Smart Buckets: An Interactive Interface Enabling Sensory Integration

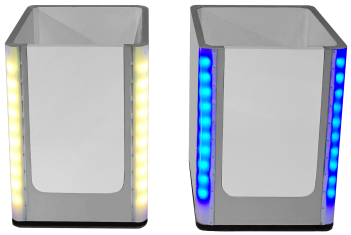

Figure 1: A couple Smart Bucket prototypes. You can see the sliding door and the controllable colored LEDs.

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Abstract

In literature a lot has been done to investigate the possible advantages of integrating the virtual and physical world, combining the benefits of both and improving the overall user experience. Plenty of tangible user interfaces were designed, to facilitate the development of cognitive skills, motor skills, social skills, or more concrete notions such as STEM concepts for children. Also, thanks to the flexibility provided by digital systems, it is recently growing a sub-research field that specifically addressed people with a cognitive disability. In this scenario, immersive multi-sensory environments are gaining more and more interest as a support tool for learning and therapeutic methods. In this paper, we present Smart Buckets, an interactive interface integrated into "Magika", a multi-sensory system; the result of co-design with therapists specialized in the treatment and education of children with a cognitive disability. The paper illustrates the multi-step co-design process used to produce this idea as a tailored support for their therapeutic activities. Finally, it highlights the importance of adding a new customizable tangible interaction combined within the multi-sensory experience of Magika system.

Author Keywords

Tangible User Interfaces; Multisensory Environments; Children; Cognitive Disabilities; Customization; Education

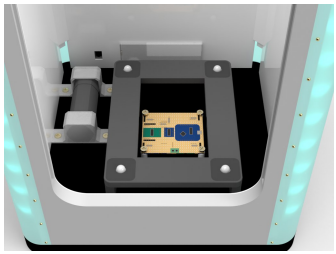

Figure 2: Front view of the bucket, see the underlying bare circuitry.

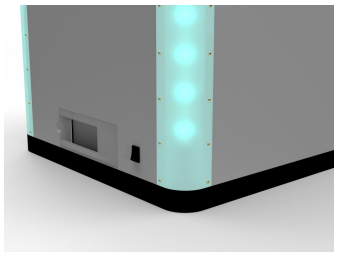

Figure 3: Back of the bucket, see the rounded luminous corner to guarantee safety and the lid hiding the recharging cable.

Figure 4: Smart bucket providing different luminous feedback.

CCS Concepts

•Human-centered computing → User interface toolkits; *Accessibility systems and tools;* **•Social and professional topics → People with disabilities;**

Introduction

The growing debate on multi-sensory processes, arised in literature in recent years, highlights the considerable potential that a sensory experience might have in helping children, especially those with cognitive disability (CD), to improve their abilities[12]. Moreover, combining the physical and virtual world and offering multi-sensory stimuli through built-in interaction, provides an additional support for these subjects. Some papers have explored how tangible interaction with smart objects [5] can proffer children with an interactive environment, in which they can develop social, cognitive, and behavioral capabilities[1]. In our previous work we developed "Magika", a multi sensory environment that provides gentle stimulation of different senses while offering a nonthreatening, relaxing, but also an educational experience[6]. Magika is a system grounded on the theories of embodied cognition and sensory integration combining different features in a unique way, proposing a pervasive inter-connected space where all children are involved in new forms of full-body, tangible, playful, multi-sensory, learning activities. This paper describes a new interactive interface deeply integrated in our multi-sensory environment that enhance the tangible aspect of Magika and offer different customizable activities. Furthermore we are going to show the main features of a control panel displayed on a tablet that allow therapists to manage children activities.

Related work and Motivation

Tangible interaction for children learning is a field deeply investigated during the past two decades. Different products were designed and prototyped to improve skills and knowledge in different fields such as STEM area as well as soft skills such as verbal and social skills[11, 7]. These systems, from smart toys and social robot[2] to multi-sensory environment (MSE)[6, 10], seem to be effective tools in therapeutic and learning contexts and are currently investigated on their effectiveness. Recently, some works have defined guidelines to successfully design new smart objects from their experiences with (co)design, developing, testing with end users and reiterating this process multiple times[9, 3]. In particular, Kara *et al.*[9] have performed evaluation study and developed a custom smart toy based on RFID tags to do storytelling with preschool children. They also put effort on the integration between virtual and physical world. Instead, Crovari *et al.* derived guidelines from the experience with smart dolphin SAM, from its analysis as stand alone toy to the full integration into the MSE. However, if badly conceptualized, the risk of these kind of objects is to become an burden to regular activities and schedules held by the therapists more than traditional tools. To avoid this issue, we focus to design a robust system with respect to contexts changes, obtainable through careful listening of end-user past experience.

