Politecnico di Milano
Scuola di Ingegneria Industriale e dell'Informazione
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Ingegneria Informatica

GEA
AN EDUCATIONAL VIRTUAL REALITY GAME FOR PEOPLE WITH NEURODEVELOPMENTAL DISORDERS

Relatore: Prof.ssa Franca GARZOTTO
Correlatore: Dott.ssa Eleonora Aida BECCALUVA
Dott. Vito MATARAZZO
Dott. Nicoló MESSINA

Tesi di laurea di:
Federica BLANCO Matr. 875487
Giulia PENNATI Matr. 882962

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Sommario

In italiano, descrizione NDD, scopo tesi, descrizione tecnologia usata(in breve), nome sistema sviluppato e collaborazione. (circa 1 pagina)

Abstract

Traduzione del sommario.

Ringraziamenti

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Federica e Giulia

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Introduction

0.1 Food problems and their impact on childhood

One of the main problems of modern society is the one related to nutrition. Nutrition has changed a lot in history thanks to the industrial development that allowed the massive production of foods that in the past were produced only by hand (and with high costs) and thanks also to scientific progresses that allowed the discovery of food conservation and their elaboration to obtain new kinds of food that are more suitable to our need. Montignac [42] also identifies other causes that brings the concept of "nutrition" to assume the current meaning, for example the habits evolution and the female emancipation that has changed the ancient vision of women as "landladies" and that has promoted the progression of the "ready meals" industry and therefore of pre-cocked and packaged meals that today are consumed increasingly. However, the main phenomenon that has taken place in our era is the one related to the globalization and standardization of destabilized north american eating habits that has promoted the global growth of fast-food, indicated by WHO (World Health Organization) as a "pandemic" since 1997 given its extraordinary expansion that carried also a lot of other problems.
Childhood obesity is surely one of the clearest examples of these diet's changes of the new millennium. According to a seminar held by CB Ebbeling, DB Pawlak and DS Ludwig [15] childhood obesity is a phenomenon that has had a great increase in all the world in the last twenty years, as we can see from this diagram.

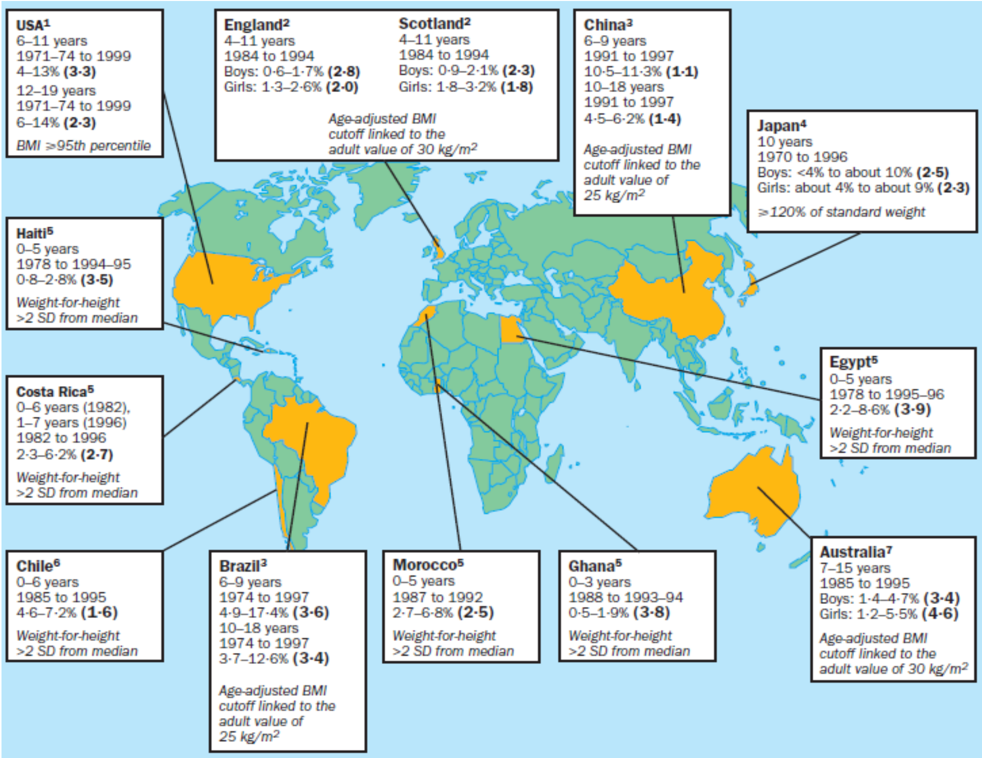

Figure 1: Childhood obesity diagram

Historically, a fat child was seen as healthy because he was likely to survive better to illnesses and infections; however, excessive fatness has become one of the most diffused health problem in children. The three experts have underlined how the problem is most common in developed and industrialized nations in which diet has changed radically favouring foods containing saturated and trans fat and with high glycaemic index, typical of fast-food in which also bigger portions are served. Moreover, these foods are also poor of fibre, micronutrients and antioxidants that the body needs for a correct functioning of metabolism. The excessive consuming of these foods brings the child to have health problems such as heart diseases, vascular disorders, hypertension, chronic infiammations and diabete of type 2, illness that in the past was not present in teenagers, but that now has had a rapid spread.

Another important problem that affects the food safety of children is represented by allergies. According to the data collected by AM Branum and SL Lukacs [6] it is possible to observe an increasing in cases of all kinds of food allergies including milk, eggs, peanuts, tree nuts, fish, shellfish, soy and wheat of around the 18 per cent on individuals under the age of 18 from the 1997 onwards in US (but we have reasons to believe that this can also be found in all the industrialized world). Reactions to these foods may vary from small diseases to anaphylactic shock that, in severe cases, could lead to death. The researches have also underlined how, in the same period analized previously, there was also an increasing of hospital discharges (clearly after an hospitalisation) due to allergic reactions as we can see from this barplot.

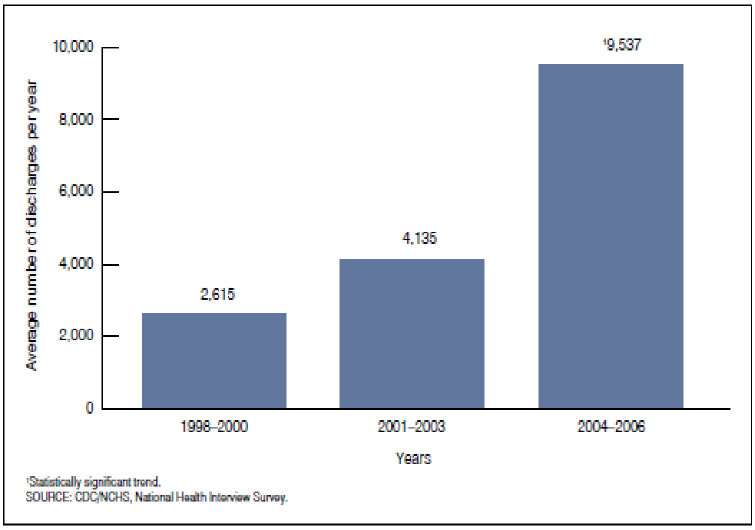

Figure 2: Allergy hospital discharges barplot

All these problems that have been reinforced in recent years, lead us to think that it is necessary to support nutrition education and to make it a fundamental thing during childhood and adolescence, in order to empower everyone to a correct care of their health.

0.2 Virtual Reality

"Virtual Reality is electronic simulations of environments experienced via head mounted eye goggles and wired clothing enabling the end user to interact in realistic three-dimensional situations." (Coates, 1992)
We can define it using two variables: vividness, richness of an environments representation, and interactivity, extend to which a user can modify form and content of a mediated environment. The vividness is composed by sensory breadth, which refers to the number of sensory dimensions simultaneously presented,and sensory depth, which refers to the resolution within each of these perceptual channels; the interactivity instead is formed by speed, which refers to the rate at which input can be assimilated into the mediated environment, range, which refers to the number of possibilities for action at any given time and mapping, which refers to the ability of a system to map its controls to changes in the mediated environment in a natural and predictable manner. [54] All of them, combined together, influence the telepresence that refers to a set of technologies which allow a user to feel as if he was present at a place different from his true location. So a "virtual reality" is defined as a real or simulated environment in which a perceiver experiences telepresence. [59]

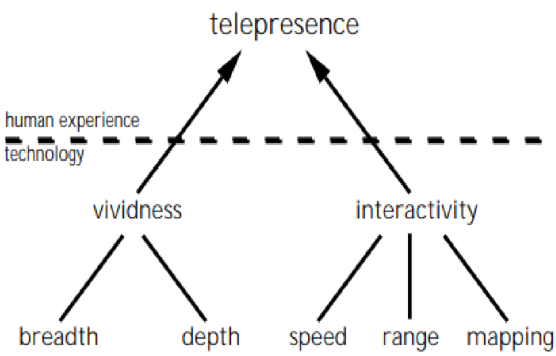

Figure 3: Telepresence infuencing variables

We focus our project on Wearable Immersive Virtual Reality (WIVR). Immersive is the term that refers to the degree to which a virtual environment submerges the perceptual system of the user in computer-generated stimuli. The more the system captivates the sense and blocks out stimuli from the physical world the more the system is considered immersive. [24] Wearable indicates that the virtual environment is displayed in specialized small screen: we use a binocular head mounted displays (HMD) which allows to reach a fully immersive experience as we can see from this taxonomy by Muhanna [8].

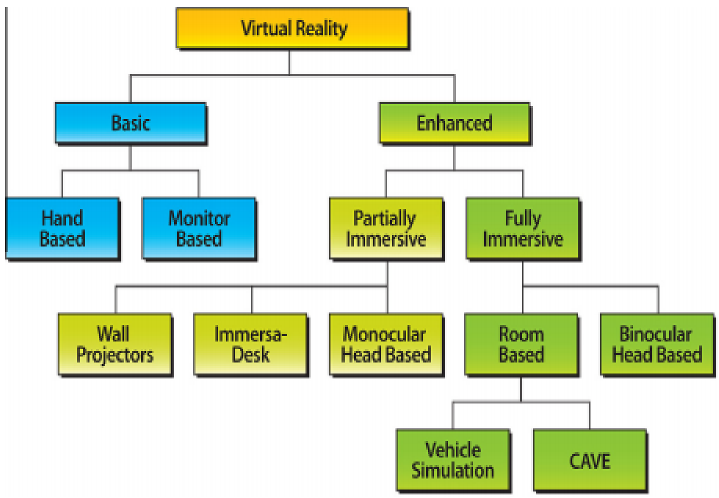

Figure 4: Virtual Reality taxonomy

The HMD "trick" our brain using the principle of stereoscopic vision to simulate the perception of depth and to create 3D images and spaces, the VR has to generate two different images one for each eyes. The lenses of the visor augments the eyes in such a way we can converge the two scenes to obtain only one but that seems to be in the 3 dimensions space. Finally it can track the head movement so when we move it the space updates.

Figure 5: Stereoscopic image and the correspondent 3D image

Nowadays HMD are very popular and the costs are in a very big range from a cheap one, like Google Cardboard [14], to a more expensive one, like Samsung Gear VR [62], so the VR is for everyone. The VR is also used in a lot of different sectors as we can see in the following graph representing the investments in the 2015 taken from Digi-Capital [18].

