Magic Orchestra

Advanced User Interfaces

Prof. Franca Garzotto

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Design and Technology

Elena Buttolo, Mathyas Giudici, Davide Salaorni

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Abstract

In literature there is plenty of examples concerning memory-based activities pointed towards people with Neuro-Developmental Disorders (NDD) to perform brain-training tasks. At the same time, since the '70s and the creation of *Snoezelen*, the employment of interactive technology and software-based approaches in this field have become more and more recurrent, due to the proven benefits brought by these methodologies.
Our work aims to blend one more time these two concepts, technology and neuro-psychological literature, bringing two well-known tests (*Corsi's Test* and *Digit Span Test*), which no one before now has conceived in a software version, inside a smart space, where there are different kinds of interaction and stimulus and the experience is very engaging. Furthermore, following psychologists' suggestions, we have implemented also another task, that, with the previous two, forms *MagicOrchestra*, a smart space software that offers brain-training activities for people affected by NDD and a useful tool for therapists, with lots of configurable options and customizable features.
With our work, we hope to help a lot of people involved in this field, not only patients, but also therapists and researchers, since *MagicOrchestra* can be used also for testing, and we wish that this project will be carried on, so that our efforts can reach more people as possible.

The Team

Surname: Buttolo
Name: Elena
e-mail: elena.buttolo@mail.polimi.it
Phone number: +39 347 576 0184

Surname: Giudici
Name: Mathyas
e-mail: mathyas.giudici@mail.polimi.it
Phone number: +39 340 286 8540

Surname: Salaorni
Name: Davide
e-mail: davide.salaorni@mail.polimi.it
Phone number: +39 340 364 5668

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Chapter 1

Introduction

MagicOrchestra is a software designed for smart spaces and multi-sensory environments which is made up of three games: *InstruMaps*, *Quanti Numeri* and *Sinfonia di Luci*.
The tool affects the branch of brain-training related to memory; indeed, each game addresses a different part of memory and requires to perform different actions inside the smart space, interacting with different objects and moving around the room.

MagicOrchestra takes the name from the theme around which it is built: an orchestra composed of magic instruments that the user has to manage, just like a real maestro. In each game, the user has to perform a specific task which is related to the above-mentioned theme.

- *InstruMaps*: this game is a visual memory train activity because it asks the user to remember the positions of instruments on the stage and to relocate them in their correct place after they go crazy.
- *Quanti Numeri* (*Lot of numbers* in English): this game involves the short term memory and it is based on the *Digit Span Test*, in which the patient has to memorize a sequence of numbers and to repeat them in direct or reverse order. In the context of the orchestra, each number is associated with a certain amount of instruments, a variation which is inspired by the *Mind Palace Technique*.
- *Sinfonia di Luci* (*Symphony of Lights* in English): this game recalls the *Corsi's Test*, which is very grounded in literature. It focuses on the visual-spatial memory and asks the user to solve the task, so that its completion allows to compose the melody and perform the concert.

Figure 1.1: **MagicOrchestra logo**

MagicOrchestra has been thought to be played as a single game with a story mode (guided-tour pattern) or as three split games (index pattern), which are still related to the theme of an orchestra.

Moreover, we have inserted an important feature that allows playing the three games *without* a context, so with a very aseptic design, that could be interesting for research on advantages or disadvantages of contextualization of brain-training activities.

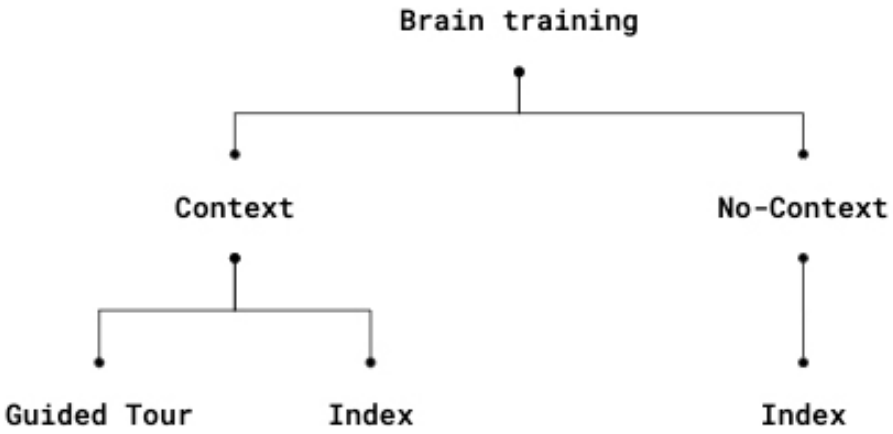

Figure 1.2: **MagicOrchestra schema**

1.1 Acronyms

NDD: NeuroDevelopmental Disorders

RFID: Radio-frequency identification

SEN: Special Education Needs

STM: Short Term Memory

UX: User eXperience

WM: Working Memory

Chapter 2

Target Groups and User Needs

2.1 Main Target Groups

Before pointing out goals, target groups and requirements of our project is useful to consider which stakeholders are involved:

- People with and without NDD [*Primary Users*];
- Caregivers (therapists or teachers) [*Secondary Users*];
- Family of people with NDD which participate to the activities;
- i3Lab people;
- Researchers and specialists.

