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Development of Virtual Advanced Learning Environments

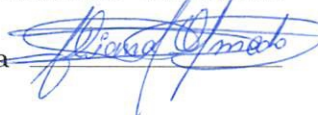Settore Scientifico Disciplinare: M-PSI/01

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Todo lo puedo en Cristo que me fortalece. Fil 4:13

Dedicado a mi amado esposo, amigo y compañero Jorge. A nuestro angelito quien por poco tiempo nos acompañó en esta tierra. A mis queridos padres Armando y Sandra,a mis sugros Martha y Jorge, a mis hermanos Cristian y Daniel, a mis hermanas Gaby, Caty y Vale, a mis sobrinas,a mi familia y amigos quienes son parte de este logro.

Acknowledgements

Abstract

The fact that the humanity is living in the digital era is undeniable. In fact, the advancement of the technology and the interconnection of everyday devices has become the Virtual Learning Environments in a powerful alternative acquiring knowledge. This is possible through an infinite access to information and also a dynamic interaction among people around the world. The capacity of these environments to transmit immersion sensations motivates the users to perform useful activities. Consequently, the users occupy their time on strengthening skills while enhancing their intellectual and social development.

The literature review about advanced 3D virtual environments has been a useful and fundamental starting point. This has allowed deepen on the potentialities and possible benefits of the relationship between education and new technologies such as the Internet, multimedia systems, augmented reality, intelligent tutoring, 3D immersion systems among others. Hence, the study of educational games, mobile learning applications, virtual museums and laboratories, from a theoretical point of view, has to be linked to modern learning fields like STEAM (Science, Technology, Engineering, Arts, and Mathematics) education and Special education as well.

Based on the before mentioned approaches, an interactive Virtual Advanced Learning Environments (VALE) have been developed. It consists of different advanced 3D virtual scenarios devoted to the teaching of STEAM Education and Special Education fields. Inside these environments, several educational activities are performed in an entertaining way. These learning activities are carried out through virtual laboratories, interactive museums, games challenges, video-modelling activities and training/tests applications.

In particular, the VALE for STEAM education includes three scenarios devoted to the Chaos Theory, Educational Robotics and Programming in Scratch. While the VALE for Special Education consists of two applications. The first one is aimed to enhance the Simple Social Skills, and the Social Communication Concepts in people with special needs. The second one is devoted to strengthen skills of Emotion Recognition also in people with special needs.

All the activities available inside the VALE give to the users the opportunity of freely discover and learn interesting concepts and develop skills in a fun way while they develop

knowledge. The results of the experimentation of the VALE have been satisfactory. In general, the participants showed efficient response during the development of the activities demonstrating an affinity with the knowledge learned. Furthermore, the developed applications for Special Education needs have proven to be useful in specific contexts such as emotion recognition. This has been demonstrated by assessments conducted with people with autism and mental retardation.

Riassunto

È innegabile che l'umanità stia vivendo nell'era digitale, dove l'avanzamento della tecnologia e l'interconnessione di dispositivi di uso quotidiano hanno convertito agli Ambienti Virtuali di Aprendimento in una potente alternativa per l'acquisizione della conoscenza. Ciò è possibile grazie a un accesso illimitato all'informazione ed anche ad una interazione dinamica tra le persone di tutto il mondo. La capacità di questi ambienti di trasmettere sensazioni coinvolgenti per gli utenti, motiva questi ultimi a svolgere diverse attività utili ai fini dell'apprendimento. Di conseguenza, gli utenti occupano il loro tempo sul rafforzamento delle competenze, migliorando il loro sviluppo intellettuale e sociale.

La revisione della letteratura sugli avanzati ambienti virtuali 3D è stato un punto di partenza utile e fondamentale. Questo ha permesso di approfondire le potenzialità e i possibili benefici del rapporto tra l'educazione e le nuove tecnologie come Internet, sistemi multimediali, realtà aumentata, tutoraggio intelligente, sistemi di immersione in 3D tra gli altri. Quindi, lo studio di giochi educativi, applicazioni mobile learning, musei e laboratori virtuali, da un punto di vista teorico, deve essere collegato ai campi moderni di apprendimento come l'educazione STEAM (dall'acronimo inglese Science, Technology, Engineering, Arts, and Mathematics), ed anche l'istruzione speciale.

Sulla base degli approcci su menzionati, sono stati sviluppati ambienti interattivi denominati Virtual Advanced Learning Environments (VALE). Questi ambienti si compongono di diversi scenari virtuali 3D dedicati all'insegnamento della educazione STEAM e dell'Istruzione per i campi della Educazione Speciale. All'interno di questi ambienti, numerose attività didattiche sono svolte in modo divertente, cioè attraverso laboratori virtuali, musei interattivi, giochi da sfide, attività di video-modelling e applicazioni di Training / Test activities.

In particolare, VALE per l'educazione STEAM è formato da tre scenari dedicati alla Teoria del Caos, Robotica Educativa ed alla Programmazione in Scratch. Invece, all'interno del VALE per l'Educazione Speciale sono state sviluppate due applicazioni. La prima ha lo scopo di migliorare le semplici abilità sociali, e diffondere concetti di comunicazione sociale a persone con bisogni speciali. Il secondo è dedicato a rafforzare le competenze nel riconoscimento dell'emozioni anche da parte di persone con bisogni speciali.

Tutte le attività disponibili all'interno dei VALE danno agli utenti l'opportunità di

scoprire liberamente e imparare concetti interessanti, sviluppare le competenze in modo divertente mentre si sviluppano conoscenze. I risultati della sperimentazione dei VALE sono stati soddisfacenti. In generale, i partecipanti hanno mostrato risposte efficienti durante lo sviluppo delle attività che dimostrano un'affinità con le conoscenze apprese. Inoltre, le applicazioni sviluppate per i bisogni educativi speciali hanno dimostrato di essere utili in contesti specifici come il riconoscimento dell'emozione. Questo è stato dimostrato dalle valutazioni condotte con delle persone con autismo e ritardo mentale.