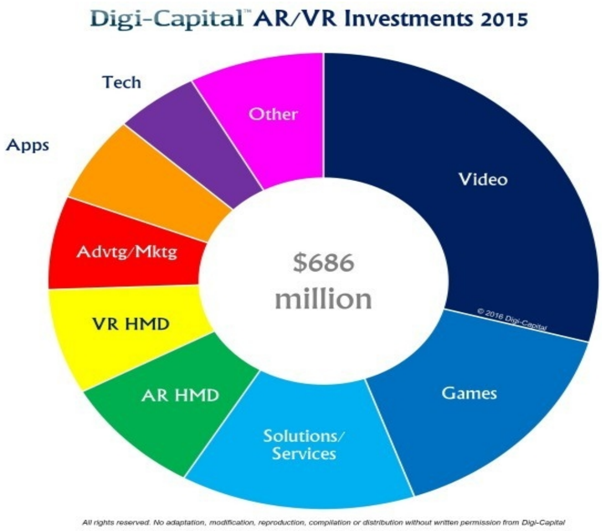

Figure 6: Virtual Reality investments sectors

0.3 Touchscreen

Touchscreen technology is something we have had for a longer time one can think. The first touchscreen device in fact was a radar built in capacitive way and dates back to around 1966. Its invention is due to E. A. Johnson and it works using a sheet of conductive, transparent material with a small current flowing on it. The central computer computes the current at each of the four corners, and when an objects touches the screen, a capacitor is formed between it and the platform and measuring

again, the current on the corners the computer is able to approximately compute the point in which there was the touch.
At first this technology was abandoned, then in the first 2000s it was used on BlackBerry devices, but the major explosion of touchscreen devices is in the 2007, when Apple releases the first iPhone. [29] From that point on, touchscreen devices become increasingly used (as we can see from the graph below related to phones) and have had an explosive growth due to their main characteristic: the human computer interaction.

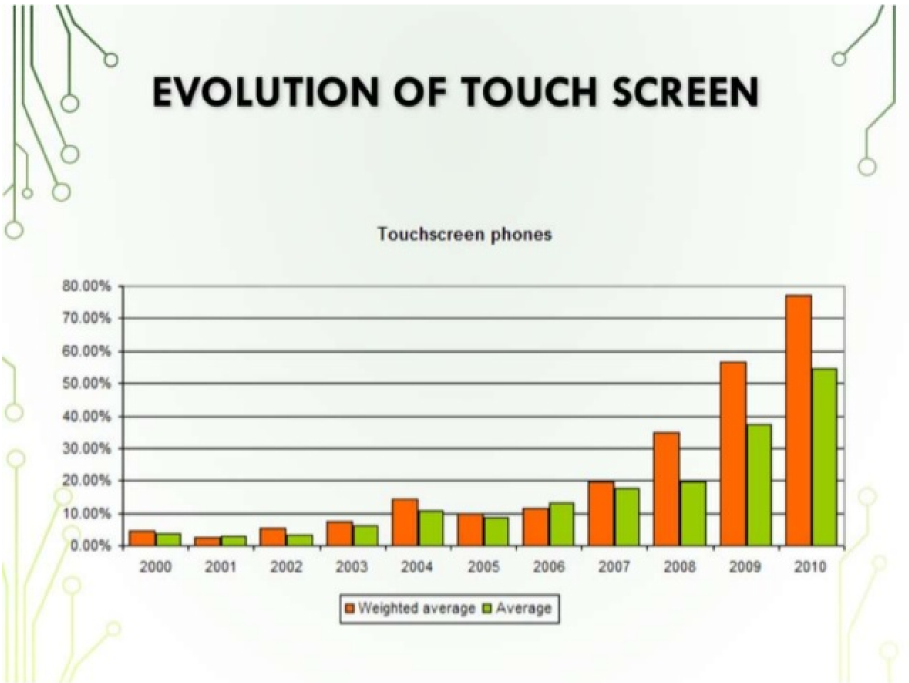

Figure 7: Evolution of touchscreen

This interaction could be exploited by the fact that the user could touch directly what he wants without recurring to a third element (like a mouse) and this is particularly appealing because it makes the interaction more intuitive and allows a better usability of the system that is one of the main reasons of the success of this kind of devices. Moreover this improved usability will result in a easier training of people that learns faster and better with reduced costs due to the fact that this technology has grown a lot in recent years and it is no longer excessively expensive and resource-hungry [17].

0.4 Neurodevelopmental Disorder

The term neurodevelopmental disorder, NDD, contains within it all the conditions that are caused by a dysfunction of a part of the brain or nervous system that show some symptoms in the physical and psychological development of the child [21].

Among the most common diseases we find Autism, ASD, attention deficit and hyperactivity, ADHD, and Down syndrome [10]. Children who suffer from these syndromes need help in developing cognitive abilities such as attention and language, social skills such as the ability to relate to others and personal and domestic autonomy skills. Dr. Dorothy Strickland, Department of Computer Science of North Carolina State University, in her treatise on the study of a VR application for autistic children [60], states that among the great benefits that can be found are: control on input stimuli, small changes to reach a generalization, safe learning situations, personalized treatment and learning with minimal human interference. In recent years there has been an increase in interest in the use of VR especially in the field of NDDs, [65] and [25], as, as stated in [36], both the strength and limitations of Virtual Reality seem to adapt good for the needs that the learning tools for this type of disability require.

As for the spread of these diseases take for example the autism on which there are no certain data, but there is agreement on the fact that the phenomenon is growing. According to the World Health Organization (WHO), ASD affects one child in 160 and recent estimates by the Cdc (Center for Disease Control) indicate that 3 million people are affected by this disorder in the US and about 60 million in world. According to estimates gathered by World Atlas, it would be Japan and Great Britain where autistic disorders occur more often.

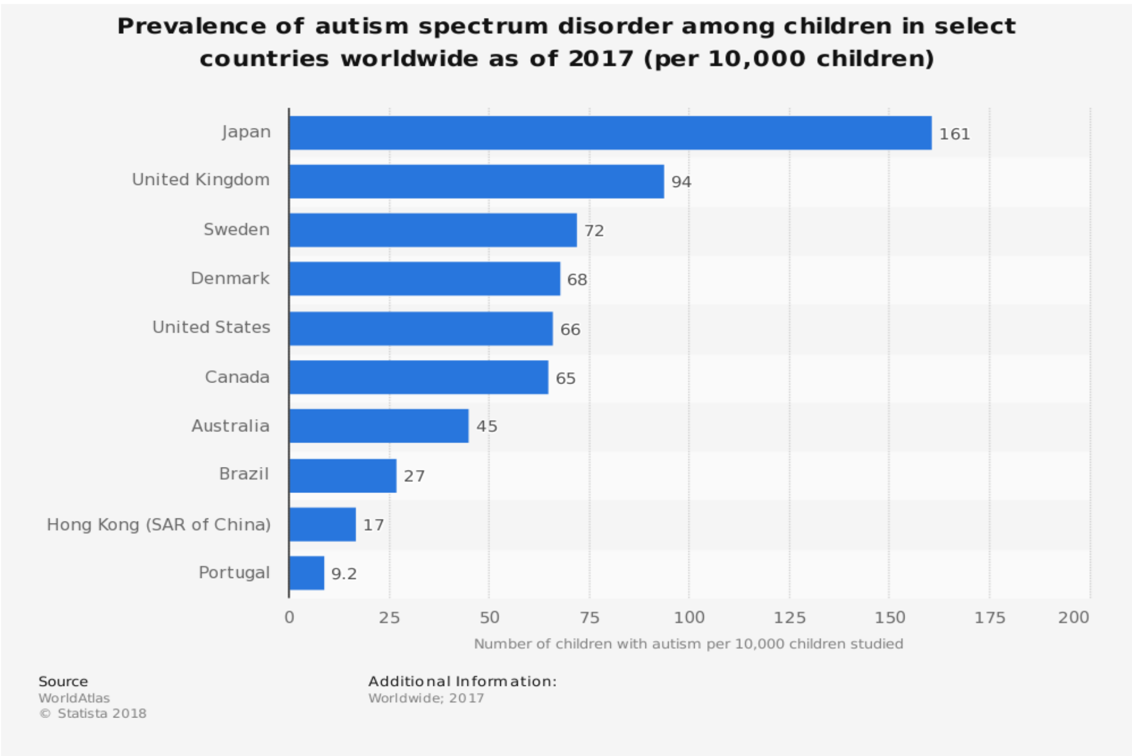

Figure 8: Autism diffusion by World Atlas

0.5 Participatory Design and Therapy

Over the past six decades, designer have been moving increasingly closer to the future users of what they design. In particular, design is becoming something that is more and more related to what the user needs, this imply the necessity of the collaboration between the experts in field (designers) and the final users (that are usually not experts) leading to what is now called co-design process.
The historic user-centred approach, in which designers thought as the user as final objective of their studies, but considered him as a passive entity, have been gradually substituted by the co-design process since the 1970s because people have been giving more importance to activities in which their opinion is required.

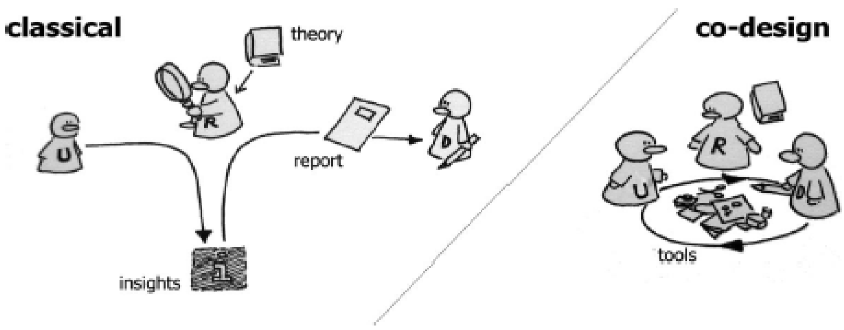

Figure 9: Classical approach vs codesign approach

In the classical approach in fact, as we can see in the image above, there were different entities that collaborates to the final design of the product, but the user was considered a passive object of study: researches brings knowledge from theory and developed some more through the observation and interviews. Designer then apply this knowledge to conceptualize the final product. In co-creation approach, on the other hand, the roles get mixed-up: the user is involved as "expert of his/her experience" and plays a large role in the knowledge development idea generation and concept development [20].
In the field of NDD, this could lead to multiple benefits: in particular, the target user perspective is taken into account since the early design phase and this allow to create something ad-hoc for this kind of people (for example the usage of simple words in explanations, the usage of certain kind of graphic stuffs and so on) and for the participants point of view, this could lead to a greater self-awareness and a more positive social behaviour.

0.6 GEA and its Codesign process

Considering the kind of target our application would have had and the importance of the subject we wanted to treat, we have decided to go through a co-design process which have involved both the final users and the therapists.
The starting point of our research were the kind of activities done in food education laboratory: in the first meeting we have observed how these activities are performed and then we have discussed with patients about these activities to hear their opinion and their engagement on them.
Then we have proposed our idea to create a virtual reality game based on the learning process provided by those activities that would have been used as a test to verify how much the patients have understood and assimilated the concepts.
These concepts have an important role in everyday life because they are related to self-awareness and autonomy in preparing and eating foods that some patients did not have initially and they have to improve their skills on them.
The patients have collaborated actively and with a lot of enthusiasm so we have decided to create a first abstract prototype of the application (with mockups and conceptual functioning).
In the second meeting we have first exposed our ideas about the three initial mini-games GEA was composed of to the therapist that evaluated their coherence with the food laboratory and their adequacy to the target end user it was thought for.
We understood the kind of difficulty required for the game also regarding the kind of interaction the game might have had, so we have changed small stuffs in our first idea, for example we have been informed that not all the users could read and that the presence of a lot of explanation was not useful for the game purpose, so we have thought how to improve the final usefulness of the game.
We have then implemented the first prototype of the game, that was tested from twb (ECCETERA, PER ORA IN SOSPESO)

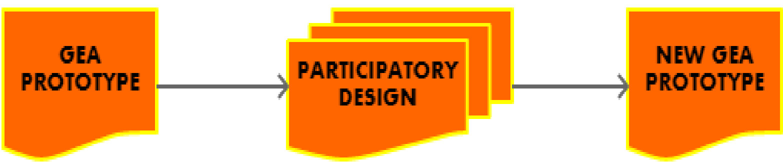

Figure 10: Phases of the work

0.7 GEA

0.7.1 Thesi Structure

The thesis is organized as follows:

Chapter 1 (State of the art) In this section we show all the technologies for Virtual Reality, explaining how they works and their relation with NDD people. We present also an instrument very useful for terapist that allow to replicate the smartphone's screen, Google Chromecast, and the touchscreen evolution. Finally we describe the projects already developed about food education.