2.2 Context and Needs

The **context** of our project is a multi-sensory interactive smart physical indoor space in schools and therapeutic centres.[1]

The **needs** are:

N1 Need for improvement of short-term memory and working memory;

N2 Need for improvement of the ability to complete tasks autonomously;

N3 Need for different stimuli and different activities to get out of repetitive and isolating attitudes;

N4 Need for comfortable and funny spaces in which do activities, reducing the stress and frustration sometimes found in difficult daily activities;

N5 Need for activities that can be considered interesting and engaging also by users not affected by NDD;

N6 Need for other forms of submission of exercises to people with NDD, different from paper-based ones;

N7 Need for activities in which patients feel comfortable during their training session;

N8 Need for support in therapist research by simplification of collection of data;

2.3 Goals

G1 Create multi-sensory and game-style activities for supporting specific brain training tasks in NDD treatment; [N1,N3,N5,N6]

G2 Create predictable, controllable and safe activities to have fun and chances to play, explore and be creative; [N2,N3,N4,N7]

G3 Support the customization of the activities by therapists and teachers; [N6,N7]

G4 Create brain training activities that can enrich the analysis and work of researchers, providing different scenarios and situations for new cases of study, keeping in mind the past literature related to this field; [N3,N6,N8]

2.4 Constraints

C1 Inability to have all the literature about brain training exercises specifications, because of the price and the fact that they are reserved only to few universities or research centres;

C2 Limited precision of the technology used to detect the user's gestures and movements;

C3 Game content must be scalable in order to fit different sizes of smart rooms;

C4 Each training task should take approximately at most 10 minutes to complete.

2.5 Requirements

R1 Adopt a design-for-all approach, taking into account all possible types of NDD disorders, diseases and different ages; [G1,G2]

R2 The users must feel comfortable, engaged and motivated within the smart space; [G1,G2]

R3 The multimedia graphics must be relevant to the stimuli already used in the scientific literature; [G4]

R4 It is important to insert the user in a context that motivates and reminds what he/she is doing. It is also important to make the user the protagonist of the activity to store more information; [G2]

R5 The application should give clear and positive feedbacks when users complete tasks successfully as an accumulation of stars or tangible rewards; [G2]

R6 In case of failure, it doesn't give a score but gives the user more information or help to do better; [G2]

R7 The methods of interaction should be the human body gesture recognition, human body tracking, the use of smart materials and smart objects; [G1]

R8 The device used by the therapists or teachers is a smart device from which is possible to choose activities, customize them and check the solutions; [G3, G4]

R9 Therapists or teachers must be able to visualize the progress of users; [G3,G4]

R10 The difficulty of the activity played must be scalable and decidable by the therapists and teachers first; [G2,G3]

R11 Minimize the user's memory load. The interactions with the application must be focused on one task at a time (not too much complex activities or too many stimuli); [G2]

R12 The interactions as gestures and movements must be suited for each of the tasks and customizable by the therapist depending on whether the user knows how to read or is deaf or maybe has some particular impediment; [G3]

R13 All the senses (apart from taste) must be used, not just the visual part. The task presented in multiple modalities may help boost the recall of that information; [G1]

R14 The activity should be played without the direct support of the therapist (that he/she is always present during activities), so the interface has to be intuitive; [G2]

R15 The activities must be re-playable; [G3]

Chapter 3

State of the Art

Neuro-Developmental Disorders (NDD) are a group of disorders which affect the development of the nervous system, leading to abnormal brain function which may affect emotion, learning ability, self-control, and memory [2].
The effects of Neuro-Developmental Disorders tend to last for a person's entire lifetime, creating impediments in basic life skills. Moreover, NDD is chronic and patient's improvements are generally very small and slow.

In the last years, technology had a great impact on people's lives and also in therapeutic contexts is becoming more and more important.
Starting point could be identified from the multisensory Snoezelen room [3] and MEDIATE [4]. They provide a sensory environment for people with learning disabilities; in fact, they are rooms equipped with visual, olfactory, auditory, tactile and proprioceptive stimuli, and their purpose is to relax the person, reduce anxiety and stimulate their senses; more recently has been found memory improvement and balancing skills in people with moderate learning disabilities [5].

Figure 3.1: **Snoezelen experience**

An interesting study evaluates the impact of a computerized visuospatial memory training intervention on the memory and behavioural skills of children with Down syndrome pointing out that visuospatial Working Memory (WM) training can be delivered in a school setting and that it leads to sustained improvements in non-trained tasks assessing visuospatial Short Term Memory (STM). The computerized method of training used shows great potential and paved the way of evaluations of memory training [6].

In literature is also present that motion-based activities in a classroom setting to facilitate social interactions among students with autism have a positive impact on students' engagement, social behaviour and motor skills.
Moreover, in the study *Designing motion-based activities to engage students with autism classroom settings* of 2015, are highlighted the benefits of interactive technologies for children with autism, that move beyond didactic instruction to create more naturalistic social contexts, within which peer interactions may take place, and bootstrap interactions between children with autism and peers in a group setting [7].