Codesign

In order to collect the requirements that lead us to the Smart Bucket definition, we organized a co-design session in a therapeutic center specialized in CD. We involved our multidisciplinary team composed by two engineers, two designers and a psychologist with six caregivers that had already worked with us in the requirements definition of Magika. We split the co-design process in two sub-phases: observation and discussion.

In the first week-long phase, we observed the caregiver's routine when working with children. We avoid any interference with caregivers or children during activities by keeping

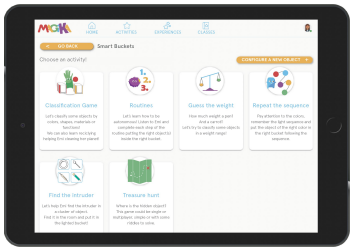

Figure 5: The Control Panel initial page, showing the available activities.

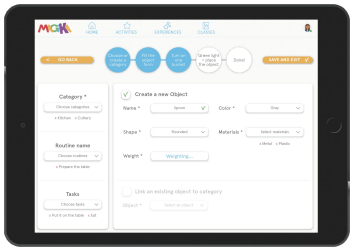

Figure 6: The object configuration page of Control Panel.

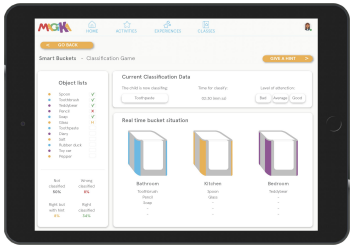

Figure 7: The Real-time Activity Control page view of Control Panel.

a neutral and silent attitude. This phase was useful to get some preliminary information about habits and working routine at the therapeutic center.

The main finding was that the activities are planned, organized and performed with a precise schedule that include room rotation. Moreover, the activity are slightly changed each time and from children to children accordingly to their needs. We observed that the main activities favored collaboration, and aimed to develop personal care skills, classification, collection and counting. Finally this phase helped us to collect pinpoints that helped us to orient the discussion held with therapist in the second phase.

In the second phase, considering that the therapists were already familiar with Magika, we made a focus group in which we presented the available technologies including smart objects integrated with the system. Our aim was to let them understand the potentiality and their possible technological support for their daily activities. After that we tried to elicit what is the level of technology integration in the center. All therapists emphasize that fine tuning for each child is fundamental, especially because they usually prepare all material from week to week, changing it continuously, to fully adapt to the children's needs. In such a dynamic and ever-changing environment, the only effective support tool they use is mostly paper material: it is cheap, easy to modify, easy to manipulate both from children and therapist. During the past years, they had tried to translate papers material to digital screen, losing "tangible" interaction, and with poor results in term of therapeutic goals. Moreover, many actual smart toys are not a right fit, because they do not allow such heavy flexibility.

At the end of the co-design sessions, we collected our observations, notes and useful tips from therapists and we summarized them in different requirements to design our tangible interface:

- R1 It should have a visual affordance, to let children get involved.
- R2 It should avoid unknown shapes or feedback, because they could bring fear to CD children.
- R3 The content should be minimalist, to avoid the children get distracted by irrelevant details.
- R4 The experience should be customizable by the therapist,to be adaptable to each child.
- R5 It should be able to collect and show data about sessions, to allow monitoring of children's progress.
- R6 It should be safe for children in terms of materials and design.
- R7 It should be an edutainment system, in order to be flexible in any context.
- R8 It should be maintained by spending the lowest effort possible, to avoid becoming a burden.

Smart buckets

From the co-design process we came up with a final idea called "Smart Buckets", an interactive system which promotes tangible interaction, designed both for children and therapist. The children can interact with the buckets while they are immersed in the multi-sensory environment combining virtual and physical world stimuli, through different activities described in the next section. During these activities is expected that the children accomplish different tasks placing real object in the buckets and receiving multichannel feedback. The therapists can achieve several therapeutic goals and control children activities through a visual interface via tablet.

The Buckets

The buckets are smart containers designed to recognize objects placed inside them. These containers are repro-

ducible by anyone in a DIY fashion[8], yet robust and with an appealing design. The main structure is built using plywood, easily cut and milled using hand-tools or CNC cutter. It measures 30x30x40cm, sized for children (R2). It does not include the lid, so the bucket can hide nothing (R2), yet the electronics is covered by a wooden base (R6). On the frontal side, there is a sliding door to let the users on a wheelchair use the bucket from a table without bending (R4). We 3D-printed "L" brackets to join the side panels: they serve as a support for the LED strips on the vertical edges of the buckets. We used thin PVC sheets to build the semi-transparent curved edges (R6), covering the LED strips, smoothing the sharpness of LED light (R1)(Figure 4). At the base of the bucket, there is the main circuitry (Figure 2): the load cells weight sensor(resolution $\pm$1g), taken from common kitchen scale, the Wemos D1 Mini, providing the WiFi connectivity to interface with Magika, and the Li-Po battery, in order to avoid cable during the play (R6, R8). The back panel has a little lid containing a cable to recharge the battery (R8)(Figure 3). The weight sensor is covered by a soft material to protect it from impacts and to avoid damage to objects.

