Magika:
an Immersive Multisensory Environment for children's inclusion, education and well-being

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ABSTRACT
Awareness on the role that technologies play in educational, clinical and inclusive contexts has augmented noticeably in the past years. The body of knowledge on the topic is rapidly expanding. Moreover, there's a multidisciplinary, interest among clinicians and researchers, to explore the potential that technological innovations can offer to individuals with disabilities or special needs. The benefits that arise from the use of such technologies are wide-ranging and multifaceted. Prior human-computer interaction research indicates that offering multisensory stimuli through embodied interaction and combining physical with digital worlds brings a significant support for persons with disability or special needs. In this context, Interactive Multi-Sensory Environments (iMSEs), physical indoor space enriched with digital devices embedded in the physical environment, are among of the most powerful tools to provide gentle stimulation (e.g., light, sound, projections, blowing bubbles, tactile feel, aromas) to different senses. Our work focuses on the use of iMSEs in primary education contexts and for mixed groups of young students -i.e., children with and without disability- as inclusive educational setting to improve learning, well-being and socialisation.

Author Keywords
Interactive Multisensory Environment; Children; Children with Special Needs; Primary School Education; Well-being; Smart Object; Smart Space; Embodied Interaction

INTRODUCTION
The impact of a diagnosis of disability echoed both on subjects and on caregivers [1], often results in a low quality of life, social isolation and lack of inclusion [4,5,7]. For these populations, the keys to overcome everyday-life challenges are enclosed in cutting-edge research. Especially in those studies that focus on the role that new interventions or instruments can play in this context [13]. Also, it is become more and more evident the need to careful planning tailored interventions and strategies to better fit each individual difference [2,18,22]. In this regard the saying goes: "the sooner, the better". Childhood is the most flourishing period of a human being. All skills, from movement coordination to abstract reasoning, develop over this period, consolidating when it is reached the first stage of adulthood [15,16, 23]. Early intervention leads to better outcomes [12], positively impacting on the future. It is no surprising that a large portion of current research or studies focus heavily on children or young adults. Recent studies suggested that the use of new interactive technologies could offer an innovative context for training [19] and overcome the limits of traditional methods [20]. To date, in order to achieve this goal, various forms of interactive technologies are used, spacing from simple standard devices such as tablets, PCs of VR application ([6,25]) to more sophisticated solutions such as Interactive Multi-Sensory Environments (iMSE).

For example, virtual settings seem to be particularly suitable for subjects with ASDs as they allow a custom adaptation of specific features to the user personal characteristics (identifying strengths and weaknesses) [14].

Children playing in a iMSE (Magic Room).

Another example, although much more challenging, are Multisensory Environments. IMSE allow stimuli and interactions to be digitally controlled by caregivers and customized to the needs of a single child, a group of children or to address the unique characteristics of each person. The multisensory approach of iMSEs is grounded on theories of embodied cognition [26] and sensory integration [24]. Tangible interactions with smart objects, [11], smart toys, [3] or soft robots can empower children with sensory processing disorders to engage in self-reflection, self-directed activity, and language use. The iMSE supports multimodal embodied interaction (based on touch, manipulation, gestures, and movements) with ambient projections, physical objects, and lights, and offers stimuli to the vestibular, proprioceptive, and tactile sensory systems. Smart lighting enables a vast gamut of luminous effects with different colors, intensity, and dynamics. Lights provide pleasurable stimuli for relaxation or reward purposes [21]. They aim to provide pleasurable experiential space for persons with disability or special needs to learn through play, helping them to exercise the perceptual system and practice social, emotional, cognitive or motor skills.

The use of IMSE offers several advantages with respect to traditional interventions:

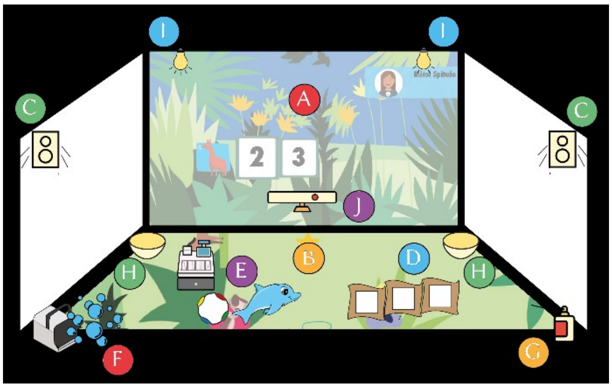
- Researchers can manipulate stimuli in a controlled ecological environment. It is possible to: i) control the confounding effects of pragmatics (related to background knowledge or past experiences) and facilitate the subjects' focus on specific aspects; ii) design context-related activities that are more "natural" because of a higher coherence between tasks and surrounding environment
- Embodied immersive experiences make the experience engaging, stimulating and playful.
- Collection of quantitative and qualitative information on subjects' performance and behavior can be automated. Data can be analyzed using state-of-the-art Artificial Intelligence and visualization tools.