Smart space is defined as a special room equipped with projectors, cameras, smart objects, led carpets and other technological items, in which children can play and socialize in a controlled environment. These space offer an immersive and multi-sensory experience, that with playful activities stimulate the development of important concepts, like cause-effect understanding and motor skills [8].
Magika combines and extends the features of existing multisensory digital systems [as seen before Snoezelen and MEDIATE] in a unique way, proposing a pervasive inter-connected space where all children are involved in new forms of full-body, tangible, playful, multisensory, learning experiences [1].
Is also relevant how in magic rooms, according to caregivers' subjective judgment, the learning effects observed in the study were achieved much faster compared to traditional interventions in the classroom. Cognitive, verbal and emotional area have had the strongest improvements [9].

Figure 3.2: **Magika experience**

Chapter 4

Solution - UX Design

4.1 General approach

At the beginning of our work, we have thought to exploit the magic room as much as possible, but, at the same time, to not be too repetitive with the choice of **interaction paradigms**.
So, we can say that *MagicOrchestra* has a full-body interaction paradigm that is split in the different activities in the following way:

- *InstruMaps*: upper-body interaction, with drag and drop gestures for Microsoft Kinect 2;
- *Quanti Numeri*: interaction with RFID reader through smart objects (enumerated cards);
- *Sinfonia di Luci*: walk-around interaction and movement around the magic room.

Moreover, we have also decided to aim for an engaging theme, that was able to enrich the experience and be suitable also for children, without being too predictable. For this reason, we have chosen a musical setting in which the user can be personally involved and a sequence of games that can create a climax, that can be concretely feel only in the storytelling mode (guided-tour pattern).

Indeed, the story presented in this mode starts with a problem inside the theater: the previous maestro has run off the day of the great concert because the magic instruments have gone crazy. Thus, the user is demanded to substitute him and tidy up the mess caused by the orchestra.
The reorganization is conducted in the first two games, in which the user is

asked to locate the instruments in the correct place on the stage and to count them, preparing the disposition the exhibition. Then, in the last game, he has to perform the concert, which will certainly be a success.

From the moment that having only the story mode could be limited, we have implemented a solution which allows to play the three games in standalone mode, both with the context of *MagicOrchestra* and without it, that is with aseptic shapes, lacking of curtains, stage and instruments.

4.2 Interactions and Interfaces

MagicOrchestra, to work properly, needs three displays, two for frontal and zenithal projections and the third for the therapist's interface, which it has been thought to be a remote tablet.
This latter is fundamental for the game execution because with it the therapist can select games, modes and settings. The following mock-ups represent the tablet's display with the choice of context-mode and games interface [Figure 4.1] and with the parameters setting of *Sinfonia di Luci* [Figure 4.2].

Figure 4.1: Tablet interface for game selection

Figure 4.2: Parameters to set before third game *Sinfonia di Luci*

InstruMaps is the first game in story-mode order: the instruments have gone crazy and the owner's theater Piero, a nice old man, asks the user to help him to remember their positions on the stage and to reorder them.
At the start of the game, the user is asked to watch at the final disposition of the stage and to memorize the place of each instrument. Here, the therapist can edit the difficulty (number of instruments to memorize) from 2 to 12 and the time that the patient has to commit to memory the disposition [Figure 4.3].
Then, the instruments are moved outside the stage and the user, thanks to drag and drop Kinect gesture, has to relocate them in the correct position [Figure 4.4].
At the end, a melody is played to celebrate the completion of the task.

