improving Inclusion in a Small MSE

The study and research project in which it is situated contribute to Human-Computer Interaction by providing insights for the design of multisensory spaces that can enhance the well-being of autistic students.

Enabling the choice. Interaction within an MSE can occur for three reasons: to stimulate interesting sensations, to change the appearance of the space based on one's preferences, or to explore in search of a goal that structures the activity. To make children feel in control and thus less concerned about uncertainties [20], we must allow them to choose their own experience [29] and then work on how to facilitate the three aspects. The presence of objects with varying degrees of interaction and outcomes with varying sensory impacts allows the child to make a choice.

Providing multimodality for accessibility. Multimodality is also an important consideration [17]. In order to provide accessibility, designers must consider the position of objects as well as their freedom of manipulation. It is also important to have items within reach without having to stand up in a small space. Activation with different tools and gestures on an interactive screen can better adapt to the child's preferred interaction modality.

Respecting the teacher's abilities, workflow, and needs. To be useful for teachers and the educational goals they seek, a technological tool for inclusion must be adaptable. To begin, the system must be manageable in order to reduce the perceived effort of use [11]. It must also be flexible enough to accommodate both planned and unplanned use. Second, whether they want to design an activity based on the desired goal or the child's characteristics, flexibility must respect the teacher's work method. While the first case begins with precise intention, the second case pursues the goal on the spot by capturing the educational cues that naturally arise during the child's experience. Third, the adaptability of multisensory stimuli must be taken into account. When creating an activity, teachers do not appear to require numerous settings, which do indeed complicate system use, but rather a few customization areas that allow great freedom within them. As a result, the performance quality is high while the effort expectancy is low [11], increasing the chances of adoption [25].

Preventing improper use. Flexibility and adoptability should not come at the expense of preventing inappropriate uses that can lead to exclusion, isolation, and even harmful experiences. Because teachers must be aware of their options when using technology for inclusion, the system controller, like the app, should encourage conscious decision-making by implementing forcing functions [24]. Furthermore, in order to promote communication and understanding, the user interface should allow children to participate as much as possible in setting selection.

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