Chapter 2 (GEA: first prototype) Here we describe how we elicitate the requirements, which are ours target groups, context, needs, constraints, goals. After that we show the UX design with description of all the app's pages and respective screenshot and flow diagram. Finally we briefly describe the implementation overview.

Chapter 3 (First evaluation)

Chapter 4 (GEA: second prototype)

Chapter 5 (Second evaluation)

Chapter 6 (Value proposition)

Chapter 7 (Challenges)

Chapter 8 (Implementation) We present all the tools used to build up our application and the hardaware and software architecture description.

Chapter 9 (Conclusion)

At the end of the thesis, two appendices illustrate the materials used during the process and shows some pictures of the process.

0.7.2 Origin of the name and mascotte

We decide to give the name GEA to our application because of two reasons. The first one is that Gea, in the greek mythology, was the personification of the Earth, the mother of all life so she is also the symbol of the nature that recalls the nutrition's topic. The second motivation is that in Italian Gea is the acronym of "Gioco Educazione Alimentare", which translated is "Food Education Game", in this way in the title there is the objective's explanation.
We have also designed a mascotte depicting a fairy of fruit and vegetables to leak the message that even the characters recognized by the community as positive eat

healthy food; it is in fact dressed with elements such as strawberries like pigtails, pumpkin like a skirt, salad like top and cherries like little bows of shoes.

Figure 11: GEA logo and mascotte

Chapter 1

State of the art

In our era technology has a foundamental role in almost every field. From the simple communications activities to those related to medical researches, technology is something we cannot do without. It is also a great opportunity in educational field, where it is demonstrated that the so called "stealth learning" (i.e. the help of technologies in educational scope) [56] is a solution to create a greater emotional involvement and that has as a consequence the ability to increase learner's learning opportunities. In our specific case, stealth learning is suitable for the treatment of patients affected by NDD to develop their cognitive, emotional and intellectual skills. Games are already widely used in therapeutic scope, due to the natural attraction people feel about this kind of activities.

More recently, some experiences have demonstrated that the use of games in educational scope is something very successful [22], due to different aspects:

- People with NDD are usually really attracted by technological devices and technological gaming experience, and this could be exploited to teach important lessons about various kind of things related to everyday life such as autonomy (eg in food education area).
- Virtual reality can be seen as a good candidate in the treatment of this kind of people, because it leads to a more focused activity in a simplified real-life context in which patients can improve their skills and then apply them to real life situations.

1.1 Modern technologies for NDD people

All the new existing technologies are now helping therapists and families to deal with neurological disabilities. In fact, in addition to virtual reality, smart objects, multisensor environments or smart spaces and conversational agents are used.

Smart objects are devices that can interact not only with the user but also with other similar devices and with the surrounding environment. Physical world can be described in terms of three properties [33]: awareness (is a smart object to be able to understand events and human activities occurring in the physical world), representation (refers to a smart object's application and programming model) and interaction (denotes the object's ability to converse with the user in terms of input, output, control, and feedback).
Examples are Dolphin Sam [1] and Huggable [2].
Smart spaces or multisensor environments are rooms in which children can play or interact in a controlled way because they are equipped with techonological items like cameras, smart objects, leds and projectors.
Examples are Magic K room e M4All [3].
Conversational agents are devices that can communicate with the user in a manner consistent with what is required: an interaction of the user is answered by the agent who must be with sense.

Figure 1.1: Dolphin Sam and Magic K Room

1.2 Virtual Reality

The great benefits of using Virtual Reality in an educational and rehabilitation context are now recognized worldwide and tested through various comparative tests between rehabilitation with the use of new technologies and rehabilitation with the use of classical methods [61], [39], [4]. In [48] a review is carried out on recent literature to support and demonstrate the effectiveness of the use of VR with autistic children and in [46] the effects of a virtual reality game are analyzed to demonstrate the increase in social and emotional activities on a sample of 30 children between 7 and 16 years who suffer from ASD.
As previously mentioned, for the development of GEA, an approach that uses Werable Immersive Virtual Reality (WIVR) has been preferred since the possibility of a complete immersion in the environment and the removal of many distractions are the basis of an effective therapy. The user is in a world similar to the real one but

safer as there is nothing that can hinder his learning and is reduced to the maximum the "fear" of making mistakes: it is as if the person could "train" the daily life so you can be ready and not catapulted into a world difficult for him. The use of the viewer also allows you to maintain a greater level of concentration because the player can not distract looking elsewhere or perceive the looks and reactions of those around, the only source of disturbance will then be sound. Once this type of games was not accessible to everyone because of the costs of technology and the problems that have been encountered in using it, such as a sense of nausea as sutied by the United States Army in [23], but nowadays many steps have been taken and viewers, as well as virtual reality itself, are within everyone's reach.
Regarding the technology of Virtual Reality viewers, HMDs, now on the market there is a clear division between two currents: embedded viewers, such as HTC Vive Pro, [52], and modular viewers, such as Google Cardboard, [14], and Samsung Gear VR, [62].

HTC Vive Pro

Figure 1.2: HTC Vive Pro

HTC Vive Pro is an advanced virtual reality headset developed by HTC and Valve Corporation.The Vive Pro uses two screens, one per eye, each having a display resolution of 1440x1660. The displays are made of AMOLED technology, having a refresh rate of 90 Hz (90 frames per second). The device uses these sensors: SteamVr Tracking, G-Sensor, gyroscope, proximity and IPD sensor. It uses optimized ergonomics and lenses with 110 degrees. But it has a very high cost: 879 euro only the visor and 1399 euro the complete pack (from the official store).

Google Cardboard

Figure 1.3: Google Cardboard

Google Cardboard is composed of two biconvex lenses mounted on a plastic or cardboard frame available in different colors and shapes. The smartphone placed inside this structure shows the visual contents, subdividing them into two-dimensional images with two identical dimensions, and the interaction is obtained through the focused gaze. The user can navigate the virtual world by rotating his head which will consequently rotate the virtual scene projected on the display.

Samsung Gear VR

Figure 1.4: Samsung Gear VR

Samsung Gear VR is still a modular HMD, produced by Samsung and Oculus VR. It is lightweight and with a good quality of materials,it has accelerometer, gyroscope and proximity Sensor but we can use it only with Samsung smartphones with some specifics. It costs more than Cardboard but it is not so expensive.

During the implementation and testing phases of GEA we decided to use the modular visor as it turns out to be the most economical choice on the market and the financial factor is of great importance since the game is designed to be integrated into existing and widely adopted in therapeutic programs.

1.3 Touchscreen

The massive evolution that touchscreen devices have had in recent years, has strongly influenced our way of life. The amount of time a person spend on internet or on electronic devices in general is something that continues to grow every year. From a general point of view this is surely not a good thing because it has a large number of consequences that we have to take care of.
This new trend of life surely influences also children, that spend a lot of their time playing games on touchscreen devices, that are more accessible than traditional computers and video games because the motor skills needed to use them are not necessary.

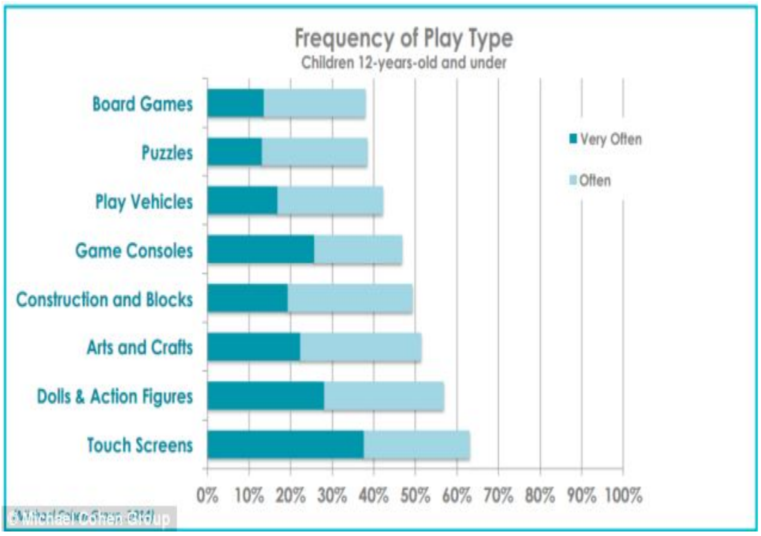

Figure 1.5: Time spent by children at playing games

Despite this kind of behaviour is largely criticized and not recommended by doctors and psychologists, the experiment conducted by B. Huber, J. Tarasuik, M.N. Antoniou, C. Garrett, S.J. Bowe and J. Kaufman [11] demonstrated that children could learn from touchscreen educational games and apply this knowledge on physical problems. In fact there're a lot of applications thought for this purpose that help children to develop memory, problem-solving and executive functioning skills that could then be applied to real-world problems. The experiment shows substantially that there's no difference in learning for children that use real objects from those who learn only on touchscreen application. In particular, as observed by M.J. Mayo [37], games could involve children more easily due to the presence of images, animations and sounds. Moreover, they're particularly adept at dosing information delivery. On a touchscreen application it is easy to complicate things and to add visual elements as the difficulty increases, while mantaining the focus on a small area that avoid extraneous distractions, so these educational games seems to be effective in enhancing motivation and increasing children interest in subject matter that leads to more effective learning [9].

1.4 Google Chromecast

Google Chromecast, [16], is a support device that we need for our application in order to exploit all its functionalities. It is a device that allows to send audio and video streams from a screen to another, without any wire through a technology called Google Cast.

Figure 1.6: Google Chromecast

In particular the link between the smartphone or tablet (what we want to replicate) and the Chromecast is done through a common wi-fi connection and Google Home app, then from the Chromecast to the television or computer (where we want to see the replication) through the direct connection of the key from the HDMI port. In this way we can replicate live contents and see what's going on inside the VR application or in the touchscreen one. [44]
This technology, as said before, is essential for the purpose of our application, because we need it in order to allow group training and the possibility for the therapist to give explanation on what to do during the experience, that is one of the main feature of our application.

1.5 Projects about food education

In the specific field of food education, we could find different kinds of game developed for touchscreen devices. In particular one example is the Food pyramid game developed by the Colorado State University [55] as a game to teach children what are the five main food groups and how to apply this knowledge to plan meal and snacks in order to increase their self-efficacy. This game is composed by various challenges regarding the food pyramid, and the researches has concluded that a game composed with a challenge is more effective that one based on a storyline.
Important companies are committed every year to the promotion and development of interactive educational games for children in this field both for the school and for the home, it is an example Nestlé with the project "Nutrikid", [43], prepared with advice Scientific Committee of the NFI, Nutrition Foundation of Italy. As they read from their website "The Nutrition Foundation of Italy, was constituted legally as a non-profit association in December 1976, with the aim of activating interactions and collaborations with government bodies, universities and industry to contribute the development of scientific research, the exchange of information in the field of nutrition and the promotion of interdisciplinary research in this field.", [47], for this reason we have drawn great inspiration from it during the development of GEA. Other projects in this field are continually promoted by the FEI, Food Education Italy, a foundation of accredited participation at the Ministry of Education, University Research, which lives on voluntary contributions and is involved in helping schools and teachers to develop their role of food educators, [31].
Instead, as regards the specific field of food allergies, the state of the art appears to be scarce. It is possible to find, as applications, on the App Store and Play Store, only two games in this regard and both are in English, they are "Wizdy Diner" and "Allergy Reality" developed with touch screen technology and for PC. [27] and [57]
On the website of healthy eating [19] we can find other kind of games related to food education developed for personal computer. One of them "My plate match game" teaches the user to characterize the different kinds of food in a correct diet and how much of every food is needed daily. The objective of this game can be divided into three mini goals:

1. Fill the plate with different colored shapes related to different kinds of food, this is quite trivial, because it is easy to understand where to put the shapes. At the end, the user could read some explanations about a specific food by putting the cursor on the shapes.