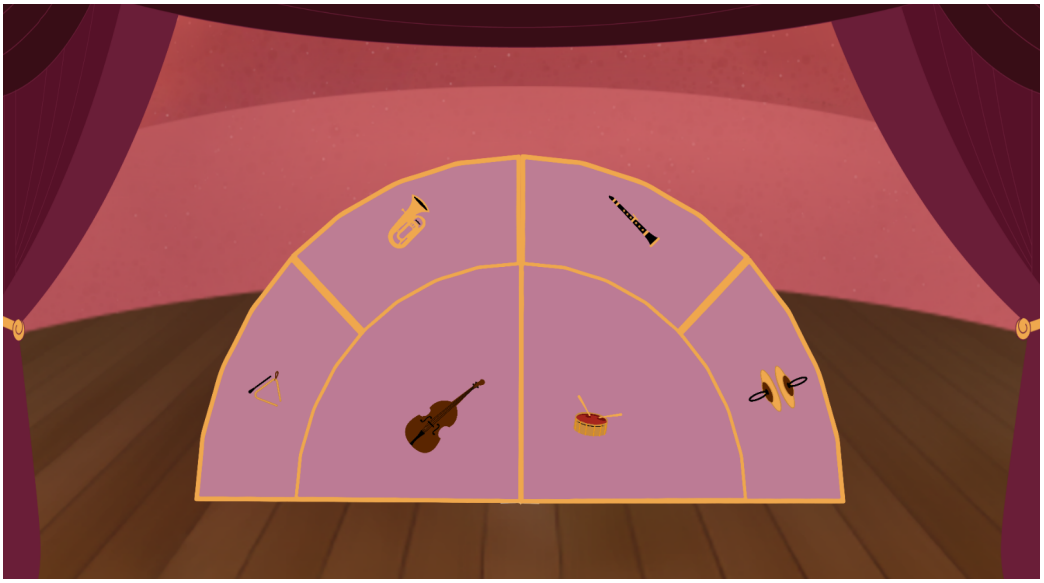

Figure 4.3: Disposition of instruments in first game *InstruMaps*

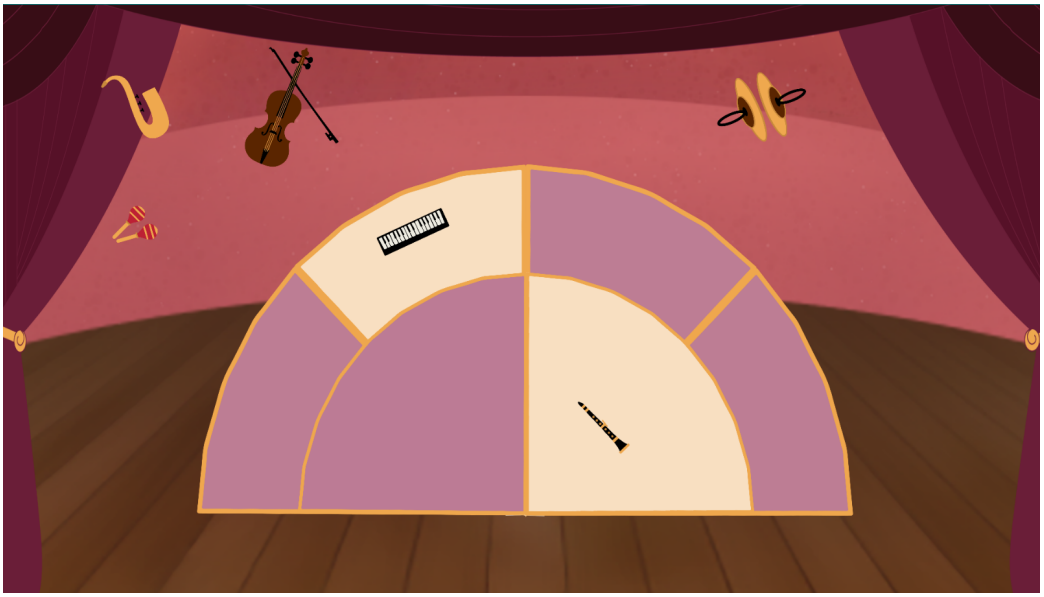

Figure 4.4: Completing the first game *InstruMaps*

In the no-context mode, the functioning of the game is the same, but the interface looks more aseptic and the instruments are substituted by generic symbols [Figure 4.5].

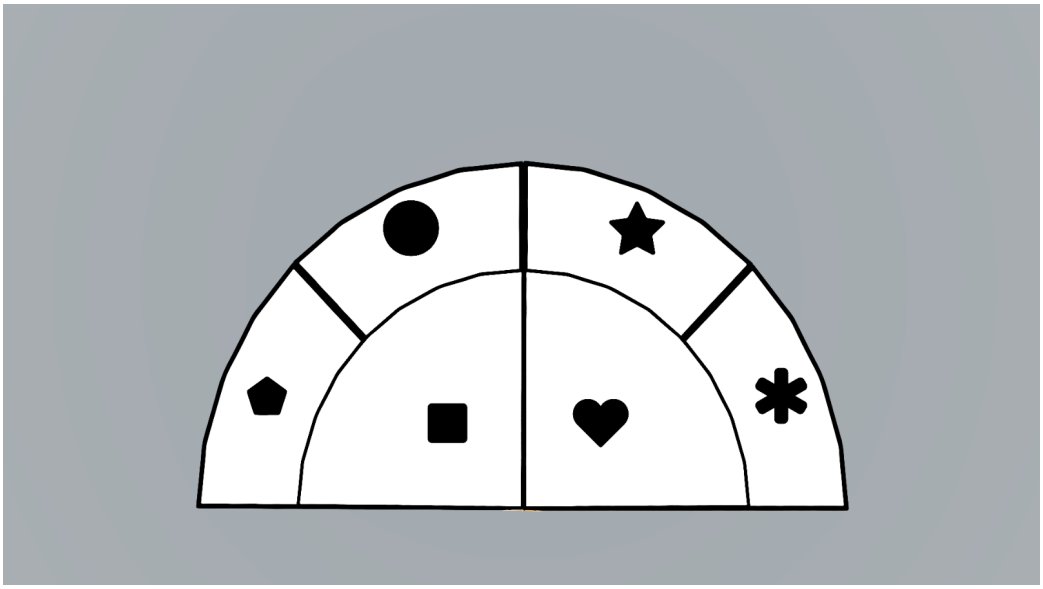

Figure 4.5: Disposition of instruments in first game *InstruMaps* in no-context mode

Quanti Numeri is the second game in story-mode order: the instruments, that have been put in order, need to be count, because they like to stay in groups and it's necessary to have a correct amount of them in each group. This is the excuse to perform the *Digit Span Test*, which can be done in direct and reverse order, with an instrument associated to each number of the sequence and with different sequences, choosing a difficulty in the range from 2 to 9 numbers per sequence [Figure 4.6].
After the sequence has been displayed, the user has to repeat it in the correct order using RFID reader and some cards which have been configured to correspond to a precise integer number [Figure 4.7].
At the end, is still played a melody to celebrate the completion of the task.