Pubblication List

1. Vaca Cárdenas, L., Bertacchini, F., Tavernise, A., Gabriele, L., Pantano, P., **Olmedo Vizueta, D. E.** Bilotta, E. (2015). *Coding with Scratch: The design of an educational setting for Elementary pre-service teachers.* Florence, Italy. **http://doi.org/978-1-4799-8706-1**

2. Vaca Cárdenas, L., Bertacchini, F., Gabriele, L., Tavernise, A., **Olmedo Vizueta, D. E.**, Pantano, P., & Bilotta, E. (2015). *Surfing Virtual Environment in the Galápagos Islands Edutainment for improving the learning of STEAM.* 12th International Conference on Remote Engineering and Virtual Instrumentation (REV), (February), 199–205. **ISBN 9781479978380**

3. **Olmedo Vizueta, D. E.**, Bertacchini, F., Vaca Cárdenas, L., Gabriele, L., Pantano, P., & Bilotta, E. (2014). *A Video-Modelling system for improving social skills and lexicon in Autistic Spectrum Disorder children.* 6th International Conference on Education and New Learning Technologies, (July), 6081–6087. **ISBN 9788461705573**

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5. Bertacchini, F., Bilotta, E., Gabriele, L., **Olmedo Vizueta, D. E.**, Pantano, P., Rosa, F., . . . Valenti, A. (2013). *An emotional learning environment for subjects with Autism Spectrum Disorder.* 2013 International Conference on Interactive Collaborative Learning (ICL), (September), 653–659. **ISBN 978-1-4799-0153-1. http://doi.org/10.1109/ICL.2013.6644675**.

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Acronyms

ALS Amyotrophic Lateral Sclerosis

App Application

AR Augmented Reality

ARM Architectural Reference Model

ASD Autism Spectrum Disorder

AU Action Unit

BAP Body Animation Parameter

CAEE Center for Advanced Engineering Environment

CALS Cubic Advanced Learning Solutions

CPS Creative Problem Solving

DFE Dynamic Facial Expressions

DIMES Dipartimento di Ingegneria Informatica, Modellistica, Elettronica e Sistemistica

ESG Evolutionary System Group

FACS Facial Action Coding System

FAP Face Animation Parameter

FAPU Face Animation Parameter Unit

FBA Face and Body Animation

FDP Facial Definition Parameter

FER Facial Expression Recognizer v1.2

FP Feature Point

GPS Global Positioning System

GUI Graphical User Interface

HCD Human Centred Design

HCI Human Computer Interaction

HFASD High Functioning Autism Spectrum Disorder

HFA High Functioning Autism

ICD International Classification of Diseases

IHS Information Handling Services

IoT Internet of Things

LFA Low Functioning Autism

MARA3D Mobile Art Reference App 3D

MEMS Microelectromechanical Systems

MEST Ministry of Education, Science and Technology

MMHCI Multimodal Human Computer Interaction Systems

MPEG-4 Motion Picture Experts Group - v4

M&S 3d Modelling and Simulation

MR Mental Retardation

IQ Intelligence Quotient

PRT Pivoral Response Training

SAAC Sistemas Aumentativos y Alternativos de Comunicación

SCORM Shareable Content Object Reference Model

STEAM Science, Technology, Engineering, Arts and Mathematics

STEM Science, Technology, Engineering and Mathematics

TD Typical Development

UCD User Centred Design

UNICAL Università della Calabria

VALE Virtual Advanced Learning Environments

VE Virtual Environment

VLE Virtual Learning Environment

VM Video Modeling

VMIT Video Modeling Imitation Training

3DVLE 3D Virtual Learning Environment

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Introduction

The advancement of technology and networking infrastructure has made possible to the Virtual Learning Environments become in a powerful alternative to acquire knowledge. The last is possible through an infinite access of information and also a dynamic interaction among people around the world. The capacity of these environments for transmit immersive sensations to the users motivates them to perform useful activities. Consequently, the users occupy their time on strengthening skills while enhancing their intellectual and social development (Fernández-Gallego, Lama, Vidal, & Mucientes, 2013; Chau, Wong, et al., 2013; Chau, Sung, et al., 2013).

Literature review about 3D virtual environments is a useful and fundamental starting point to deep on *state-of-the-art* in the present work, studying the potentialities and possible benefits of the relationship between education and new technologies, such internet, multimedia systems, augmented reality, intelligent tutoring, 3D immersion systems among others. Hence, from a theoretical point of view, the study of educational games, mobile learning applications, virtual museums and laboratories has to be linked to modern learning fields like STEAM (Science, Technology, Engineering, Arts, and Mathematics) education and Special education as well.

Continuing in the teaching context, the STEAM education is a new trend of a convergence science education in the world. As a learning method, STEAM emphasizes in the stimulation of students' problem-solving abilities and their motivation and interest in Science and technology fields, as well as promoting creativity to train the next generations as innovators (Kang, Kim, & Kim, 2012; Y. Kim & Park, 2012b; Vaca Cárdenas, Bertacchini, Gabriele, et al., 2015).

Equally important is the special education field because the people grouped into this category requires different tools and methodologies to acquire skills. Achieving the acquisition of both physical and social skills could help the people with special needs to deal with the everyday situations in a better way. As a consequence, this can produce a better quality of life for these people (F. Bertacchini, Bilotta, Gabriele, Olmedo Vizueta, et al., 2013; Moore, 2000).

With the before mentioned approaches, a Virtual Advanced Learning Environments (VALE) is presented. The latter consists of different advanced 3D virtual scenarios

devoted to the STEAM Education and Special Education fields. Inside these environments, various educational leraning activities can be followed in an entertaining way. These learning activities consist in virtual laboratories, interactive museums, games challenges, video-modelling activities and training/tests applications. All these activities give to users the opportunity to freely discover and learn interesting concepts and develop skills in a fun way while developing knowledge. A detailed description of each of these scenarios, focusing on their construction and scientific background, are realesed in the following chapters.

Chapter 1 provides a general overview of Advanced Learning Environments, outlining the "Traditional Learning" again "Advanced Learning Environments". Then, a complete description of the emerged STEAM education approach will be performed, focusing on its accelerated diffusion throughout the world and its relation with VALE. In this way, a review of the current research in 3D systems for education is presented, providing some examples of VALEs. Afterwards, an approach to the Special Education field, focusing on the Emotion Recognition, and Simple Social/Communication Skills, is presented. Such approach regards to training and test for Emotion Recognition and Video-Modelling for teaching of daily tasks.