2. This second mini goal is more related to the association food-group. There are various foods and the user must put them in their correct food group.

3. The last goal requires to insert a lot of physical activities in a clock until it

reaches a total of one hour.

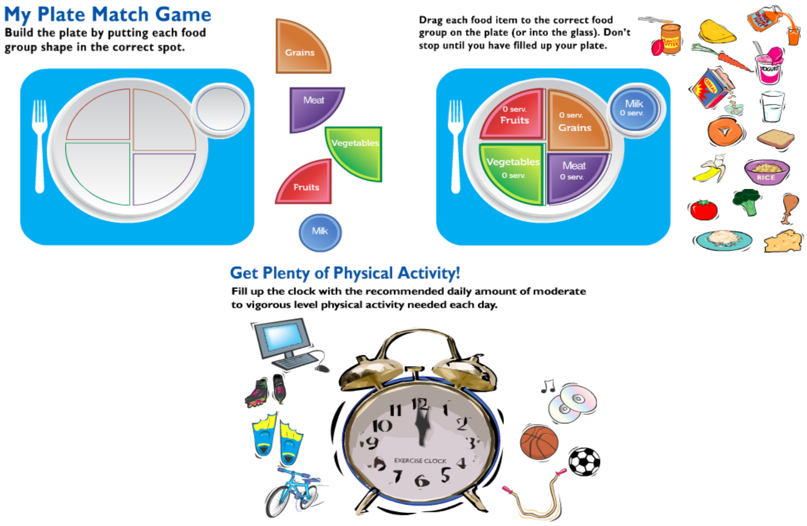

Figure 1.7: My plate match game

This game has not a proper feedback, because it will continue until all the goals are reached correctly (there's not error counting).
On the same website there is also another game specifically designed for healthy breakfast, "Power up your breakfast": this game is similar to the previous one, at the beginning the user must answer to some question regarding the importance of breakfast. The last game we have found is "My very own pizza" that allow the user to build a customized pizza without a true objective (the user could insert all the ingredients he wants). However, surfing on the internet we have seen that games related to food education in general are quite common, another example we have found is Nourish interactive website [30] that contains a huge amount of games with the food theme.

1.6 Projects about food allergies education

Contrary to what we have seen for food education in general, it is not easy to find previous digital works about the specific field of food allergies. Most of the work, in fact, are paper games based on previous explanations or in-game explanations. The only digital games we have found are on "My kids food allergies" website [32] in the arcade section, however most of the games we have tried does not work, only 3 out of 8 titles can be played.
"Supermarket search" is the first game we had faced with: there're three characters, each one has two kinds of food allergies and at the beginning of the game, the user must choose one of them. The chosen character asks the player to help him/her to buy some thing at the supermarket related to the preparation of a specific recipe. The

player must choose among two different choices the correct one (the foods alternative could be allergens or things that are not related to the recipe) and the game is completed after five steps.

Figure 1.8: Supermarket search

The second game we have tried is "food allergy bubble games" in which the user must choose one allergen among seven choices and when the game has started, the user must break the bubbles that contains that specific allergen, by moving a nose that has a needle. It is difficult to choose only the allergens because the bubbles are too much near each other and it's possible to make only three errors.

Figure 1.9: Food allergy bubble games

The last working game is based on a memory in which the user must associate the correct image to the word that represents its name, this can be useful to associate

a specific allergen to its iconic representation on food boxes.
All the other paper games are more related to symptoms of allergies, to their spelling and their consequences.

1.7 Participatory Design

1.7.1 What is Participatory Design?

Participatory design is an approach to design which aim is to involve the final users as active stakeholders and not just as targets or entity of study that tries to guarantee that the final product will meet their needs and that it will be usable. This approach is focused on processes and procedures of design but it is not a proper design style.
Recent studies [41] have proven how designers that works in a co-design fashion creates more innovative products, concepts and idea rather than working on their own and it is clear how the participation of the final users in all the product design phase raise the importance of their opinion that previously were considered only in testing phase.
In participatory design, participants are invited to cooperate with designer in different stages of the product design, from the very starting point in which there's idea discussion, where the participants could increase the domain knowledge of the problem (for example if a product will be designed for a certain kind of target, the participation of user belonging to that category will be of great help to understand pro and cons of each idea), during the development in which they evaluate proposed solution, until the final product effective release. Pieters and Maarten [49] describe co-design as a part of the complete co-creation process that refers to the "transparent process of value creation in ongoing, productive collaboration with, and supported by all relevant parties, with end-users playing a central role" and covers all stages of a development process.
The approach of participatory design was actually bornt in Scandinavia in the 1970s and at the beginning was called "cooperative design" even if, as the US community which the method was presented to noticed, initially it was something that create a separation between the managers and workers because there weren't sessions that include them both and in which they could discuss and compare their ideas but there were separate meeting without a direct cooperation.
Later they understood the importance of previous experience to give the product design something more that allows the reach of major achievement with methods developed through the focus on hands-on experience. Co-design is often used by trained designers who recognize the difficulty in properly understanding the cultural, societal, or usage scenarios encountered by their user. As Prahalad and Venkat recognized in

their book [51] "The meaning of value and the process of value creation are rapidly shifting from a product and firm-centric view to personalized consumer experiences. Informed, networked, empowered and active consumers are increasingly co-creating value with the firm" and we can see how in the last years the importance of co-design has reached different design fields, in particular the mobile app development.

1.7.2 Participatory Design with children

Participatory design method can involve a wide variety of kinds of people that goes from sportspeople to elder people, so it must consider even children as a valid participant category.
Co-design with children is something really important because we have to consider that a wide variety of thing are designed for children: for example games, transports, books and so on. In our specific field it is important to collaborate with children to understand their needs, their wishes and their knowledge to build a suitable educational game.
When participatory design implies the presence of a specific category, one must take care of the different requirements that must be satisfied for that kind of people. In particular, when dealing with children, in addition to robustness, reliability, validity, thoroughness and efficiency, one must care that the implied techniques allow to produce a useful result and - at the same time - that said procedures are appropriate and suitable for children as active participants.
One of the most relevant aspects of co-design is that the participants must be really attracted and interested on the design activity and on what the designer are trying to produce because the product will be something that they will use. Children by nature get easily bored and more distracted by an activity, specially if it has going on for a long time and with repeated tasks. It is vital to produce a participatory design session that is immersive for them in order to exploit all their suggestions and impressions. A way to reach this objective is to guarantee that the process is continuously renewed in order to keep the participants' attention and interest level high [45]. With respect to this aspect, many point out that efficient ways of countering the distraction/boredom factor are to make use of a storytelling setting for the sessions, or even to focus the PD process around a game: these two approaches mix together emotional involvement and interactivity, and often improve the way in which children participate in the design process altogether.
Another problem that raises from the participatory design with children is the fact that they have limited communication skills, so a session based only on lone verbal and written opinion may result in leaving out some of their suggestions that they don't know how to express.
Therefore it is crucial to find other ways to use as communication channels to allow for more complex interactions between participants and design experts that could

otherwise be limited by the restrictions on communication itself [38] some researches have underlined the efficacy of more "manual" communication means as drawing and crafting simple objects, the use of tables or of multiple choice sheets. In particular it has been observed how some props are efficient to design a proper communication between the designer and children because they can be seen as a stimulus (maintaining also high level attentions and wander) to design something new. This could lead to exploit multiple children opinions and to raise the level of the design object in analysis.

Figure 1.10: Example of participatory design with children

Another important aspect is the familiar context in which such co-design activities must be build on. Children must have a reference to which they could ask questions or tell things that otherwise they would not tell strangers (such as a bad opinion on some ideas raised during a discussion), this familiar context could be developed by the presence of a familiar figure as a teacher or a facilitator in the relationship with children.
Generally speaking, we can summarize the most important aspects of participatory design with children as follows:

- *Engagement factors*: the continuous renewing of the session process with the usage of different communication channels that allow the children to maintain a high level focus on the objective and not get bored and that allow the designers to collect as many ideas as possible.

- *Management factors*: the creation of a familiar environment that allow a more "relaxed" session in which the presence of a familiar figure could interact with children and vice-versa in order to exploit all the opinions (even if bad).

As for all participatory design groups of targets, the presence of children allows the designer to build a final product more suitable to the children experience and in line with their point of view. What emerges strongly from studies, is that children are perfectly able to generate design ideas if supported appropriately, even if sometimes these ideas could be difficult to be developed in a real product context, so they need to be revised before an actual implementation.

1.7.3 Participatory Design and people with disabilities

Technology is increasingly being seen as a beneficial addition to the strategies for supporting children with Autism Spectrum Disorders (ASD). Children with ASD typically exhibit an affinity for computers , which provide a safe environment to learn and practice skills that they may find difficult in everyday life. Computers have a number of features particularly appealing for children with ASD, such as the ability to repeat tasks and easily correct errors as pointed out by the National Autistic Society [58]. As Malinverni et al. point out from their study with children with special needs, PD activities - if planned properly - can lead to the development of a sense of empowerment and a feeling of competence, both of which reflect a general beneficial effect on the individual, that can derive satisfaction or fun from a useful activity and, at the same time, actually feel the usefulness of his/her contribution [35]. This approach can often present challenges related with properly defining the role that these children can assume in the design process. Defining the role of children represents a delicate issue since we move in the continuum between overwhelming the child and relegating him in a marginal role, in which his skills are not fully considered. The involvement of ASD children as informants has been reported by several authors [26], [63] and [40], which propose different methods. Methods vary from efforts to get feedback from children about design choices, to the analysis of their preference, the creation of scenarios or the observation of their behavior. The incorporation of these methods permits integrating children's contributions directly into the initial design stages, allowing a deeper influence on the definition of the final product.

Approaching PD with people with disabilities comes with a number of challenges that highlight the points to address with more attention whenever performing a series of design sessions in this mindset. The main difficulty is related to the heterogeneity of the participants, with respect to their ages and the degree of their conditions; this factor requires for innovative solutions and, most importantly, for extreme levels of flexibility on the researchers' part - both in terms of planning and of interaction with the participants. As a consequence, some practical factors must be ensured:

- The continuity of the team working with the PD group grants a simplification of the entire design setting, by establishing a reassuring personal relation between the members of the whole PD team

- The gradualness of the design process - and in particular the focus on small, constant changes to the final product - to help giving a sense of completeness and avoiding the dispersion of attention and interest
- The use of simplified, variated and personalized channels in the process to tackle the difficulty to express the participants' contribution, while helping them understand the structure of the activities they are going to participate in
- The clarity of the process structure in itself, down to the number of sessions and the individual design activities involved in each session.