Figure 4.6: Sequence of number in the second game *Quanti Numeri*

Figure 4.7: RFID reader in *Quanti Numeri*

In the no-context mode, the functioning of the game is the same, with the lacking of the association between number and figures. Moreover, everything is more aseptic and decontextualized [Figure 4.8].

Figure 4.8: Sequence of number in the second game *Quanti Numeri* in no-context mode

Sinfonia di Luci is the last game of the story-mode and the one in which the user/maestro has to perform inside the theater. It is based on the *Corsi's Test* and each cube of the sequence it's like a piece of the melody that has to be played. So, completing the task makes the melody take form and at the end it is reproduced by the orchestra.
As in *Corsi's Test*, the patient has to watch the sequence of lit cubes [Figure 4.9] and reproduce it on the zenithal projection, by walking around in the room and selecting the correct cubes with a cursor [Figure 4.10]. Still, the therapist has a lot of parameters to set, as we can see in [Figure 4.2]: the showing time of the sequence, the colors of the cubes, the recognizing time of the Kinect and the difficulty of the game, that is the length of the sequence. At the end the melody is played and eventually the user receives a loud applause from the audience and the compliments from the theater owner.

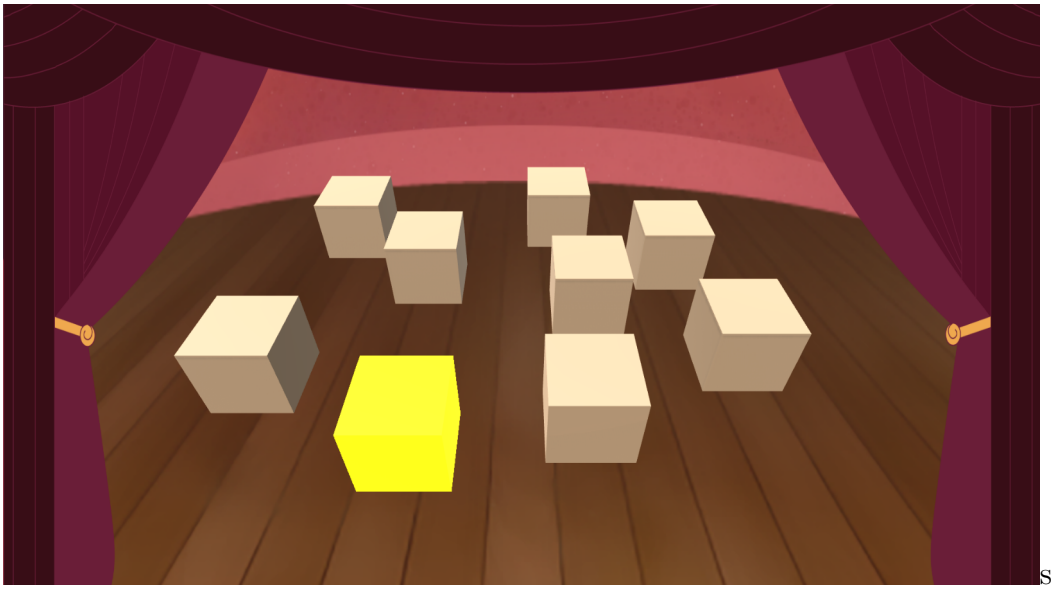

Figure 4.9: Sequence shown in third game *Sinfonia di Luci*

Figure 4.10: Playing to third game *Sinfonia di Luci*

In the no-context mode, the functioning of the game is the same [Figure 4.11].