Chapter 2 deals with all the considerations to be taken into account in the interaction with virtual worlds, and how it has been evolved. Similar importance is the topic about the Human Computer Interaction (HCI), explaining its beginnings through a literature review and describing the principles applied in HCI. Afterwards, an overview of the existing technologies and recent advances is also presented. At the end, HCI devices used in VALE project are described.

Chapter 3 is dedicated to the technical aspects and tools oriented to the creation of these advanced learning environments. In particular, it describes how the different scenarios have been developed, which leads to understand the uses and characteristics of following software used in the development of the whole environment: Autodesk 3Ds Max (for 3d modelling), Unity3D (for animation and rendering), iClone (for real-time 3D animation), Scratch (for programming Darwin's game), Adobe Photoshop and Adobe Illustrator (for the edition of textures). With regards to the rendering in real time, the latest technologies in this field are described including the advances in 3D projections and mentioning the advantages that this offers.

Chapter 4 concentrates specifically in the VALE-STEAM implementation starting by the Introduction to the project and then focusing in the Analysis of the training aspects, deepening in the development of the scenes, both at modelling and animation stage. Afterward, a description of the interactive part implementation, considering the project objectives aimed at the creation of an Advanced Learning Environment and future developments.

Chapter 5 is focused on the VALE-Emotions App. The introduction is briefly outlined, followed by a detailed description of the User Requirements stablished. The key aspect discussed into this chapter is the proposal of a parameterization model for Dynamic Facial Expressions. This parameterization proposal was developed based on two codification models also presented inside this chapter. To conclude, a complete descrip-

tion of VALE-Emotions App developments and the future developments is shown.

Finally, in Chapter 6 the experimental research is explained, it consisted in two experimentations. The first one is the VALE-STEAM experimentation, and the second one is the VALE-Emotions in Spetial Education experimentation. For both experiments are described in detail subjects and materials, methods. At the end of each respective experimental results and discussions are presented.

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Chapter 1

Advanced Interactive Learning Environments: Beyond Traditional Education

1.1 Virtual Advanced Learning Environments (VALE)

The fact that the humanity is living in the digital era is undeniable, where the interconnection of everyday devices, such as video game consoles, tablets, mobile phones, TVs, portable PCs, among others, are increasing and rapidly becoming available to more users, as confirmed by IHS Inc.[1]. They have anticipated that between 2015 and 2017 will be produced and web-connected around 19.42 billion of new devices (IHS, 2013). The educational sphere, where children and youth are formed will be benefits. In fact, in the particular fields of education, advanced virtual worlds focus on the learning have emerged as a popular trend in the last years. These are less costly than traditional learning due to advancement in the computer interacting technology and the network infrastructures (Webster, 2015).

However, before going deeper into the Advanced Learning Environments concepts, it is essential to make a brief description of various terminologies that these new learning environments have brought to light. First, starting with the definition of Virtual Environments (VEs), which are a type of online community that takes the shape of a computer simulated environment, in which users can interact with others (Shin, Biocca, & Choo, 2011).

In the same approach, but adding the education factor, the Virtual Learning Environments (VLEs) have emerged. These are educational spaces also hosted on the web, and designed to support learning in a virtual environment that accessing them remotely through the internet connection. VLEs consist of a set of tools that allow a didac-

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[1]Information Handling Services (IHS) Technology (https://www.ihs.com/index.html)

tic interaction that supports training activities for teachers and students (Shin et al., 2011). Such activities range from assessment, transfer of contents, communication, file administration for student works, administration of student groups among others.

These VLEs originally were created to promote the distance education; but now they are also used to supplement teaching in the traditional classrooms, to make more efficient and interactive learning experiences (Benta, Bologa, & Dzitac, 2014). This form of education is known as learning mixed or b-learning. It consists of a systematic combination of face-to-face (teacher-student) and media technology interactions. This new way of teaching has gone beyond the traditional school environment. It has been created favorable conditions for the acquisition, exchange and produce knowledge, modifying the thinking strategies and the way of seeing the world (Limniou & Smith, 2010). It should be emphasized, through these VLEs the educational professionals have the possibility of transmitting their lectures to geographically dispersed students (Shin et al., 2011).

The advancement of three-dimensional (3D) technology quickly has carried the VLE term in a close synonym of 3D Virtual Learning Environment (3DVLE). The essential component is the three-dimensionality integration. It includes environment design with characteristics of representational fidelity that resembles the real world or even abstract environments. Moreover, also the creation of characters known as "avatars," that represents to the users, allow them to interact and move into these environments. These avatars allow users to construct, explore and manipulate the virtual objects. Hence, all the sensory organs are immersed in these artificial environments, generating a sense of reality and presence into the computer (Chau, Wong, et al., 2013). This feeling, above mentioned, is known as immersion, and it is one of the main features that distinguish these environments. This is based on the technical capabilities of Virtual Reality technologies to generate sensory stimulus, lead to enhancing spatial knowledge representation and growth in the engagement/motivation, all of these, without neglecting the opportunities of experiential learning (Dalgarno & Lee, 2010).

For the generation of immersion senses, as mentioned before, the systems need to be complemented on a specialized hardware. It can range from a special glasses of 3D visualization, one of the most commonly used, until full immersion systems where the user wears several kinds of devices to feel totally surrounded by virtual space. For example, full body suit embedded with biosensors, data gloves, and head-mounted displays. There are also available external mechanisms such as multidirectional treadmills, multi-wall Cave Automatic VE systems (known by the acronym 'CAVE'), high-degree-of-freedom input devices and video tracking systems (Carter, 2013).

Another of the main features of the 3DVLE is fidelity, whose primary objective is to generate a realistic representation and visualization environment interpretation by creating a high-quality 3D modeling. This based on the use of perspective and realistic textures with very detailed tricks to improve the effect of light and shadow of global illumination. These effects are known as Ambient Occlusion. Currently, it is possible to incorporate technologies sound and generate both a spatial perception as well as effects of direction and distance (Dalgarno & Lee, 2010).