Benton et al in [13] provide designers with a framework that guides them in adapting PD to account for neurodiversity. The framework facilitates the development of PD methods, which direct designers' attention to children's strengths, while supporting their difficulties. Based on the degree and type of disorders, in fact, strengths and difficulties can be isolated: the PD activity can consequently be shaped around the detailed profile of the participants, in order to leverage on their strong assets and - at the same time - to avoid discouraging them with tasks in which they struggle more. The most recurring strength in this context is the enhanced creativity of the individuals [64], which hints again at the importance of visual and manual communications skills; their spontaneity and risk-taking tendency may have both beneficial and negative effects, raising the necessity of a controlled environment in which the potential consequences of these traits are channeled towards positive outcomes. It often occurs that participants show an extreme attention towards details and precision , along with remarkable talent in some very specific area of their interest , and these features can bring much value to the final design [26]. This inclination towards detail is often a signal of what the focus of the PD sessions should be: concentrating on the finer details first and then gradually combining them into a final design is sometimes ideal and preferable to more "top-down-like" approaches.
Thus, in general, stress has been put on both the attention to difficulties and the leverage of strengths of subjects suffering from various disabilities, in order to craft the PD activity in the most suitable way possible. It must be noticed that, as all the observed studies point out clearly, not all cases can be summed up in predefined categories and that no ready-to-use solution can exist in dealing with neurodiversity, neither to tackle difficulties nor to exploit strengths. This factor suggests once more how, in the context of PD, it is of vital importance to plan the design process at best, understanding the culture of participants and subsequently tailoring the experience to best fit the whole group, in order to maximize any child's potential for making meaningful contributions to the design process [13]. This includes not only considering each individual's strong and weak points, but also possibly a personal-

ization of the means with which each individual interacts and communicates within the PD sessions. More practical experiences [35] in the context of PD with people with disabilities have highlighted some aspects that may influence the effectiveness of the process concretely. One of them is the importance of having a regular scheme defined for all the sessions; scheduling meetings close together and using a fixed general structure for all of them often helps creating a sense of continuity for the group, as is also suggested in more general terms by studies mentioning the positive effects of routine elements as introductory recaps and scheduled task checking, for example [13]. Temporal proximity of the sessions also helps maintaining the process efficacy, as the participants may find it hard to remember the progresses made over long time periods, depending on the degree of their conditions.

A great practical importance has been noticed in the use of physical materials: these kinds of props not only may raise the level of interest of the participants, but also gives a tangible indicator of progression, a sense of achievement and confidence in one's own capabilities. Clearly, the materials must be appropriate for the age and characteristics of the group members; a very intuitive rule-of-thumb is to make materials and prompts essential and clear, as to avoid inducing confusion and, in extreme cases, discouragement in the participants. Depending on the situation and on the composition of the group, it is also possible to vary the type of material used during the design sessions: in particular, it is important to adapt the structure to a more or less restrained way of collecting the participants' inputs, based on their profiles and conditions. The literature over this topic shows some disagreements on the efficacy of using physical schedules explicitly during the design sessions: according to the context, some authors warn against it as a possible introduction of bias in the participants' behavior within the various sessions [35]; some other, instead, recommend the use of it as a visual indicator of progress [12] or to create familiarity and establishing a beneficial routine element [13].

Whatever choice is made on this point, all studies highlight the vital importance of a continuous and direct communication between the design process coordinators and the participants about the planned activities: this can have the beneficial effects of a schedule, while not introducing any risk of biasing the participants' behavior toward one particular activity or another. During practical PD sessions, the fundamental role of previous knowledge of the participants is evident: this influences the familiarity with which they approach the design problem the group is called to face together with the designers. Studies have proven that previous knowledge on both the subject of the design process and the logic behind the designed elements - especially if such elements are interactive mechanics of a game or application - may have a direct impact on the improvement of the participants' contributions to the final design [35]. To this end, it is quite important to consider the possible need to include familiarization sessions in the design process: in general, this is especially required when the object of the design process is technology, as the participants may not be accustomed to the type of devices they will use during the design sessions. Lack of familiarity may, as a direct consequence, induce either over-stimulation due to the novelty of the situation or fear and general uneasiness; needless to say, both conditions are to be avoided, as they are usually harmful to both the process, the individual and the group - especially considering their potential social impact. Effectively, the involvement of children and adults with NDD or various disabilities within a PD framework may generate a mutual advantage for the designers and the design group: at a practical level, the final design benefits from the intervention of a group of people that best reflects the real needs and perspective of the intended user category, as part of the same "culture"; contextually, the participating group undergoes a virtuous process, as their role in a socially-useful task is made more evident, and a sense of individual empowerment and group responsibility is generated in the subjects [35]. The actual validity of the final design process output may vary a lot, due to the extreme variety of potential end-user conditions. Generally speaking, the similarity of the participants' mindset to the end-user category certainly has the positive aspect of channel the process towards an overall right direction: as Benton et al. observe in their study while validating the PD process, both the actual participants and a consistently comparable group showed very similar behavioral responses upon interacting with the final design product. Still, though, those who did not participate in the design pointed out a considerably higher number of desired features - either missing or different from expectation/desire - with respect to the group which had an active part in the design process [12]. This experience suggests extreme caution while measuring the positive effect of PD methods on the design pipeline and especially on the end product quality, as the improvement might not be as evident as expected, and - according to the very context of execution of the design process - may even end up being negligible or irrelevant.

As we explored the general features assumed by the PD techniques involving people with disabilities, it becomes really clear that most models proposed in literature have been crafted with children or adolescents with special needs in mind. However, it must be noticed that - as several studies point out, e.g. [50], [53] and [34] - most of the general indications we listed above work quite well for both children, young adults and even seniors suffering from NDD or disabilities in general. Of course, this factor is rendered quite uncertain by the heterogeneity of the community these kind of design processes are involving; still, some common features emerge and allow us to consider the possible guidelines provided by a number of research studies as suitable for people with disabilities of virtually any age. In particular, recurring common elements in studies with adult subjects with disabilities include:

- the need for multiple communication channels to avoid limitations deriving from the difficulties of expressing concepts, and in particular the necessity of adapting traditional methods to a suitable level, based on the specific group

- the importance of practical design sessions alongside more general interview-based ones
- the beneficial effect of using props and technological probes towards an improved contribution to the design by participants in direct and indirect ways
- the importance of structure clarity within and across sessions
- the positive effects on both the design and the group, in the latter case particularly the induction of empowerment and feeling of competence

Having established a general equivalence - set apart the due considerations about the appropriateness of the activities level with respect to the individuals in the group -, we can observe how several researchers have provided useful frameworks and guidelines to follow whenever undertaking a new PD study. Benton et al. [12] outline some "best practices" to remember for PD sessions by extracting them from multiple experiences with groups of subjects showing varying degrees of developmental disorders:

- Value is attributed to the process by ensuring that participants understand and are interested in what they are doing, meaning that it is vital to ensure that they are familiar with the subject and are stimulated by it to constructively participate to every session.
- Concrete thinking must be preferred to abstract thinking as it is closer to the way most people with disabilities interact with the social environment; also, it allows for very direct feedback, which - despite being potentially discouraging for somebody - may be much more useful in design processes as it favors quick and to-the-point information collection.
- Structure organization using visual means is useful to create continuity and involvement in the group; however, this has proven not to be the case in some practical experiences [35] and may strongly depend on the nature of the group and the context in which the process takes place.
- It is also very advantageous to the process to involve enthusiastic and very flexible people from the teaching/tutoring context, as this could help leverage the activities on the strong suits of the individual participants, thus building up their confidence and willingness to contribute.

Focusing on the variety of interests of the participants - especially when dealing with younger subjects - can help channel their willingness to participate in design activities instead of inducing a feeling of uneasiness by "forcing" them to take part in an activity that may be perceived as unpleasant, unfamiliar or even scary. The framework builds over this key factor to obtain a well-defined infrastructure of the design activity: the next factor to consider is the integration of the participants' social background as a whole: families, tutors and educators are included in the process directly, in order to take full advantage of the existing relationships between them and the participants. This way, the social aspect is leveraged to produce new constructive types of contributions; at the same time, the additional human factor can make certain social situations and contexts very evident, thus allowing to tailor the design activities according to the constraints and opportunities induced by the social backgrounds of every subject involved. Having laid out a structure specifically shaped around the personal and social spheres of the participants, the focus can be moved to the result of the process, and in particular to the efficacy, flexibility and suitability of the resulting product. These factors are the core of the product design analysis: with the inclusion of the extended social background of the participants, these measures of adequacy and suitability to the given needs can be explored more in depth; in fact, the design activities are planned since the beginning to evolve in an emulated social environment , that allows to better understand the real-life effects of the designed product or service. After that, the framework invites to bring the design to the real social and physical environments , so that the details neglected by the previous "approximations" are observed and accounted for. This includes the analysis of interactions and engagement with the artifact or service in an everyday context, from which we can derive information on actual usability and usefulness. The key idea of focusing the design work on the involved subjects' strengths as opposed to their difficulties is also central in Benton et al. [13], whose research outlines a flexible framework, adaptable according to the individual participants' profiles in order to simultaneously exploit the multiple strong characteristics exposed by neurodiversity and reduce the attrition posed by obvious difficulties. The overall framework proposed by the study focuses on the key concepts of understanding neurodiverse cultures as different structures for thinking and behaving, with associated strong assets and weaknesses; and tailoring the activities to the individuals , as to account for their unique and distinctive characteristics. This allows to draw a very detailed picture of the group, having explored the needs, interests and skills of its members thoroughly and at multiple levels: both "generally" as part of a culture presenting very peculiar common features and "specifically" as an individual equipped with his/her personal set of skills and vulnerabilities. This type of framework provides a highly flexible way of proceeding when structuring a PD activity, to the point that the activities can be adapted and shaped around the individual profiles of the participants. Breaking out the details of the involved subjects' cultures is relevant to highlight very practical elements, essential to the subjects themselves, to be accounted for in many situations; at the same time, the involvement of additional support from adults, parents, tutors or educators and the customization of activities allow to take full advantage of the whole skillset of the individual, as well as the typical characteristics associated with his/her background culture. All the features extracted with this method necessarily reflect both the complexity of the culture the individual belongs to and his/her specific individuality. The framework effectively describes a way to generate PD methods rather than defining a unique and generalized model to adapt to; this reflects the general mindset of PD quite well, as it is a way to give value to each participant based on his/her actual skills and ability to better reflect needs that are typical of the culture he/she belongs to. Despite having a tendency to produce "disposable" process structures, the researchers' experience with the framework points out how its employment and gradual enrichment contributes - as a sort of by-product - to enlarging the base knowledge of designers engaging with neurodiversity, by extracting and modeling the general traits of the expertise in this field longitudinally. Among the outlined models for PD, the recurring element is the focus on the extreme importance that the need extraction process assumes when structuring design process involving people with disabilities. As most perspectives focus on the strengths and difficulties of the participants in order to craft the design activities and tasks accordingly, it appears very clearly that the key to good PD is accounting in a very focused way for the special necessities exhibited by them and tailoring the experience as best suits each single one of them. Variety is indeed the key to success, as it perfectly reflects the landscape of disability with its exceptional range of perspectives and unique conditions; no real general method is possible in such context, as generalization would necessarily impose limits to the possible extent of an individual's contribution, as it would in fact be an enforcement of a mindset and a behavior that would prove unnatural or simply incomprehensible to him/her.