To detect the placed object, we considered three different alternatives: RFID, image recognition and weight matching. We opted for the latter because it is the cheapest solution to recognize multiple objects at the same time, keeping the bucket structure simple and allowing the simplest personalization of the experience.

About the latter point, since objects do not need any physical alteration such as in Ekin *et al.*'s work[4], you are free to use objects used in real life such as fruits, clothes, etc. as well as custom designed objects (R4). In the latter case, you can use digital model and 3D printing or more traditional approaches such as play dough, transforming the preparation of the main game in another purposeful activity.

The main constrain of this choice is that two items may weight very similarly, inducing an ambiguity error. In order to overcome this problem, the configuration interface allows to register different set of objects, to have distinct weights each set. The interface notifies if two objects are too similar (after some trials, we set the threshold 3g). Considering this limitation, you can easily create a set composed about 15 objects without too much troubles.

The Control panel
The Smart Bucket's control panel is a web application designed to run on a tablet, to give to the therapists full control over the activities. It's main features are:

1. Select a specific activity among the available one (more details in the next section) and configure it (e.g. change difficulty, select number of players, ...) (R7) (Figure 5).
2. Register a new physical object and put it in a specific set. This is possible thanks to "Memorize mode", in which a bucket acts like a connected scale (R4) (Figure 6).
3. Control the activity in real time, to help the children in case of misunderstanding (R4) (Figure 7).
4. Visualize their progress and performance (time to complete an activity, number of errors, ...) (R5).

Since it runs in Magika multisensory environment, the graphic style is shared with Magika's control panel.

Activities

We had designed a number of potential activities based on the current curricula of the therapeutic center. We developed them with different difficulty levels and parameters

Figure 8: A scene of recycling activity: the child is playing with Smart Buckets, while Emi (the guiding character of the world of Magika) is telling instructions to clean her world.

Figure 9: A scene of recycling activity: Emi (the guiding character of the world of Magika) is giving positive feedback of children actions.

(e.g themes, time constraints,..) to allow a better customization. All the activities are designed to be integrated in the multi-sensory system and to give children the opportunity to experience tangible, visual and auditory interaction. Here a list of the designed activities:

Recycling activity: each bucket becomes a bin dedicated to a specific type of rubbish paper, plastic and organic, identified by symbols and name displayed through floor projection. We have build a story involving one of the character of Magika World [6]. Her planet is dirty and the child must help to recycle objects to make the planet clean again. (Figure 8)(Figure 9)

The activity of routines: each routine is composed by a certain number of steps (therapist can change the difficulty level based on each child). An object or multiple objects are associated at each step and one step refers to one single bucket. The therapist chooses the routine and the steps based on the child. The wall animation asks to the child to complete the routine and follow each step. The child has to think to each step and put the associated object(s) inside the right bucket.

Repeat the sequence: each bucket turns on in a colored sequence. The child has to remember the sequence of color and put the objects accordingly to their color and order.

Find the intruder: a character shows to the children a set of objects through the front projection. The children have to understand which one is the intruder, find it in the room and put it in a lighted bucket.

The treasure hunt: children have to solve riddles and explore the space to find the treasure. For group play, the therapist can add movement constraints, e.g. the number of steps that each child can take each turn.

Conclusion and future work

The flexibility of our multi-sensory environment Magika allowed us to easily integrate a new tangible interface accordingly to the needs of children and therapists. This addition increases the versatility of our system, enabling it for different purposes, enhancing the tangibility for a more comprehensive sensory experience. We also had developed the first activity, *recycling activity*, in order to perform the first exploratory study with children to check if they are engaged in the mid-term period. In parallel, we plan to make a preliminary user test to validate the usability of the control panel with therapists. Once the system has passed this first step, we are going to evaluate "Smart Buckets" on the long term from both children and therapists perspectives. The study will lasts 6 months, involving at least 10 therapists and 24 children, to observe performance and engagement about the former and the adoptability and sustainability about the latter. Given the interest of the therapists, we plan to include the product in the therapeutic center curricula. To create the baseline, we will split the group in two, one maintaining the traditional activities and the second one working with the Smart Buckets. This will favorite long term, rigorous and ethically approved experimentation aiming to assess the long-term effects of Smart Buckets with respect to the traditional activities.

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