After a descriptive introduction to 3DVLE, it is necessary to define the concept of

"Advanced", which has several connotations and interpretations. For this study, the Advanced VLE with a greater foundation in theory and practice were selected. Even the work of several universities and advanced development environments focused on learning are mentioned. It is worth mentioned that, the VALE concept is the main idea of this thesis.

One of the leading companies in the development of immersive training systems called Cubic Advanced Learning Solutions (CALS), argues that an "advanced" teaching environment combine the best cutting edge technologies with the most sophisticated processing formation. CALS systems are based on the use of highly immersive 3D virtual environment combined with the use of haptic technologies. Also, the known industry standards, such as Shareable Content Object Reference Model (SCORM), are taking into account for efficient interoperability e-learning. CALS systems integrate Augmented Reality (AR) technologies, where additional information is given to the users through mobile devices while they observe or navigate the real or virtual world. The goal of CALS systems is to increase the efficiency of training and provide cognitive assessment tools for customers (Cubic, 2015).

Moreover, the Center for Advanced Engineering Environments (CAEEs)[2] of Old Dominion University integrate into their projects engaging interactive modeling, visual simulations, and intelligent agents that have autonomy, proactive and reactive behavior and ability to interact with humans and even with other agents.

In this context, according to Murray, the several researchers, and developers of educational software are targeting their efforts in carrying out: Intelligent Tutoring Systems, Knowledge and Instructional based Adaptive Systems, and, Immersive Interfaces. The purpose is to reduce development costs and attain the active participation of educators in creating these systems (Murray, 2003).

From the perspective of OULU UAS (University of Applied Sciences), who are also developing projects in Virtual Advanced Learning; these environments has a key elements of the immersion and free exploration using 3D technologies together with the use of AR. Such environments can allow the construction of experience immersive learning without neglecting the narrative learning that allows dynamic interaction between the user (player) and the plot, where the user is transported. In this way, the player can feel as somehow within the environment, so being convinced that seems real and developing narrative as an actor in a play (Mott, Callaway, Zettlemoyer, Lee, & Lester, 1999). In another project called "Geoworlds," Second Life is used to develop knowledge of Advanced Geoscience," it has used the environments of multi-user 3D learning. Here, the students can interact with other users. Due to collaborative constructivist activities, students can solve advanced problem developing skills that are necessary for a society based on knowledge (Russell, Davies, & Totten, 2008).

Finally, but focused on special education, it is also presented the study of an advanced learning environment that effectively achieves the learning of social skills in children with Autism Spectrum Disorder (ASD), through "natural" communication between the child and a virtual character. In this case, multi-touch screen and the supervision of three web

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[2]http://www.aee.odu.edu/index2.php

cameras were used. The latter was used to detect the child's attention and expressions simultaneously. Through the collection of data, the system can adjust the virtual scene according to the information received (Chen, Chen, Wang, & Lemon, 2010).

As presented above, there are some common characteristic factors presents in the Virtual Advanced Learning Environments (VALE). These factors are the immersion, intelligent tutoring systems through intelligent agents, Augmented Reality and last narrative-centered learning. VALE makes enrich the learning experiences through the use of these latest technologies for the service of education.

1.1.1 Traditional Learning vs. Advanced Learning Environments

In the traditional way of teaching, teachers communicate and teach in a face-to-face relationship, transfer their knowledge and always maintain to control the teaching process. Through interpersonal interaction, such as observation of the behavior of their students, teachers are enabled to understand instantly if the subject has been understood or not (Yang & Liu, 2007). Teachers share lectures and presentations using PowerPoint slides, and teaching material that is delivered as predetermined texts. Students learn in a passive environment that generates little motivation in the students to participate actively in class or take part in discussions between teacher and students, much less between students themselves (Limniou & Smith, 2010). This is one of the problems in the traditional education system because it is based on learning methods teacher-centered and theories that does not fully integrated technology into the learning environment where only the teacher determines what is learned and when it is taught (Shi et al., 2010).

On one hand, we should also consider the difficulty of the teacher to focus on small groups of students and finding time to work with them individually. On the other side, another important aspect is the different learning styles that students have; which has been studied by several researchers who aim to improve the performance of pupils in the learning process. Even the teachers themselves have demonstrated their interest in these mentioned learning styles; but even if they knew all learning styles of their students, they could not implement them at the same time and in the same class, attempting to satisfy each one of the needs. This demonstrates another limitation that the traditional education system possesses (Limniou & Smith, 2010).

The advantage of this education system allows both teachers and students observe and communicate with each other directly, and not only in the terms of what each person said and how to do it. This interaction allows teachers to see how students work and collaborate and gives them the opportunity to teach collaboratively, and develop their interpersonal skills.

However, this form of education can become chaotic. Even though the most dedicated students, who had adopted the teaching methodology, fail to retain all the information submitted. In other cases, students are bored, so they lose interest and attention to the lesson. This cause distractions in the process of taking notes and leave gaps in their theoretical training, it also creates difficulties in understanding the goals of the class. In the end, both of the student and the teacher get unsatisfactory results and become

frustrated (Limniou & Smith, 2010).

In contrary, VALE presents an approach to student-centered learning, so enable to active learning and critical, leading to an improvement in the activities of acquiring knowledge through practice. Students are actively engaged in the recognition and resolution of problems, strengthening the long-term memory, improving both social skills and self-efficacy to cope successfully with real situations where such skills and knowledge are required (Shi et al., 2010).

Another benefit is the possibility that multiple users, such as teachers and students, geographically dispersed can explore at the same time a common environment. In these environments, each one is represented by an avatar, visible to other users. It enables them to communicate, interact and even carry out joint tasks. This is possible by using text and audio tools afforded by these systems as well as high-fidelity simulation environments in some of the particular situations. This leads to a rich collaborative learning to improve knowledge transfer. In these immersive environments, the objects that are found inside can be manipulated and moved freely. It is even possible to perform actions that are not possible easily perform in a real life such as flying or teleporting. It develops spatial skills and strengthening spatial cognitive skills that current generations of students already possess (Dalgarno & Lee, 2010). These environments are also appreciated because allows the simulation of tasks that compared with the real life could be dangerous, expensive or involve other some risks (Oliveira, Coelho, Guimarães, & Rebelo, 2012). So, these virtual environments are used to facilitate tasks of experiential learning that would be impractical and impossible to perform in the real world.