Chapter 2

GEA: first prototype

2.1 Requirements elicitation

The requirements, needs and goals for GEA were collected through meetings with psychologists and experts in the field of NDD, mainly Eleonora Beccaluva of the *Fraternitá & Amicizia Onlus* in Milan with whom we collaborated starting from the general idea up to the actual development. To better contextualize and define the themes of the educational game, we took part in some food laboratory activities organized in the aforementioned therapeutic center with patients with high functioning NDD. During these days the boys themselves showed a high interest in wanting to learn properly nutrition emphasizing a need for self-sufficiency that could be achieved through a game of support and continuation of educational activities usable by home and not only during dedicated hours. They showed us the environments in which they teach lessons explaining how they are structured, what are the main points on which they focused and they have specifically asked us to turn all this into a fun and educational game at the same time. Both patients and educators have shown themselves to be very supportive of the idea of using Virtual Reality for many positive factors such as being able to recreate the safe environment in which they are accustomed to work, thus maintaining the same serenity even at home, being able to avoid distractions and the ability to customize the difficulty depending on the individual skills.
The first meetings for the collection of the requisites were carried out as follows

1. First meeting:
    - Questions:
        * Where is the feeding laboratory performed?
        * How is the feeding laboratory performed?
        * What types of topics are treated?
        * What materials are used?

    - What level of difficulty is reached?
    - What are the most difficult issues?
    - What is the relationship of young people with new technologies (ex. VR viewer)?
    - What should we try to avoid or limit?
    - Can GEA be useful?
    - How is the subdivision into three mini-games considered?
  - Participants: Therapists and patients, suffering from NDD syndrome, from *Fraternitá & Amicizia Onlus*
  - Context: 8/11/2017 in a classroom of *Fraternitá & Amicizia Onlus*
  - Execution: The questions were addressed to therapists respectively and guys, who have worked actively with a lot enthusiasm, and later the idea of GEA was showed and expressed opinions about that
  - Result: The idea was met with great enthusiasm so we decide to continue

2. Second meeting:

  - Questions: Ask for an opinion regarding graphics, setting, content and structure of games
  - Participants: Eleonora Beccaluva, therapist of the center *Fraternitá & Amicizia Onlus*
  - Context: 23/11/2017 in a classroom of the I3Lab laboratory at the Milan Polytechnic
  - Execution: The mockups were shown to Eleonora Beccaluva and the questions were asked
  - Result: We were provided with suggestions regarding graphics and underlined the fact that not all children are able to read

2.1.1 Fraternitá & Amicizia Onlus

FraternitàeAmicizia
Cooperativa Sociale Onlus

Figure 2.1: Fraternitá & Amicizia Onlus logo

Fraternitá & Amicizia (F&A) is an onlus association in Milan that works with disabled people of different ages. They often work with persons with light cognitive deficit, people that apparently do not have serious problems, but that suffer discomfort to be disabled and tend to isolate themselves avoiding contacts and discussions with peers. They have many difficulties to find a job, to integrate in the society and to build their future but it is important to help them in reaching these goals, giving them the dignity they deserve. F&A supports disabled people, with the aim to empower, maintain, rehabilitate or qualify psycho-operative competences or motor, manual and cognitive functions, without neglecting each person's past and the individual, relational and social aspects of every patient. Therefore, in parallel with traditional learning, the association promotes activities able to stimulate each individual's emotional world through verbal, painting, graphical and musical channels to help these people build their own personalities [7].
We had some meetings with Eleonora Beccaluva, coordinator of several services at F&A and other psychologists, therapists and experts that collaborate with the center in helping people with NDD. WIVR was already a well-known technology, thanks to a past cooperation between F&A and Politecnico di Milano. WIVR games were powerful experiences for patients with NDD, challenging their cognitive abilities in a positive way. Through a continuous exercise in the virtual environment with everyday life activities and situations, the subjects can learn to execute in autonomy tasks that are considered "normal" for most of us, such as taking a bus or tying their shoes, but that can be difficult for the specified target. Moreover, the acquired knowledge can improve also related capabilities, like social capabilities. In a context where integration with peers is complex, being able to carry out everyday life activities can generate more self-awareness and encourage the individual to establish social interactions with other people.

2.1.2 Main target groups

Our system is designed to be easily used by different kinds of users that must have a little bit knowledge about nutrition, like for example the food pyramid. There are three main categories of stakeholders involved in our application:

- The first group is composed by children with NDD because they can have great benefits in using it. The application doesn't have a target age for this group, but it is important to note that during our conversations with therapists, it emerged that WIVR experiences and social experiences are usually proposed to people with mild to low NDDs. It can also be used by children not affected by this syndrome but it can result "simple".

- In the second group there are therapists, in hospitals or organizations, educators and all the other people that have to teach food education to NDD children. They can integrate their lessons with a game session using GEA to improve understanding and have a feedback on children's knowledge so it can be used in specialized centers or schools but also at home because you need only few technological instruments and not very high capabilities in computer science.

- The third group encloses developers, managers, researchers, designers, VR companies and all the people that can be affected by GEA diffusion and results.

2.1.3 Context and need addressed

The context of use of GEA is predominantly a room in a specialized center during a feeding laboratory session with the presence of a therapist. It can also be used at home, even if preferably with the presence of someone who can explain the mistakes made. Finally it could be used in schools for post-lesson learning exercises and tests.

The need our application tries to satisfy is a necessity development of personal and domestic autonomy in the field of nutrition: therefore increase the ability to establish independently which foods are correct eat, in how many doses and at which meals of the day.

2.1.4 Constraints

The proposed application should be able to execute on simple and for everyone WIVR devices, such as smartphones. This constraint is necessary since the application is meant to be used not only in therapeutic centers but also in different contexts, such as at home where there could be economic difficulties or not very high interest in sophisticated technologies. So, if we want a large diffusion of GEA we must develop it for the most common and popular device. It is important that the application should be usable and customizable by people with a poor, or maybe absent, knowledge about Virtual Reality applications so great ease of use is another constraint. After that it is important the presence of internet connection due to the fact that the application must load from a database the dynamic contents like foods and difficulties. Finally we try to have as low power consumption as possible because we want the user to do a lot of games and not stop due to the battery level.

2.1.5 Goals

The goal of the GEA project is to create an application that can teach to children with NDD food education through an experience of interactive game.

2.1.6 Requirements

After the meetings with therapists and patients and after analysing what they reported to be the key issues and the peculiarities in working with NDD patients, we elicited several requirements for our application to satisfy in its design and implementation. At a high-level, the requirements for GEA can be summarized as follows:

- Requirement 1: Customization
  The therapist must be able to set a level of difficulty in the game based on the child's skills so as to adapt the game to his/her level of knowledge and then gradually increase the difficulty

- Requirement 2: Inherent contents
  The contents of the game must be inherent and reflect those used during the food laboratory work-shops. For this reason, the developed games should be based on the food pyramid, on the recognition of healthy foods and on the ability to associate dishes and meals.

- Requirement 3: Simple virtual environment
  Because of the various disabilities affecting the users, particular attention to the visualized graphics should be kept: the environment should contain only elements essential for the specific task and cold colors should be avoided, as well as unexpected or flashing animations, as they could trigger negative reactions in the users

- Requirement 4: Visual explanations
  The possible users of the game differ in age and severity of disability, so there is the possibility that not everyone can read. For this reason, each task must include visual explanations about the goal of the game and how to complete it.

- Requirement 5: Importance of Feedback
  Every user's action during the game must receive the right feedback. Giving a positive feedback when the right action is accomplished and a negative one when a mistake is made helps maintain the children attention span and their engagement in the game

- Requirement 6: Session monitoring
  The therapist must always keep under control what the child is doing during the game experience, in order to follow his/her improvements and difficulties and to be able to provide the necessary explanations.

2.2 UX Design

2.2.1 Home page

Starting from the above requirements, we designed GEA as an easy-to-use smartphone application including an initial menu, from which the therapist can select which game to launch and its level of difficulty, and three VR games, based on the real activities of the previously cited food laboratory.
When the application starts, the home page is shown, with the three available games, as shown in 2.2, "Learn with the pyramid!", "Healthy or not?" and "Let's eat!".

Figure 2.2: Home page

After that, the therapist chooses the level of difficulty of the selected game 2.3. The difficulty does not lie in the way the game is played or in its objective but in the type of food shown: for example, in the easy level users can find common foods such as pasta, pizza or cake while in the difficult level there are foods such as barley, chickpeas and papaya, that are less known to children. The choice of the game and the difficulty is made via touchscreen on the smartphone, before inserting it in the VR viewer: in this way, the therapist can easily setup the experience before putting the patient in the virtual environment.

Figure 2.3: Level page

In figure 2.4 is shown the flow diagram of the application. As described above the app starts, then there are game's choice and relative selection of difficulty, finally the mini-game is launched. At the end of the session it comes back to the home page.

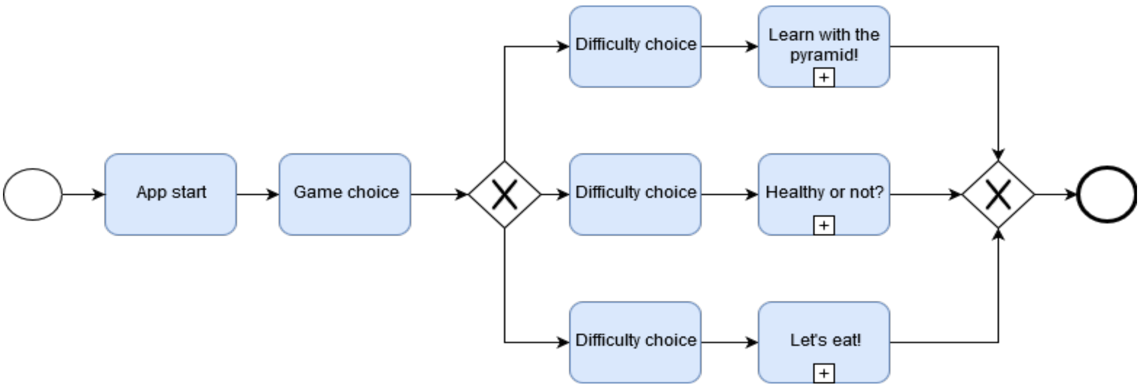

Figure 2.4: Home page flow diagram

When the game starts, the patient is immersed in the virtual space, which is the same for all the games and reproduces the real setting of the therapy: there is a room with a table, a fridge, a window,a door, a sofa and a kitchen, in order to keep the space as simple as possible but also inherent with nutrition. In front of the user, a short explanation for each game and a play button appear. The explanation is represented by graphical clues, to be understandable also by users who cannot read. Moreover, a fantasy character serving as mascot of the game was created, with the goal of making the application more fun and serving as visual feedback after each user's action. At the end of each session with each game the number of correct and wrong answers is shown to the user, with the total scored points.
In figure 2.5 is shown the flow diagram of each mini-game, they are all structured with the start and appearing of the choices. After that the user as to select what

he/she thinks is correct and a feedback confirm or not with a respective increment or not of the points. At the end of three or five session (depending on the game) the total score is displayed and after some seconds the app come back to the home page.