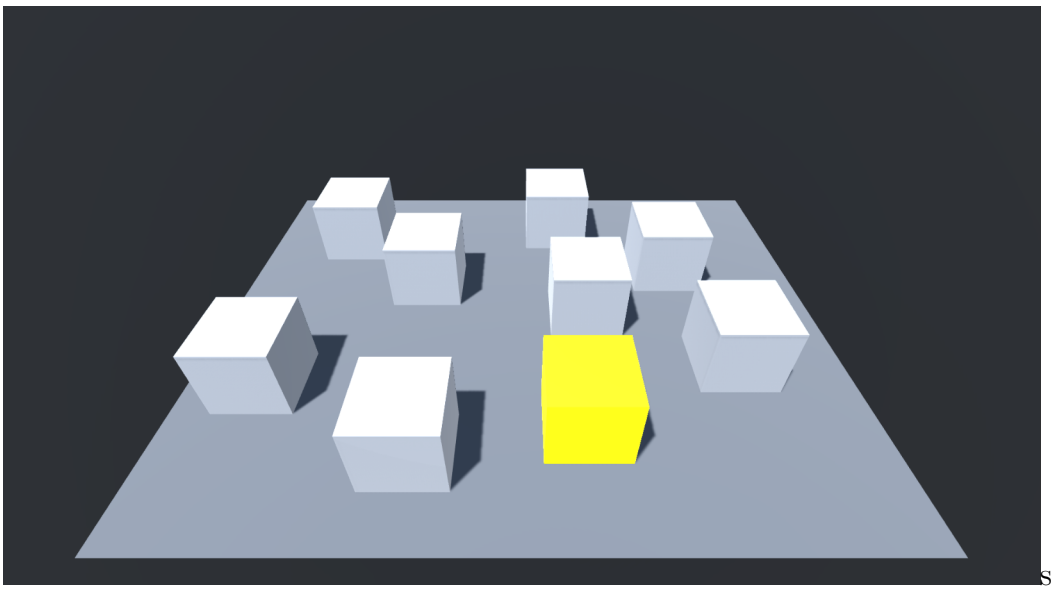

Figure 4.11: Sequence shown in third game *Sinfonia di Luci* in no-context mode

In each game we have implemented some usability feedback, like positive and negative responses, through smart lights. Moreover, to enrich the experience we have added also auditive feedback, that can be turned off in the tablet settings, because they could cause lack of attention in the patients.

4.3 Scenarios

After a brief presentation of *MagicOrchestra*'s interfaces done in previous section, now we will discuss all the scenarios and games more in details.
From now on all games will be described with the guided mode and all points that have [*] disappear if the activities are played in no-context mode.

1. The caregiver and the user enter the magic room;
2. The caregiver, through his/her smart device, opens *MagicOrchestra*;
3. First of all, the caregiver has to choose between context-mode or no-context-mode;
   (a) If the choice is context-mode the caregiver has also to decide if he/she wants to play the full guided-tour or only a selected activity;
      i. If the choice is guided mode there will be cut-scenes and the three games will be reproduced in predefined order.
      ii. If the therapist selects only one game there will not be cut-scenes, but the game will have context elements.
   (b) If the choice is no-context-mode the activity will be presented without any background and context, as we can see in literature.

4.3.1 InstruMaps

1. The caregiver has to set:
   (a) How much time the image must be shown;
   (b) How much pieces must be put in the arena (from 2 to 12);
   (c) Add or not a confirmation feedback (sounds).
2. The user sees the intro where the owner of the theatre explains to him/her that he needs some help to prepare the concert and to locate the orchestra member in the right position; [*]
3. The user sees for a given amount of time the image of the disposition of the arena;
4. When the image disappears the user sees an empty image of the stage and around it the related parts (context: instruments, no-context: symbols);

5. The user has to make a gesture to catch the instrument of the stage and drop it in the correct position; (if sounds are enabled, when the user select a given instrument and drop it, in the arena, a feedback is produced);

6. When the activity is completed the success will be celebrated with sounds and lights.

4.3.2 Quanti Numeri

1. The cards (for the RFID reader) representing the numbers are given to the user;

2. The caregiver has to set:

   - How much numbers the user has to remember (from 2 to 9);
   - If the goal is to repeat the sequence in the reverse order;
   - The duration of the presentation of a number (from 1 sec to 5 sec);
   - If some figures (representing instruments) are shown near the numbers to help the user in the exercise. In this case the caregiver could also decide if keep the default mapping number-instrument or randomize the associations; [*]
   - Add or not a confirmation feedback (sound).

3. Theatre's owner needs help remembering the number of instruments on the stage; [*]

4. According to the choice of the caregiver, the numbers are shown to the user that, at the end of the sequence, has to pass over the RFID reader (*Passaporta*) the cards corresponding to the numbers in the correct sequence order;

5. When the user completes a sequence:

   (a) If the sequence is correct the success will be celebrated with sounds and lights;

   (b) If the sequence is not correct the game invites the user to retry.

4.3.3 Sinfonia di Luci

1. The user has to wait at the starting point
2. The caregiver has to set:
    - How much numbers the user has to remember (from 2 to 9);
    - The duration of the light of the cube corresponding to a specific number (from 1 sec to 5 sec);
    - The color of the light of the cube;
    - The duration of the user over a box to select the cube (from 2 sec to 10 sec);
    - Zenith camera projection ortonormal or prospective;
    - Add or not a confirmation feedback (sound).
3. The owner says that everything is ready for the concert and recommend to the user to keep attention to the block to play an amazing melody; [*]
4. After that the user has seen on the frontal projector the sequence of lit boxes, walking over the boxes projections on the floor has to replicate the sequence and return to the starting point.
5. When the user completes a sequence:
    (a) If the sequence is correct the success will be celebrated with sounds and lights and a final cut-scene is displayed; [*]
    (b) If the sequence is not correct the game invites the user to retry.

Chapter 5

Solution - Implementation

5.1 Hardware

Magika combines and extends the features of existing multisensory digital systems in a unique way, proposing a pervasive inter-connected space where all children are involved in new forms of full-body, tangible, playful, multisensory, learning experiences [1].

Physical hardware and interfaces created for the smart space *Magika* is used also for *MagicOrchestra*. More relevant hardware elements of the magic room are:

Projectors In the magic room are available two projectors: one for the frontal wall and one for the floor (zenith projector).

Microsoft Kinect 2 Kinect is a line of motion sensing input devices produced by Microsoft and first released in 2010. The Kinect is used to exploit body skeletal detection up to six people and gesture recognition (hands open or closed). With its feature Kinect enables the user to perform a hands-free interaction with the system.