Meanwhile, the current generations of a student, who's born after 1989 and are known as "Digital Native," are characterized by a different way of processing information. They are very familiar and trained in the use of the new technologies and even regarded as a necessity for everyday activities and learning as well. Another feature of the Digital Native is that they prefer to receive information quickly and to use multiple communication channels to access such information as well as communicate with friends and teachers (Vaca Cárdenas, Bertacchini, Gabriele, et al., 2015; Shi et al., 2010; Chau, Wong, et al., 2013; Dalgarno & Lee, 2010).

As mentioned above, VALE has many advantages over traditional teaching due to the improvement of the learning experiences. However, they also have a drawback. Students do not receive human expressions or verbal explanation from teachers. So, they could miss the impact of gestures of teachers in the learning process. Besides of that, the contextual misunderstanding may occur due to lack of immediate feedback to check whether the issue has been understood (Yang & Liu, 2007).

Moreover, it is necessary to consider that the mere presence of VALEs does not guarantee optimal results in the learning process. These also require to be accompanied by an innovative pedagogical system and efficient management, through continuous training to educational professionals in the appropriate use of technologies and pedagogical innovations. Consequently, the new technologies in education do not replace teachers; but on the contrary, this intensifies their work more time for planning of learning strategies and supporting the learning activities performed by the students.

1.2   Virtual Advanced Learning Environments and STEAM

In this section, the education model called STEAM, which is an acronym for Science, Technology, Engineering, Arts and Mathematics, is introduced. This educational model involves the traditional academic subjects mentioned above, and these were structured in an integrative study program (Yakman, 2008).

Currently curricular projects address the different topics independently, but the new pedagogies claimed the union of emotion and reason. In response to this need, in 2006, Georgette Yakman developed a deep study of the model STEAM. She described one of the clearest existing conceptualizations:

*"ST $\sum$ @M : **Science** and **Technology**, interpreted through **Engineering** and the **Arts**, all based in a language of **Mathematics**."*

Yakman also gives a precise definition of each STEAM discipline and of each subfield that conform them currently, such as:

*"**Science:** what exists naturally and how it is affected,*
***Technology:** what is human-made Nature of Technology,*
***Engineering:** use of creativity and logic, based on mathematics and science, utilizing technology as a linking agent to create contributions to the world*
***Arts:** how society develops, impacts, is communicated and understood with its attitudes and customs in the past, present, and future,*
***Mathematics:** the study of numbers and operations."*

A pyramid structure of the STEAM fields, shown in the Figure 1.1, has been designed by Yakman (2008) to organize the teaching of these areas without establishing hierarchies between the disciplines of STEAM. This structure classifies all the areas of study, which allow students an understanding of the importance of relations among such fields. This pyramid shows how all branches of education and life works together, and how they are interconnected in the real life. All of this teaching concepts can be used with the students to develop skills in all areas.

In the book *"The Age of STEM"* of Freeman, Marginson, and Tytler (2015), the authors clarify that the Science, Technology, Engineering and Mathematics (STEM) disciplines are not superior to other disciplines. They also emphasize the need to raise the potential of the humanities and enhance the ability of education systems in social science, foreign language learning, occupational and vocational training outside STEM.

The integration of the Arts into STEM has been strongly considered in the last years (Kang et al., 2012). This fact shows that the Arts contain all divisions that interact with
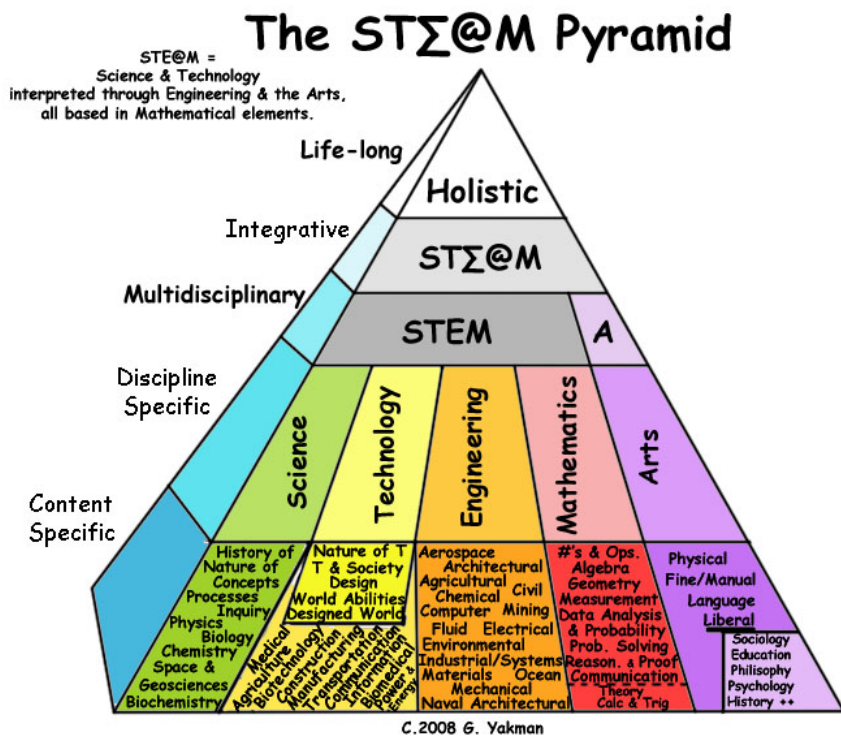
Figure 1.1: Pyramid structure designed by Yakman (2008) to organize the STEAM disciplines without establishing hierarchies between them.

the possibilities of combination with the other fields (Yakman & Lee, 2012). This faces us with a new framework for learning, where the desire to know and curiosity becomes knowledge engine and guidance. A starting point for exploring different solutions is a permanent research for personal satisfaction. This model provides an interdisciplinary education integrated approach, connected with the real world to generate the Creative Problem Solving (CPS).