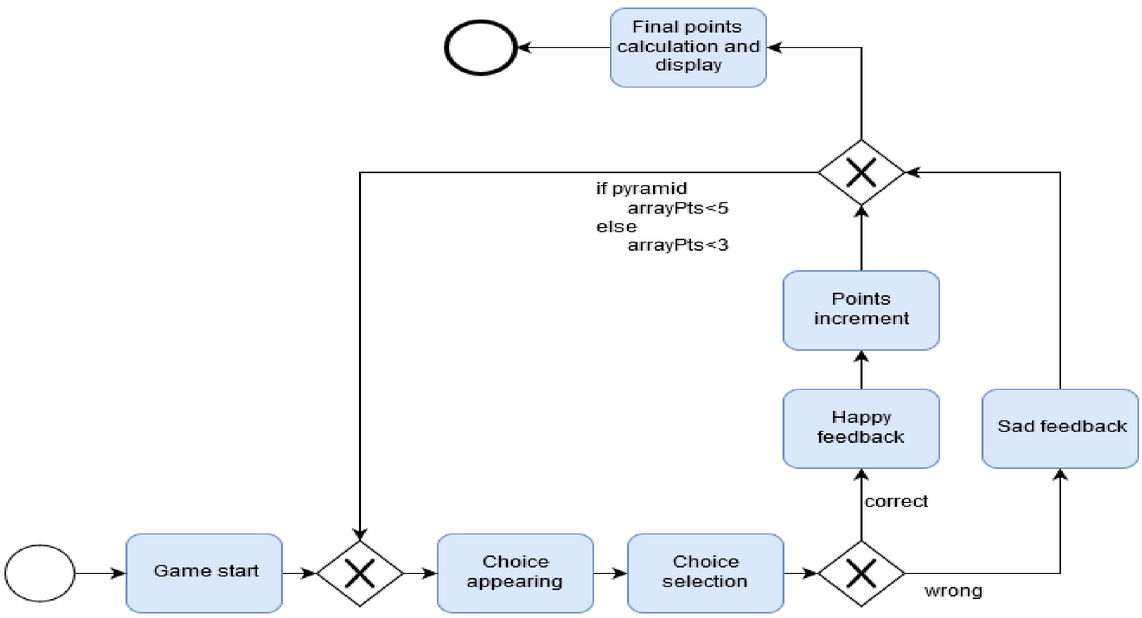

Figure 2.5: Games flow diagram

2.2.2 "Learn with the pyramid!" page

This game aims to teach how to complete the food pyramid, by selecting which food goes in each level. In the virtual environment appears a pyramid divided into five levels, with a pointer indicating which level the user is currently completing and the table with three options 2.6. The red circle in the image is the pointer representing the current user's focus point. The user has to focus on the correct choice for a certain time interval to give the answer, avoiding possible unwanted answers while the user is looking around in the environment. After an answer is given, a feedback is provided: the game mascot appears with a sad expression if the answer is wrong and the active level of the pyramid becomes red, if the answer is correct a happy mascot is shown and the level becomes green.

Figure 2.6: "Learn with the pyramid!" page

2.2.3 "Healthy or not?" page

This game is proposed to train patients in recognizing if a dish is healthy or not. When the game starts, two dishes appear on the table of the virtual room, with a bin and the visual explanation of how the game works 2.7: the user must select the "junk food" with the eyes and move it, by keeping the gaze focused on it, until it is thrown in the bin. There are three repetitions of this game, with different choices, and after each answer a feedback is shown, like the one described before.

Figure 2.7: "Healthy or not?" page

2.2.4 "Let's eat!" page

This game aims to teach how to associate meals of the day to specific dishes. It was created in particular for those patients who have difficulties in understanding when they can eat something or they cannot. In this case, the virtual environment presents four images representing the four main meals (breakfast, lunch, afternoon snack and dinner) and a dish 2.8: the goal is to select the correct meal/s in which the dish can be eaten. Like in the second game, there are three repetitions and after each answer a feedback is given.

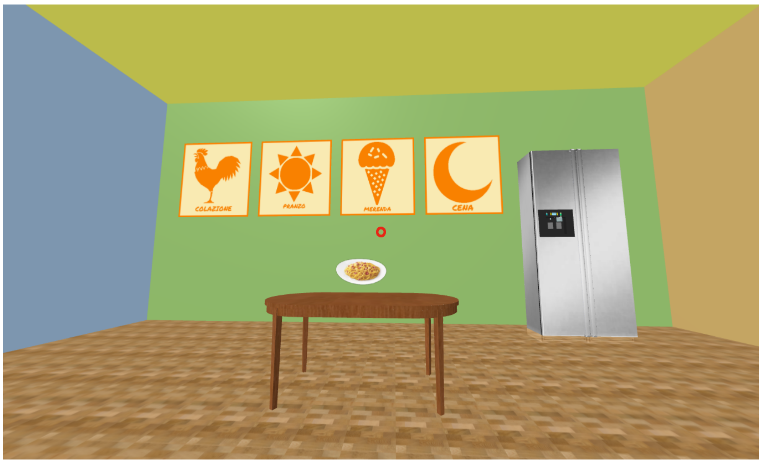

Figure 2.8: "Let's eat!" page

2.3 Implementation Overview

In this section, we briefly go over the general implementation choices we made for the initial prototype of GEA. The chapter 8 focuses more precisely on all the implementation details, delivering a complete view of the game application structure, both for the initial and final stages of the development; here, we just give a quick overview of the technological choices on which the development process was based off.

On the hardware side, very few requirements had to be met: the only devices required to use GEA are one smartphone-based WIVR headsets (Google Cardboard is the cheapest solution) and one smartphone running Android 4.1+ and basic functionalities as internet access and a working accelerometer/gyroscope.

The core of GEA's WIVR experiences is based on A-Frame, an open-source web framework for building virtual reality experiences with JavaScript and HTML. Developed by the Mozilla VR team, it is one of the easiest as well as most powerful ways to develop VR content on the Web (WebVR). A-Frame is based on top of HTML, making it simple to create virtual scenes inside web pages.

Languages used	
HTML	Standard markup language for creating web pages and web applications
Javascript	High level programming languages that enables interactive web pages, client-side
CSS	Is a style sheet language used for describing the presentation of a document written in a markup language like HTML
PHP	Is a server-side scripting language designed for Web development
JQuery	Javascript library designed to make it easier to navigate a document, select DOM elements, create animations, handle events, and develop Ajax applications
A-Frame	An open-source web framework for building virtual reality experiences with JavaScript and HTML

Table 2.1: Languages used during the development

Softwares used	
Altervista	Is an italian web platform where you can open a free web site
Brackets	Is a modern text editor that makes it easy to design in the browser
Imgur	Is an online image sharing community and image host

Table 2.2: Softwares used during the development

Chapter 3

First evaluation

In the first evaluation, we introduced GEA to a group of therapists and a group of patients from Fraternitá & Amicizia (one of the therapeutic centers that collaborated with us in the requirements elicitation phase) and we made a first assessment of the tool's usability from their point of view, collecting useful suggestions and comments. This was done with the collaboration of "TWB" project (Therapeutic services based on Wearable virtual reality and Bio-sensors) better explained in [28].
For privacy issues, together with the centre we collaborate with, we established to use aliases instead of real names.

3.1 Therapists

The therapists come from the staff of Fraternitá & Amicizia and include psychologists and experts of NDD working daily with this class of subjects. The location of the evaluation was "Fraternitá & Amicizia" - Soc. Cooperativa Sociale - Onlus - Via Washington 59, Milan. The project involves 7 sessions, through a 2-month period (from Monday 8 September to Monday 19 November 2018), but only two of them were related with GEA so we write here only data related with respectively session number 2 and session number 3 and their results. In all the sessions each therapist practiced with TWB platform and services for about 20 minutes.

ALIAS	AGE	QUALIFICATION
Operator One	BOH	BOH
Operator Two	BOH	BOH
Operator Three	BOH	BOH
Operator Four	BOH	BOH
Operator Five	BOH	BOH
Operator Six	BOH	BOH
Operator Seven	BOH	BOH
Operator Eight	BOH	BOH
Operator Nine	BOH	BOH
Operator Ten	BOH	BOH
Operator Eleven	BOH	BOH
Operator Twelve	BOH	BOH
Operator Thirteen	BOH	BOH
Operator Fourteen	BOH	BOH
Operator Fifteen	BOH	BOH
Operator Sixteen	BOH	BOH
Operator Seventeen	BOH	BOH
Operator Eighteen	BOH	BOH
Operator Nineteen	BOH	BOH
Operator Twenty	BOH	BOH
Operator Twenty-one	BOH	BOH
Operator Twenty-two	BOH	BOH
Operator Twenty-three	BOH	BOH
Operator Twenty-four	BOH	BOH
Operator Twenty-five	BOH	BOH

Table 3.1: Therapists' data

3.1.1 Objectives

- Usability
- Adoptability
- Therapeutic potential
- Perceived utility
- Collect feedback about how to improve the user interface
- Collect feedback about possible extensions of the tool's functionalities

3.1.2 Participants

The evaluation was done with 25 therapists.

3.1.3 Test setup

The evaluation sessions with therapists where performed in 3 different rooms of Fraternitá & Amicizia center in Milan, Via Washington 59. All the rooms were equipped with 1 PC running TWB web Platform, 1 headset and 1 mobile phone to play the WIVR application and, depending on the session, it was possible to have the EEG headset and Empatica Wristband. The room was also equipped with 1 videocamera with an integrated microphone to record each session. In each session, one expert of TWB and one therapist followed the entire session.

3.1.4 Introduction to the test

The week before the first session, a preliminary presentation of the entire TWB project and the evaluation process was organized with therapists, patients and patients' parents. During this meeting, we presented our system to them and explained how we wanted to perform the following experimental sessions.

3.1.5 Test procedure

We wrote down notes about reactions and comments coming from therapists while playing with the VR activities and after every session therapists had to fill in questionnaires to evaluate VR activities used during the specific session in terms of VR effectiveness, satisfaction, willingness to play again and engagement, both for them and for their patients. Moreover, questions about VR adoptability and perceived utility were asked and each session was recorded through a videocamera and a microphone to allow successive analysis.
During session number 2, performed on 15 October 2018, they play with the mini-game "Learn with the pyramid!".
During session number 3, performed on 22 Octber 2018, they play with the mini-games "Let's eat!" and "Healty or not?".

3.1.6 Feedback

3.1.7 Results

3.1.8 Conclusions

3.2 Patients

The patients, between age of 17 and 51 years old, were all selected among the users of Fraternitá & Amicizia Cooperativa Sociale, the therapeutic center in Milan collaborating with us. The subjects differ in diagnosis and functioning level, as the following table shows. The project involve 7 sessions and the locations are:

- Fraternitá & Amicizia - Soc. Cooperativa Sociale - Onlus - Via Foppa 7, Milano
- Fraternitá & Amicizia - Soc. Cooperativa Sociale - Onlus - Via Washington 59, Milano

ALIAS	AGE	DIAGNOSIS
User One	27	BOH
User Two	26	BOH
User Three	19	BOH
User Four	26	BOH
User Five	28	BOH
User Six	32	BOH
User Seven	33	BOH
User Eight	34	BOH
User Nine	20	BOH
User Ten	17	BOH
User Eleven	37	BOH
User Twelve	32	BOH
User Thirteen	25	BOH
User Fourteen	20	BOH
User Fifteen	18	BOH
User Sixteen	31	BOH
User Seventeen	24	BOH
User Eighteen	27	BOH
User Nineteen	46	BOH
User Twenty	51	BOH

Table 3.2: Patients' data

3.2.1 Objectives

- Biosensors acceptability and wearability

- Virtual Reality usability and acceptability
- Effectiveness variables: satisfaction, engagement, willingness
- Effectiveness of WIVR applications in terms of skills improvement (attention, behavioral skills etc...)

3.2.2 Participants

The evaluation was done with 20 patients.

3.2.3 Test setup

Evaluation sessions with patients where performed in 2 different centers belonging to Fraternitá & Amicizia located in Milan: Via Washington 59 and Via Foppa 7. In both the centers, the rooms used for the evaluation were equipped with 1 PC running TWB web Platform, 1 headset and 1 mobile phone to play the WIVR applications and, depending on the session, it was possible to have the EEG headset and/or Empatica Wristband.
The room was also equipped with 1 videocamera with an integrated microphone to record each session. In each session, two experts of TWB and one therapist followed the entire session

3.2.4 Introduction to the test

The week before the first session, a preliminary presentation of the entire TWB project and the evaluation process was organized with therapists, patients and patients' parents. During this meeting, we presented our system to them and explained how we wanted to perform the following experimental sessions.