THE MAGIC ROOM

The Magic Room presented in this paper [9] is the results of a long technology engineering process. The technological system of the Magic Room (MR) is called “Magika”; and is a modular multi-layered architecture designed to be easily extendible with new software and hardware components to facilitate technology updates or implementation of new activities. The Web *Service Layer* – running on the tablet –

manages the *Configuration* and Control Application for caregivers. The *Activity Layer* implements a set of “activity patterns”, each of which manages the interaction, control and execution rules of a specific “type of activity. The *Middleware Layer* control the physical appliances, standardizing sensing and actuation capabilities for the upper levels, managing the communication between the hardware and software components and optimizing data exchange. Lastly, the *Physical Object Layer* control the hardware components, see [8]. The Magic Room serve multiple purposes: from relaxation and free play to neuropsychological assessment, speech therapy and learning. The activities are design for mixed groups of children - with and without disability - and have been custom engineered in cooperation with a team of teachers, special education experts, and cognitive disability specialists. All the activities are game-based and offer more focused learning-oriented tasks. The MR activities are: association games, classification game, ballet ship, grocery store, immersive game, memory, wardrobe. They involve a wider number of gesture-based and full-body interaction modes, richer multisensory effects, new digitally-enhanced physical objects, and a tablet-based application for caregivers.

The Smart Room main components (bottom):



Front (A) and Floor (B) projection,

audio system (C),

Smart Materials (D),

Smart Toys (E),

Bubble Machine (F),

Aroma Emitter (G),

Lights (I, H),

Kinect Sensor (J)

Children interact with the Magic Room by manipulating objects and physical materials, or through movements in the space and mid-air gestures sensed by the Kinect. The web application allows caregivers to customize the experience according to the needs of each children’s group: selecting specific multimedia contents for each activity, setting the complexity level of the tasks, and organizing activities in automatically activated sequences.

EMPIRICAL STUDIES

Although new technologies have been successfully used for the general cognitive abilities, in today's literature only few studies have explored their role to foster inclusion and well-being. To evaluate the effect the Magic Room we conducted four empirical studies in which we deepened aspects related to usability, well-being, social interaction and learning. All studies were performed in two Magic Rooms installed in primary schools (hosting children aged 5-11) located in a small town near Milan (Italy). The groups recruited for our empirical studies were “mixed”, i.e., composed of children without and with disability.

The first study [8] focus on usability and organizational issues related to the Magic Room. 39 children, aged 7/8, were relucted for the study (21 males, 18 females, 22 neurotypical, and 17 atypical). In addition, 10 teachers and 5 researchers participated in the study. The study took place over two weeks (4 sessions in total). Results suggested that the MR is suitable for both mixed groups of children as well as e for large mixed groups or small groups. Overall Children enjoyed all activities but preferred that best express the multi-

sensoriality and the immersivity of the MR. Especially those that provides a continuous tangible interaction through objects' manipulation and interaction with projections, sound and visual feedback, or were specifically designed with the aim of immerging subjects through a progressive exposure to environmental stimuli.
The second study's [8] goal was to explore the impact of the Magic Room on both atypical and neurotypical children's well-being. We administered to each child the QBS 8-13 - Questionnaire on Well-Being at School [17] - a validated standardized paper-based questionnaire widely used in Italy to monitor well-being in educational contexts for children aged 8 to 13. All participants filled the QBS questionnaire twice; before the beginning and after the ending of the study. We recruited 68 children - 46 atypical and 22 neurotypical children, aged 7-8 y/o (mean age=7, s.d.=1.3). The study lasted for three weeks for a total of 4 sessions. According to our findings, even a relative short experience in the Magic Room might positively affect perceived well-being in the school integration environment, especially for atypical children. These effects seem to be stronger for some specific well-being indicators such as Emotional Attitude and Social Interaction (with peers and with adults) that are related to psychological functioning dimensions that are particularly critical for this population.
The third study [8] research question was: "How does a mixed group of neurotypical and atypical children behave in the Magic Room?". To facilitate the recording of observations on children's behaviors during the Magic Room sessions, we created a simple tablet-based web application called B.O.A (Behavior Observation Web Application). When the observer noticed a relevant behavior for one or more children, he/she could simply touch the screen twice: for the corresponding behavioral signal and for the number the number of children who manifested that behavior. The application automatically stored the selections associated to a timestamp. Our results suggested that the range and variety of behavioural signals was wider in neurotypical children w.r.t. to atypical ones, but the variety of positive behaviours for the latter slightly increased along the time. These findings are consistent with the characteristics of this population: any novel situation is intrinsically complex for them to manage and creates stress and cognitive load, particularly if it offers new and rich stimuli. It is important to pinpoint that in the Magic Room these behaviours tended to disappear with time, even when new activities were proposed.
The fourth study [10] investigate if the MR can facilitate children's learning. The study was based on the comparison between the traditional classroom approach and a corresponding experience occurring in the MR. The study involved 48 primary school children aged 6-8. All children were assessed for knowledge on a specific topic at baseline and after e session in the MR or in the class. Results suggests that motion-based immersive technology and embodied learning activities in regular school contexts is a promising approach, and smart spaces characterized by low-medium embodiment can be a precious tool to support children with special needs.

CONCLUSIONS

Our studies offer some preliminary evidence of the potential of iMSEs for inclusive education, suggesting that these systems could be effective for children with and without disability to improve behaviour, socialization skills, and learning. Overall, our work contributes to the educational technology research community by providing a better understanding of the potential of iMSE technologies in real education and inclusive contexts.

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