According to Sousa and Pilecki (2013), *"Skills that influence the arts develop creativity, critical thinking, communication, concentration, autonomy, initiative, and collaboration"*. In fact, many scientists, mathematicians, and engineers, evaluate their activities, retrospectively, and have seen it in *"a certain artistic qualities"* the key of success that also help to work effectively with the others.

This evidence invites to review the current role of arts education in the curriculum (Yakman, 2008). In this context, artistic practices can be understood and valued in propedeutic sense, as a pre-preparation area for effective learning, training capacity of synthesis or channeling, and development of different knowledge and skills. Therefore, the scientific research through the arts empowers the imagination paying particular attention to the process of experimentation, whose primary driver is the desire and interest of who performs that.

In the conclusion, STEAM education allows teaching/learning synergies, from an active process driven by an experimental game that promotes the breakdown of barriers between disciplines. It also includes multiple possibilities at the crossroads of art, science and technology.

1.2.1   Development of STEAM Education

Society of XXI century faces a new paradigm of knowledge, complex and variable, that needs to be addressed effectively. However, this paradigm is not a new. In fact, hundreds of years ago, several educators, philosophers, scientists and educational psychologists talked about inclusive education. For examples, Comenius, the father of Education, who gave an important argument that establishes the basis for a global approach to education with the following statement:

> *"Individual sciences are badly taught unless a simple and general survey of the total knowledge is given before. . . one ought never to instruct anybody in such a way of perfecting one brand of knowledge to the exclusion of others" (Comenius, 1947).*

Moreover, Descartes, a contemporary of Comenius, was the first philosopher of education who made significant statements that can give strength to the development of the STEAM movement. He said the goal of education should be:

> *"Examine all things. . . including falsehoods, to know their value" (Descartes, 1947).*

Several famous scientists have shown that their artistic side has been fundamental to their personal development. For instance, Leonardo da Vinci, the Italian painter, and sculptor of the Renaissance, who also has been highlighted as a scientist, engineer,

and inventor. He could be the personification of STEAM by all these attributes. Another example is Albert Einstein, who undoubtedly rests on his scientific contributions, although the less known fact about him was his inestimable skills as a violinist.

This collection of statements and testimonies of educators, philosophers and world-renowned scientists highlight the example of how the integral STEAM education is the key to academic success. Therefore, it is essential to provide students with learning experiences of reality-based research that will enable them to think and discover the nature of reality and their interconnections. At present, the integral STEAM education is emerging as a successful at all levels of education worldwide. The two of the largest world powers, United States and Korea, have focused attention on the STEAM education in K-12 (K. Kim et al., 2014).

In the US, since 2007 has increased national investment in STEM education started from the kindergarten to the post-doctoral education. For this purpose a campaign called, "Educate to Innovate" was launched, which aims to improve the participation and performance of students in matters concerning to the global economy of the 21st century (Kang et al., 2012).

On the other side, Korea, supported by the Ministry of Education, Science and Technology (MEST), has also developed in recent years a training course for the new generations to turn them into innovative and creative, adding art to the fifth level STEM, and calling it STEAM (Kang et al., 2012).

In Europe, according to the recommendation of the European Parliament and of the Council (2006), *"there are a number of themes that are applied throughout the framework and involved in the eight key competences: critical thinking, creativity, the ability of initiative, problem-solving, risk assessment, decision-making and constructive management of feelings"* (Figel, 2006). All these skills are closely related to the STEAM education.

The Australian government has also joined in this initiative and is investing in education STEAM. It has focused on higher secondary levels with prospects of increasing the number of students aiming to choice STEAM disciplines in the university level (Freeman et al., 2015).

Some emerging countries like Brazil and South Africa have also shown interest in STEAM programs. Their challenge has begun by setting the policy regarding quality education and the development of technology (Kang et al., 2012).

In the field of finance and industry, STEAM has also become the focus of the global economy. Several studies have confirmed, every nation with a strong economy is linked to an integrated education STEAM (Ko, An, & Park, 2012). Consequently, STEAM competitions are the key to higher productivity, technological adaptation, and innovation based on research. This results is the improvement of innovation in the industry, and staff productivity through the use of knowledge and skills (Park, 2014a). Facing this reality, it has been demonstrated that is necessary to begin to form STEAM skills in elementary school students, taking into account the future of society and demands.

1.2.2 Current Research on 3D Systems for STEAM Education

In the last years, along with the development of technologies that have produced devices with advanced educational content, the STEAM education has gained ground. As a consequence, the programs and applications based on the convergence of knowledge have been implemented by Hong and Hwang (2013). This leads to an advanced level of learning, through the use of variety intelligent devices. This advanced learning has opened a new form of education based on Augmented Reality (AR) and 3D content in immersive environments. All this technology produce more interactive and engaging learning (Hong & Hwang, 2013).

Some researchers note that young people should have the same opportunities to consume and create interactive media, which developed certain provisions and capacities, pointing to the need for facilitation access to environments where they can develop as creators (Boy, 2013; Brennan, Monroy-Hernández, & Resnick, 2010). In this way, students should be trained to have sufficient understanding of the issues STEAM to achieve it, so in the future, they will be able to choose which career path will be interested in dedicating their lives. Therefore, students should have ample opportunities to participate in these advanced and better systems, if they can start from the basic education (Y. Kim & Park, 2012b).

On the other hand, based on center focused on teachers, researchers are creating training programs targeted for teachers, who teach the fundamental concepts of STEAM education and also share the latest science and technology content. One of these groups has applied the principles of learning from David Merrill, who claims to learn a particular program implementation of the first principles and it will be promoted in direct proportion (Kang et al., 2012).

1.2.3 Some Examples of VALE in STEAM Education

STEAM learning framework, which has been described in the previous lines, is now complimented with several practical issues that are illustrating the main keys of these environments applied to the education.

