Supervised Smart Spaces for ASD Children

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Abstract
The focus of our research is to create smart spaces for children with Autism (ASD) that integrate physical and digital contents, provide multiple paradigms of interaction, and enable new forms of interventions. In cooperation with a team of therapists from two rehabilitation centers, we have designed and developed interactive multisensory environments which blend different ingredients: interactive virtual worlds displayed on walls, ceilings, and floor; interactive lights; and everyday objects, such as toys, which become interactive by embedding sensors and actuators. Reacting to children's manipulation and their movements in the physical space, all these materials offer a variety of visual, auditory, tactile, and olfactory stimuli and enable caregivers to engage children to relax, to play, and to exercise different cognitive, emotional, motor, and social skills.

The paper describes the challenges we have faced, and the lessons learned from the ongoing exploratory study involving 20 children and 10 therapists at a rehabilitation center.

Author Keywords
Autism, Children, Technology, Multisensory Environments, Smart Spaces, Smart Objects, Iot

ACM Classification Keywords
H.5.1 - Multimedia Information Systems; L.5.1 - Game Based Learning/Gaming

Introduction
Autism (ASD) begins during the developmental period and is characterized by significant limitations in both intellectual functioning and in adaptive behavior. Intellectual functioning refers to general mental capacity, such as learning, reasoning, problem solving, and imagination. Adaptive behavior is the collection of skills that are learned and performed by people in their everyday lives. It includes conceptual skills (language and literacy), social skills (related to interpersonal relationships, social responsibility, self-esteem, ability to follow rules/obey laws) and practical skills related to the activities of daily living such as personal care, healthcare, schedules/routines, personal safety, travel/transportation, money and time management [5]. These deficits influence day-to-day functioning, and usually last throughout a person's lifetime with devastating effects on quality of life of the subject and his/her family [6].

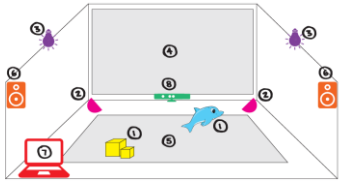

Figure 1: Basic Configuration of a Magic K-Room. (1) Smart Objects; (2) Portable Lights; (3) Bulbs; (4) Front Proj. (or display); (5) Floor Projection; (6) Sound System; (7) PC; (8) Kinect

Figure 2: Activity focusing on Relaxation and mood elevation

Figure 3: Activity focusing Environmental adaptation, social understanding and correct behavior in social situations (e.g. while using public transportation)

ASD has an incurable nature and little is known about its causes. According to some neuroscientists Autism may be ascribed to the inability to properly synthesize input stimuli and to abnormality in the neurological mechanism that controls the capacity to shift attention between different perceived signals. What is generally acknowledged is the importance of early interventions and of exploring alternative and more specialized approaches for children [4]. In this arena, the use of digital interactive technologies is regarded as one of the most promising methods. Children with intellectual disability are instinctively attracted by digital technology. Interaction with technology is easier than human-human interaction, it is more predictable and controllable, and stimuli and tasks that are indefinitely replicable. Finally, technology does not have the emotional manifestations that characterize human relationships and are perceived as confusing and distracting, often induce anxiety, and create barriers to social communication [2]. Still, researchers and practitioners pinpoint that the enormous potential of interactive technology might fail unless some specific requirements are met [1], which are at the cornerstone of any intervention with children with disability:

- To facilitate the learning process through relaxation, pleasure, and fun
- To make interventions easily customizable to the specific need of each child
- To enable children exercise a wide spectrum of basic skills (including attention, environment adaptation, cause-effect understanding, choice, communication, social interaction)
- To provide modular tasks that offer different types of stimuli (visual, auditory, tactile, motor, and olfactory) but enable the child to experience them one-by-one

The main challenge is to deliver interactive technologies that meet all the previous requirements, and does so in a way that is economically affordable for rehabilitation institutions. Complementary to supporting new forms of treatment, there are additional needs in a therapeutic process where digital technology can play an important role. We refer to therapists' activities of children's observation and collection, analysis and sharing of data about treatments, which are needed for diagnosis, therapy tuning, and children's assessment. In the current practice, during their activities at the rehabilitation center children are observed by side-by-side caregivers and on-site observers; data collection is mostly qualitative and it is typically performed manually (and on paper), during or after the therapeutic sessions. This approach has obvious negative implications: observations can be performed only locally at the rehabilitation centre; data are largely qualitative and subjective, and their gathering is characterized by huge effort, limited sharing, and poor standardization. *The second challenge is to make the process of observation, data gathering, and data sharing more efficient, complete, objective, and cost-effective.*

Supervised Smart Space for ASD Children

We have designed and developed a "Magic K-Room", an innovative multisensory interactive environment that incorporates virtual worlds, displayed in the ambient, and everyday objects, such as toys and lights, which become smart and interactive by effect of technology [3]. These materials react to children's movements and manipulation with a variety of visual, auditory, tactile, and olfactory stimuli, and offer the opportunity to engage children in a gamut of activities: to relax, to play, and to exercise specific cognitive, emotional, motor, and social skills.