Passaporta Passaporta is a Smart Object custom created for *Magika*. It is an opaque white ball that contains a led light totem and, on the top, a RFID reader.

Smart Lights They are commercial smart led lights connected with the system; light colour and intensity could be controlled.

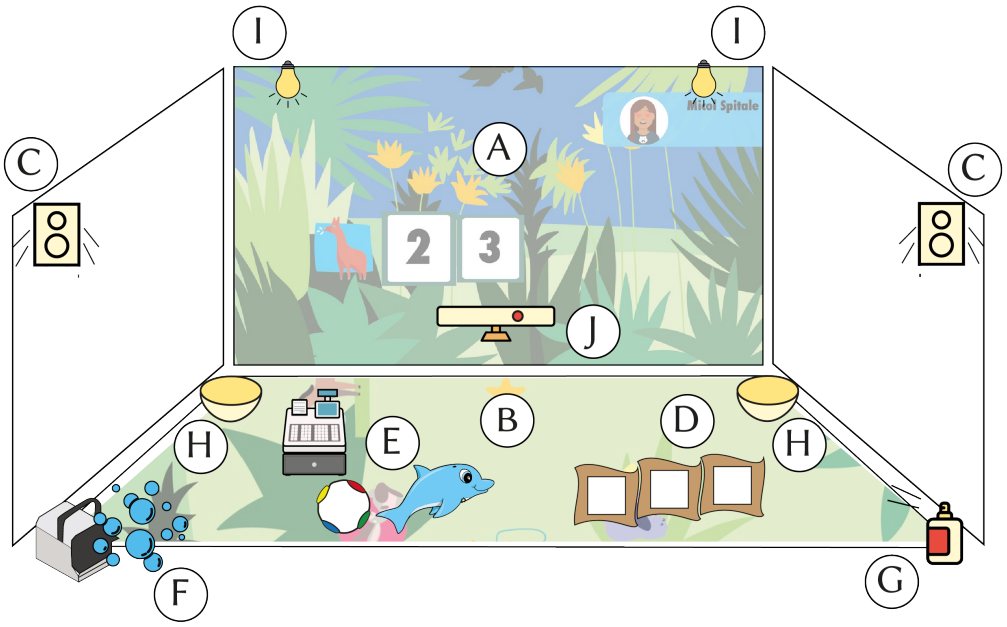

Figure 5.1: **Magika Technology** - A. Frontal projector, B. Zenith projector, C. Audio System, D. Pictures and materials, E. Smart objects, F. Bubbles machine, G. Fragrances machine, H. Portable lights, I. Fixed lights, J. Microsoft Kinect 2

5.2 Software

Unity Unity is a cross-platform game engine developed by Unity Technologies. It is used to create three-dimensional, two-dimensional, virtual reality, and augmented reality games. Moreover, Unity is leader in the augmented reality and virtual reality content creation.

C# and Visual Studio GameObjects in Unity could be controlled via script written in C#. To develop scripts one of the Unity module included in the suite is the IDE Visual Studio.

MagicRoom Adapter MagicRoom Adapter is a Unity GameObject that contains all the script to interface a general game with the hardware of the smart space *Magika*.

Blender Blender is a computer graphic tool to create 3D models, visual effects and animated films.

Adobe Suite Adobe Suite is a software suite of graphic design and video editing. All the graphics and cut-scenes of *MagicOrchestra* are made with program of this suite. In the project, Main used programs are Photoshop, After Effects, Illustrator and Premiere.

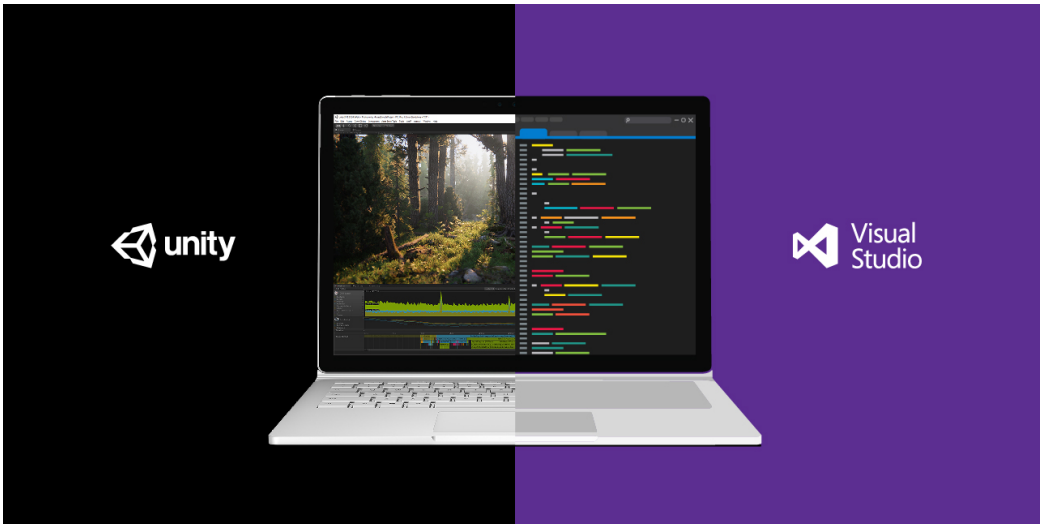

Figure 5.2: **Unity** and **Visual Studio**

Chapter 6

Empirical Evaluation

Empirical study was not performed, so evaluation could not be computed. However, is relevant putting here the Empirical Study designed (Homework of Passion in Action Program@Polimi course of *INTERACTIVE TECHNOLOGIES IN A USER CENTERED PERSPECTIVE: Participatory Design and Empirical Studies*).