The first example is the "Development and Application of STEAM Teaching Model based on the Rube Goldberg's Invention" presented by Y. Kim and Park (2012a). The authors show in their work the perfect affinity of Rube Goldberg's Inventions with STEAM education. The Rube Goldberg's Inventions, the main concern about complicated mechanisms to solve creatively simple problems and make them attractive. Various contributions and efforts to develop such mechanisms range from the scientific knowledge, the mathematical reasoning, the engineering design, and the capacity for technical operation, is required. With this basis that links all the STEAM elements, teaching materials, that can be applied within the curriculums, have been developed (Y. Kim & Park, 2012b). In particular, the development and implementation of the project are to aim for creating an amusement park using the Rube Goldberg inventions presented before. The activities are designed to be developed in a team. They also have materials such as texts guidance. For the evaluation of the outcome of the investigation, the

Figure 1.2: Goldberg's machine simulation animated by the 3D software iClone.

model "One-Group Pretest-Posttest Design" of Bell (2010), Fraenkel and Wallen (1996) has been used. This model analyzes the variation in the dependent variable after the program has been implemented. Through the development of engineering/technology related to the STEAM program, there has been an improvement in the capacity for scientific research in the elementary students who participated in the program. Besides, their interest in science has been significantly increased (Y. Kim & Park, 2014).

These types of applications are so fascinating that can be performed using 3D animations. An example of Rube Goldberg inventions using computer animation is presented below. This last was developed with the 3D animation software called iClone. This animation was based on scientific concepts with engineering fundamentals, and supported by high precision physical laws, mathematical calculations and especially with much creativity steps (see Figure 1.2).

Although, the result of each of these inventions is poor compared with the performed effort; the creation of each invention is fascinating because humans with remarkable ability can make more effort to get the simple result. Like has been defined by Rube Goldberg machines' inventor. These inventions can strengthen the student's skills in STEAM education. They also can help to find alternative solutions for solving problems in both schools and daily life.

With the equal interest in promoting creativity and generating a positive attitude toward science and engineering by students, Oh, Lee, and Kim (2013) have developed an Educational STEAM Program using a free software known as Scratch. It is a friendly learning environment programming language especially intended for children. In this case, the computer has become the primary tool to carry out the teaching process. Also with this software, children can create and schedule games in a real-time while developing artistic activities, such as to design their characters, to select background music and also to develop scripts of the game without theme restrictions. The results scratch-based STEAM education are positive, because, they improve a fluidity of ideas, originality and creativity (Vaca Cárdenas, Bertacchini, Gabriele, et al., 2015).

Also, a platform based on 3d Modelling and Simulation (M&S) for a smart learning has been developed. This work provides a learning platform for the next generation of advanced creative learning, which allowed students to absorb the knowledge and apply it rapidly through a simulation using a virtual robot. The platform provides

a simulation environment that is synchronized with the robot software. The students must understand the proposal problem and have an imagination about a robot that is capable of a problem solver. The robot is easily assembled by dragging the left parties and dropping them on the home screen. After the robot is completed, simulation and experimentation are performed (Hong & Hwang, 2013). M&S-3D education platform includes science, mathematics, and art for an intelligent learning. It consists of two parts, which are modeling and simulation. The platform allows a robot designer based on the scientific principles, artistically formed and also development software with a mathematical algorithm.

In the work performed by Park (2014b), the *"Presentation of Video Continuity Using 3D Floating Technique for STEAM Education"* is intended to teach, in an easy and a pleasant way, about the contents of mathematics, science, and technology. The purpose is to encourage students and gather any information related to science through movies, and then, to convert them into high-tech communications tools. The possibility of interesting film production is also provided within the activities. Thereby, they purport is to show how industry, technology, art and science are interrelated. Students learn to use the technique of reflection and floating 3D technology (similar to hologram technology) that used a direct projection, which allows interaction with the hologram. These techniques were used to put a picture in the air and to move it freely as in the film of the "Iron Man", when the hero uses a hologram to design a special suit and to do a test, directly on the holographic environment.

In this way, STEAM students must learn to apply the techniques and skills associated with mathematical and scientific principles. In order to acquire the ability to become lifelong learners, to conduct experiments, to analyze and to interpret data, systems design, components or process. Also developing skills to work in multidisciplinary teams, formulating and solving engineering problems and having a positive impact to the world (Yakman, 2008).

1.3 Virtual Advanced Learning Environments in the Special Education Field

There are several fields of Special Education where the virtual teaching with advanced technologies is being used. Nowadays, several researchers and educators are hardly working together with the developers' systems, to provide innovative and useful tools that offer immediate assistance to patients with special needs. Such tools promote the daily use and the integration of New Technologies in special teaching methodologies (Bilotta, Gabriele, Servidio, & Tavernise, 2010; Chen et al., 2010; Porayska-Pomsta et al., 2012). These experts have specific expertise in planning educational activities to support individuals with several developmental disorders, including Autism Spectrum Disorders (ASD). In this context, there are a lot of different studies that confirmed that individuals with special needs have the ability to use and to interpret satisfactorily virtual environments (Parsons, Mitchell, & Leonard, 2004; Saiano et al., 2015; Stichter, Laffey, Galyen, & Herzog, 2013). This ASD subjects also have been proven to be quite an

affinity with the technological means. Finally, the main areas of learning regarding the Special Education are the *Emotion Recognition, the Simple Social Skills, and the Social Communication Concepts* (Abirached et al., 2011; F. Bertacchini, Bilotta, Gabriele, Olmedo Vizueta, et al., 2013; Olmedo Vizueta et al., 2014; Santamaría Granados & Torres Gutiérrez, 2013). For these reasons have been developed several systems to enhance the learning in this particular areas. These systems are described below.

1.3.1 Facial Action Coding System: *Emotions Recognition*

When talking about the recognition of emotions, it is inevitable to mention the psychologist Paul Ekman, since his studies were beyond of the empirical knowledge at that time. In his first works, Ekman and his colleagues have founded evidence about an appeared universality in certain facial expressions of emotions (Paul Ekman, 1989; Paul Ekman & Friesen, 1971; Paul Ekman & Heider, 1988; Paul Ekman, Sorenson, & Friesen, 1969; Paul Ekman, 1970, 1984). Later on, in other studies, Ekman found arguments that were leading him to make new statements about facial expressions regarding the universals and the different aspects between cultures. Some of these statements express that *"the universal in facial expressions of emotion is the connection between particular facial configurations and specific emotions"* (Paul Ekman, 1992). Regarding the "Basic Emotions", Ekman describes both the characteristics that used in distinguishing one emotion from another and the characteristics shared by all emotions (Paul Ekman, 1999a; Paul Ekman & Davidson, 1994; Paul Ekman, 1984, 1992).