3.2.5 Test procedure

For the study the 20 patients are divided into 2 groups of 10: the first group performed the evaluation every Monday from 1st October to 12th November 2018, the other one met every Wednesday from 10th October to 28st November 2018 (except for Wednesday 1st November that is non-working day). The evaluation consisted of 7 sessions per patient, one per week (on Monday or Wednesday), lasting about 15-20 minutes, through a 2-month period (from 1st October to 21st November), during which patients experimented only the mini-game "Healthy or Not?". These activities (our "Healthy or not?" and another prototype) were chosen together with therapists and experts, among 25 possible activities, because they are considered the best ones to evaluate skills improvement. The supervisors were 2 TWB IT experts and 1 educator.

During session number 1 each patient tried to wear only Empatica Wristband, Empatica Wristband together with Emotiv EEG Headset, Empatica Writstband, Emotiv EEG Headset, Virtual Reality Headset. From S2 to S7 in the second half of each session, patient had to complete one level of the activity called "Healthy or Not?". If during the first session the patient accepted to wear Empatica Wristband or Emotiv EEG Headset or both, he/she could wear them during these sessions in VR. During the execution of this study, we collected two types of data:

- Quantitative data, including both interaction data from the WIVR activities and physiological signals measured by the biosensors worn by patients:
  - Interaction data: level of attention, number of errors, activity completion time
  - Data coming from Empatica: HR, BVP, EDA, Temperature
  - Data coming from Emotiv EEG: Excitement (Arousal), Interest (Valence), Stress (Frustration), Engagement/Boredom, Attention (Focus) and Meditation (Relaxation)
- Qualitative data, writing down errors, difficulties found and comments from the users in specific forms. Moreover, at the end of sessions 1, 2 and 7 users must answer to a questionnaire about what they experienced that day. Specifically:
  - In session S1, we wrote down notes about reactions and comments coming from patients while wearing only Empatica, Empatica with EEG Headset and Empatica with EEG and VR Headset. After the session, each patient had to complete a questionnaire about biosensors acceptability and wearability.
  - From session S2 to S7, we used ad-hoc forms to collect information about errors and completion time for each task in VR. These data were used to measure VR activities effectiveness and patients' skills improvement.
  - After session S2 and S7, patients had to fill in questionnaires to evaluate VR acceptability, VR effectiveness as well as VR satisfaction, willingness to play again and engagement. We decided, together with experts, to give questionnaire to fill in only after first and last session in which patients had to use virtual reality: in this way we could see if some answers changed from the beginning to the end of the experimentation.
  - From session S2 to S7 it was possible to collect data coming from biosensors (Empatica Wristband or Emotiv EEG Headset or both), if patients accepted to wear them during their first session (S1).
  - Moreover, each session was recorded through a videocamera and a microphone to be revised later.

3.2.6 Feedback

3.2.7 Results

3.2.8 Conclusions

Chapter 4

GEA: second prototype

Here we describe the second prototype of GEA with all the modifications, additions and new implementations coming from the feedbacks and results of the first evaluation.
For what concerns the requirements, goals, needs, target group, contexts and constraints refers to chapter 2 because they remained the same. Also the UX design of the three mini-game in virtual reality is the same as in the cited chapter except for minimal modifications reported in the following sections.
The new home page of GEA is now the one reported in Figure 4.1. Here the user can choose if he/she wants to play in virtual reality mode or in touchscreen mode.

Figure 4.1: Home page: second prototype

In figure 4.2 we show the new page for selecting the mini-game, here the user can choose between four games: "Lear with the pyramid!", "Healty or not?", "Let's eat!" and "Find the allergen!". This page is the same for virtual reality and touchscreen.

Figure 4.2: Page for selecting the mini-game: second prototype

After having choose the game the next page will be for the selection of the difficulty level, this page is the same as the first prototype and for every game.

4.1 Touchscreen

In this section with show the screenshots abouto the touchscreen part of GEA. First of all we want to impose to use the smartphone or better the tablet in the landascape mode so if the user is playing in portrait mode appears the allert message in Figure 4.3.
We have decided to do that to improve the game experience because in the portrait mode all the objects, and so the foods, are too small and we cannot represent a real room. If the user saves the game on the device the rotation will be authomatic because of the manifest we have written but when you play on a browser this is not possible.
Also during the session if the user rotates the device the game stops and the message appears then when you come back to the landscape mode you can play exactly from that moment and not from the beginning.

Figure 4.3: Screenshot of rotate message

For what concerns the logic the mini-games are remained the same, the only things that are changed are the graphic (not 3D dimensions but 2D dimensions) and the interaction (not looking at something but touching something).
In the following we can see the screenshots about "Learn with the pyramid!" (Figure 4.4), "Healthy or not?" (Figure 4.5) and "Let's eat!" (Figure 4.6).

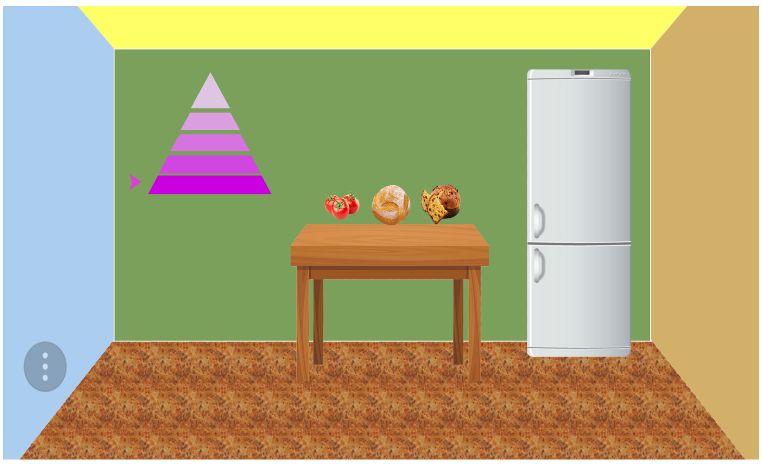

Figure 4.4: "Learn with the pyramid!" touchscreen page

Figure 4.5: "Healthy or not?" touchscreen page

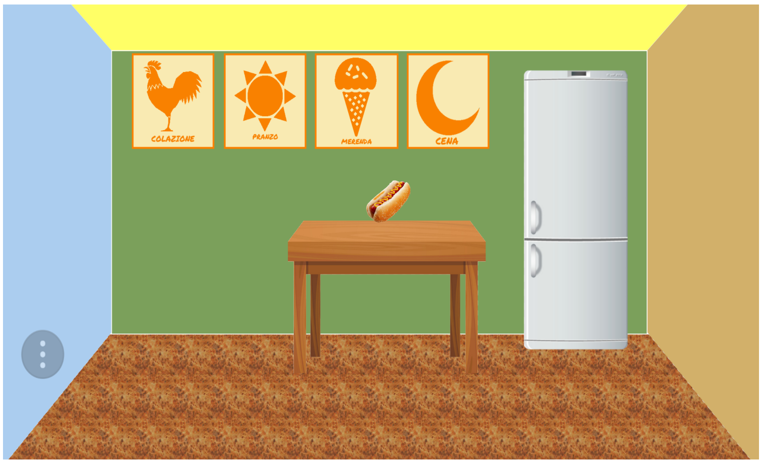

Figure 4.6: "Let's eat!" touchscreen page

4.2 Allergy game

4.3 Other modifications

Chapter 5

Second evaluation

5.1 Objectives

5.2 Participants

5.3 Test setup

5.4 Introduction to the test

5.5 Test procedure

5.6 Feedback

5.7 Results

5.8 Conclusions

Chapter 6

Value proposition

6.1 Evaluation method

6.2 Evaluation results

Chapter 7

Challenges

Chapter 8

Implementation

8.1 Tools

8.1.1 A-Frame

Figure 8.1: A-Frame logo

The core of GEA's WIVR experiences is based on A-Frame [5], an open-source web framework for building virtual reality experiences with JavaScript and HTML. Developed by the Mozilla VR team, it is one of the easiest as well as most powerful ways to develop VR content on the Web (WebVR). As a fully open project, A-Frame has grown to be one of the largest and welcoming VR communities.
A-Frame is based on top of HTML, making it simple to create virtual scenes inside web pages. However, it is not just a 3D scene graph nor a markup language; the core is a powerful entity-component framework that provides a declarative, extensible, and modular structure to Three.js, a JavaScript library used to create and display animated 3D computer graphics in a web browser. A-Frame simplifies the creation of 3D virtual worlds because it works as an abstraction layer above Three.js, which in turn abstracts the basic WebGL (Web Graphics Library) API making the manipulation of graphical elements as less complex as possible. A-Frame works on standard desktop, supports most VR headsets such as Cardboard, HTC Vive, Oculus Rift, Samsung Gear VR, and can even be used for augmented reality. This library

constitutes the basis of the virtual scenes represented in GEA.

8.1.2 Languages

The languages used for GEA's implementation are:

- HTML: used for the structure and formatting of the application's web pages. In Information Technology (IT), HyperText Markup Language (HTML) is the standard markup language for creating web pages and web applications; it is dedicated in particular to create and format the layout of hyper-textual documents available in the World Wide Web as web pages, giving them a well-defined structure.

- CSS: together with HTML, contributes to improve the web pages' design. In IT, Cascading Style Sheets (CSS) is a style sheet language used for describing the presentation of a document written in a markup language (e.g. HTML, XHTML and XML), like a website and its web pages. CSS is a cornerstone technology used by most websites to create visually engaging webpages, user interfaces for web applications, and user interfaces for many mobile applications. We have used a theme based on the Material Design (by Google) for the CSS part of our application.

- JavaScript: used to program the application logic, so the functionalities of our tool. In IT, JavaScript, often abbreviated as "JS", is a high-level, dynamic, untyped, object-based, multi-paradigm, and interpreted programming language. It is commonly used in client-side web programming to add dynamic and interactive effects in websites and web applications. Through specific scripts (JS functions), JavaScript enables to trigger different effects on the web pages in response to user's actions. We have used jQuery, a Javascript library: its syntax is designed to make it easier to navigate a document, select DOM elements, create animations, handle events, and develop Ajax applications. This enables developers to create abstractions for low-level interaction and animation, advanced effects and high-level, themeable widgets. The modular approach to the jQuery library allows the creation of powerful dynamic web pages and Web applications.

- PHP: is a server-side scripting language designed for Web development, and also used as a general-purpose programming language, PHP code may be embedded into HTML code, or it can be used in combination with various web template systems, web content management systems, and web frameworks. PHP code is usually processed by a PHP interpreter implemented as a module in the web server or as a Common Gateway Interface (CGI) executable. The web server combines the results of the interpreted and executed PHP code, which may be any type of data, including images, with the generated web page.

8.2 Hardware Architecture

Few hardware components are required to use GEA. Even if it is a web application, so it can be accessed from every device connected to Internet, these are the suggested devices to obtain the best experience using GEA:

- For VR version:
  - 360° VR headset (Google Cardboard or similar), with a slot to insert a smartphone.
  - Smartphone to be inserted in the headset on which the GEA application runs. The smartphone should have: accelerometer and gyroscope sensors to track the end-user's head movements and to allow him/her to explore and interact with the scene, an internet connection, better Wi-Fi connection, in order to connect to the server, screen dimensions from 4 to 7 inches depending on the specific headset chosen.
- For touchscreen version: a Tablet, because a bigger screen is usefull to have a better experience, with an internet connection, better Wi-Fi connection, in order to connect the server.

8.3 Software Architecture

Chapter 9

Conclusion

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Appendix A

First appendix - User manual

Appendix B

Second appendix - Questionar