Figure 4: Developing sense of control and understanding of spatial concepts (up/down, left/right)

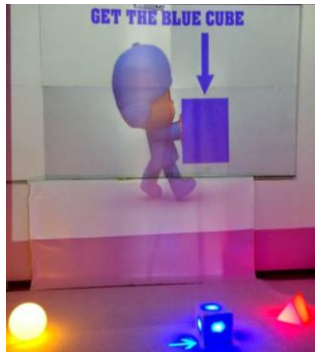

Figure 5: Eye-hand coordination, color recognition, classifications of shapes, and dimensions

Figure 6: Multiplayer activities

Concepts

Children's activities consists of simple games that involve interactive smart objects and virtual worlds. In the different games available in the Magic K-Room, kids can experience different ambient stimuli and be engaged in different tasks, each of which is focused and unfold along progressive levels of complexity, first focusing on a single stimulus that the child can learn to understand and control, and then proceeding towards more articulated situations. Examples of Magic K-Room games are shown on the side bar (figures 1 to 6).

The Power of Customization

A simple authoring tool enables caregivers to customize each game to address the specific needs of each single child, tailoring multimedia contents, behavior of smart objects and lights, and calibrating all visual, auditory, tactile, and olfactory stimuli as figure 7 shows.

Complementary Tools

Magic K-Room technology offers a set of tools that address the therapists' need of making the process of observation, data gathering, and data sharing more efficient, complete, objective, and cost-effective. These tools, fully integrated with Magic K-Room technology, enable therapists to:

- Inspect data that are quantitative and objective, are collected automatically and in a non-intrusive way, and can be easily shared within a community. These data can complement subjective and qualitative information on children's behaviors that are normally collected in a therapeutic process
- Analyze and share these information
- Remote monitoring of therapeutic sessions

Data describe:

- Data of children' interactions with smart objects (which are automatically logged by the Magic K-Room system)
- Attention and concentration levels, which are measured by interpreting the EEG signals detected by a wireless headset (Figure 8).

An integrated cloud-based application enable therapists to visualize in multiple forms the above data, to store and share them in a platform that exploit all benefits of cloud technology in terms of storage, privacy, and performance (Figure 9).

In addition, the cloud application offers the opportunity to access the live video of children's sessions for real-time remote observation of interventions (Figure 10).

Exploratory Study

All activities (Figure 1 to 6) have been designed in cooperation with the specialists of 2 rehabilitation centers (in Italy and in The Netherlands). In these institutions, an exploratory evaluation of the benefits of the Magic K-Room has been performed, highlighting the enormous potential of this technology for therapy purposes. The systematic evaluation of educational benefits is still on going.

Conclusions

This work tries to find a solution to methodologically unlock design spaces and evaluate experience of children with special needs. Our space enables technology enhanced interventions for children with intellectual disability that meet all the key requirements for the success of a therapeutic path, whatever therapeutic approach would be used (ABA, TEACCH, DIR, etc...).

Figure 7: The customization tool

Figure 8: Wearable eeg headset

Figure 9: Cloud – analysis of attention and relaxation levels

Figure 10: Cloud – live monitoring

The unique features of the Magic K-Room are many:

- the richness of sensory stimuli offered, which are rendered by smart objects and lights, as well as the multimedia contents immersed in the physical space
- the strong role given to light as a mean to attract and engage children, and to give them pleasure and to facilitate relaxation (building upon the therapeutic capability recognized at medical level)
- the variety of tasks provided, their focalization on specific skills, and their strong modularity in terms of stimuli and activities, still maintaining strong gamification characteristics
- the total customizability of these tasks by means of a customization tool, amplifying the potential of each activity with the possibly infinite transformations and forms it can take by using different multimedia contents, objects, combinations of stimuli.

As we could experience during the exploratory evaluation, activities performed at rehabilitation centers during the whole project life cycle, the Magic K-Room also supports a process of "technology appropriation" by therapists. They have been able to use and adapt our technology in unexpected ways never envisaged by the designers, or even deliberately subverting the designers' intentions. Such appropriation is an important and positive phenomenon, in which stakeholders act as catalysts of innovation, and paves the ground towards new therapeutic solutions we cannot even imagine at the moment.

Author's information

Mirko Gelsomini has a M.Sc. in Computer Engineering from Politecnico di Milano where he is currently a PhD student in Information Engineering and a visiting researcher at MIT Media Lab. He has worked at Georgia Institute of Technology (Atlanta, US) as visiting student, working on full-body interaction technology for autistic children. His life is fully dedicated to help children with special needs, in and outside his main job. Mirko can bring his cross-cultural technological expertise to the community and hopes to better define the role of interactive technology for the ASD and IDD panorama.

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