6.1 Focus

What The Magic Room is a complex interactive intensive smart multisensory environment designed to improve the learning and social skills of NDD children in the school environment.

Who The target user is composed of children (both SEN and typical ones) and teachers of elementary schools and kindergartens.

6.2 Research Goal

Research Question Is the magic room a mean that improves memory and cognitive rehabilitation for children with NDD?

Researches Variables

- Game score;
- Game difficulty;
- Game played in context or no context

- Confirmation sound presents or not
- Well-being of the user
- Gender of the user
- Age of the user
- Diagnosis of the user

6.3 Participants

Profile People (age: 6-20 years) with NDD and children without NDD.

Number 30 participants

Recruitment Participants could be people with cognitive disabilities from specialized centre or children of the schools in which the Magic Room is installed (at least one of the classmates must have to have NDD).
Caregiver must be formed to use the Magic Room.

6.4 Procedure

Type of study We can perform two types of comparison:

- Comparison between two groups of people that use *MagicOrchestra* or not;
- We can also make comparison between two groups that play the activities with or without context elements.

Physical context and spatial setting The setting is the magic room (*Magika*) with loaded the *MagicOrchestra* game.

Number of Sessions 5 sessions

Duration of Sessions 30-40 minutes

Protocol The children are invited to enter the Magic Room and the teacher operate the system to execute a set of defined activities according to the cognitive level of the children. Two researchers are present to take note of the behaviour (one for typical and one for atypical children) shown by the children but are forbidden to intervene.

Data Analysis We interpolated the data obtained from the observation and the logs from the smart environment to obtain a sequence of behaviour related to the actions in the Magic Room. For each session and class we created three scatterplots, one for SEN children, one for typical ones and one aggregating the results

Data Gathering Data are collected through a dedicated web application, saving the macro-type of behaviour, the number of children to have shown the behaviour and the moment in time that sign has been detected. Additional interesting behaviour are collected (on teacher's behaviour and room faults) to improve our analysis.

Chapter 7

Value Proposition

MagicOrchestra's strengths are engagement, high customization, different embodied interactions and activities with grounded literature.

Engagement In *MagicOrchestra* the activities have in common the theme of an orchestra composed of magic instruments that the user has to manage, just like a maestro. For this reason, the experience is even more immersive, because the user becomes a key character of the story, that without him/her it couldn't see a happy ending. The story makes the user engaged in the smart room and encourages to do his/her best.
Instead, if the activities are proposed without the context it could appear less engaging. Moreover, we have also to consider that, if *MagicOrchestra* is played in a school, the children not involved in the first person in the game, without context, could lose interest in following the activity.

Customization Customization of the activities is a key requirement for caregivers. All the activities of *MagicOrchestra* have different parameters that could be set to make the user comfortable during the activity, but also to make the exercise challenging and useful.
Customization is also a key feature for research purposes and testing on brain-training.

Embodied interactions *MagicOrchestra* has a full-body interaction paradigm that is split into different activities. Respect to a computerized version of brain training exercise, the activities we propose penalize users with high motor difficulties or blindness; however, we rely upon body interactions to not make activities redundant and keep the user engaged.

Literature In literature, there is a lot of documentation of standardized brain training test. Some of the tests, like the *Corsi's Test* and *Digit Span Test*, are historical and very well known by the scientific community. A digitalization, via tablet interface, was done in the past for research and commercial purposes; in literature, for example, we can also find a re-elaboration of the *Corsi's Test* in a physical room [10]. However, is the first time that brain training exercises in *MagicOrchestra* are proposed in smart space, like *Magika*.

During the design and development process of *MagicOrchestra*, we had to manage a "trade-off" between creating a powerful experience (with different stimuli) and keeping the feedback overload as minimum as possible to not affect the scientific test.
For us has been difficult to give more priority to an aspect rather than the other, so we have choosen to exploit high customization that allows to decide which one of the two emphasize during the activities by the caregivers.

Chapter 8

Future Works

In this section, we discuss the main future works that the project needs.

- Moving the therapist's interface for the selection of the game, the parameters and the activity flow from *MagicOrchestra* itself to the tablet interface already present for *Magika*;
- A different game mode must be evaluated and could be implemented for *InstruMaps*. The player, after he/she has seen the arena, must fill the empty arena with all the objects. Only when there is no object outside the arena the correctness of the disposition will be checked;
- Add in the therapist's interface the possibility to control the flow of the activity more in deep (e.g. if the user has to remember a sequence of numbers, allows the therapist to skip a number because the user says it without an effective interaction with the magic room). Moreover, add the possibility (with a button in the therapist's interface) to give positive and negative feedback.

Chapter 9

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