Nevertheless, until then, researchers had difficulty to perform an efficient measure of facial movements. It was due to the lack of a common nomenclature. This purpose motivated to Ekman and his colleague Wallace Friesen to develop a comprehensive measuring method of the different facial movements. This method made them become the pioneers in the development of measurement systems for facial expression (P Ekman & Friesen, 1976). This procedure is now known as Facial Action Coding System (FACS). It describes any facial movement in terms of minimal Action Units (AUs) based on anatomical analysis. The AUs are the specific facial muscle movements, and the measurement is a descriptive analysis of behavior. It is important to note that each AU could be produced by two or three different muscles (P Ekman, 1982; Stewart Bartlett, Hager, Ekman, & Sejnowski, 1999).

The FACS basically can distinguish all possible visually distinguishable facial movements. For this gain, it was necessary to discover how each muscle of the face acts to change visible appearance (Cohn, Ambadar, & Ekman, 2007; P Ekman & Friesen, 1976). The final AUs presented by Ekman and Friesen is shown in Figure 1.3. The names and the numbers of each AU are also displayed. Until now, three official versions of FACS have been released. The initial version was FACS-1978, the document-based update FACS-1992 was the second one, and the last edition FACS-2002 that includes improvements in the scoring criteria and didactic materials among others (Cohn et al., 2007).

Based on jobs of Ekman and Friesen, the pictures of facial expressions developed in their works are principally used until today in several studies that are referred to the

Upper Face Action Units					
AU 1	AU 2	AU 4	AU 5	AU 6	AU 7
Inner Brow Raiser	Outer Brow Raiser	Brow Lowerer	Upper Lid Raiser	Cheek Raiser	Lid Tightener
*AU 41	*AU 42	*AU 43	AU 44	AU 45	AU 46
Lid Droop	Slit	Eyes Closed	Squint	Blink	Wink

Lower Face Action Units					
AU 9	AU 10	AU 11	AU 12	AU 13	AU 14
Nose Wrinkler	Upper Lip Raiser	Nasolabial Deepener	Lip Corner Puller	Cheek Puffer	Dimpler
AU 15	AU 16	AU 17	AU 18	AU 20	AU 22
Lip Corner Depressor	Lower Lip Depressor	Chin Raiser	Lip Puckerer	Lip Stretcher	Lip Funneler
AU 23	AU 24	*AU 25	*AU 26	*AU 27	AU 28
Lip Tightener	Lip Pressor	Lips Part	Jaw Drop	Mouth Stretch	Lip Suck

Figure 1.3: Collection of Action Units (AU) from the Facial Action Coding System for human expressions presented by P Ekman and Friesen (1976).
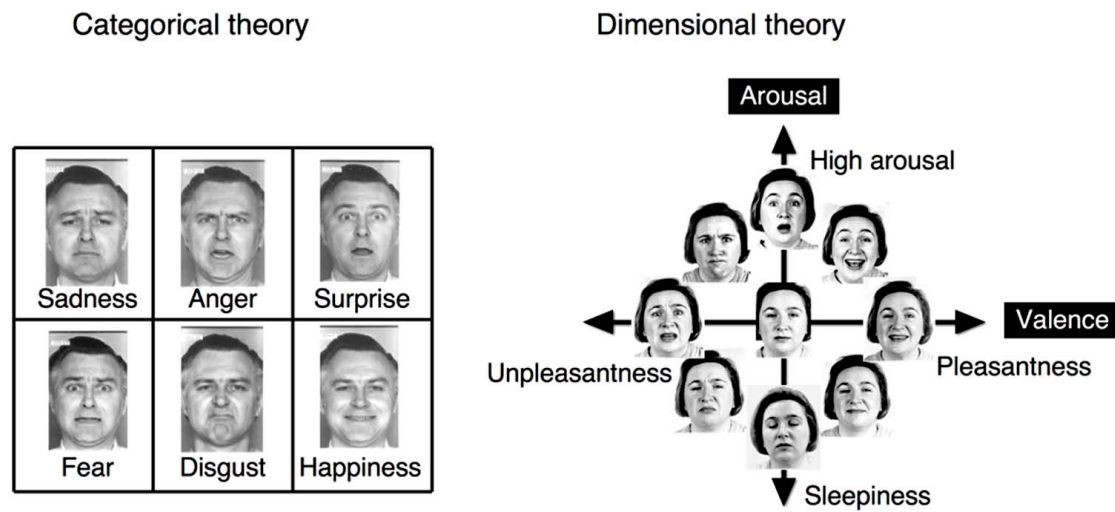
Figure 1.4: The two different theories, regarding facial emotion, verified by Matsuda et al. (2013).

emotions recognition. This is due to its descriptive power. For instance, a reliable and valid tool to identify the emotional ability to recognize faces in the Colombian context has been created by Duarte, Elías, Sarmiento, Leonel, and Santos (2012). For this purpose, an analysis of the items of an instrument to identify the facial images, that are easily recognizable by the participants, has been made which uses the theoretical model of Ekman and Friesen as a reference.

Also, the images of the six basic emotions have been used in a study of the perception of social signals transmitted by mobile facial characteristics created through a caricaturing process (Calder, Young, Rowland, & Perrett, 1997). In other cases, the prototypical expressions of the six basic emotions have been classified using neural network models. In this case, two theories, named Categorical and Dimensional, have been verified by Dailey, Cottrell, Padgett, and Adolphs (2002). In the first theory, expression categories are considered to be discrete entities. The categorical theory proposes the existence of six basic, distinct and universal emotions with sharp boundaries separating emotional states. On the other hand, in the Dimensional theory, the facial expressions perception is more graded. This theory proposes the existence of two fundamental emotional dimensions denominated *valence* and *arousal*, which form an emotional space. Moreover, the work of Matsuda et al. (2013) demonstrates that both categorical and dimensional perception are induced in an implicit way through a hybrid process that links them. In the Figure 1.4, an instantiation of these two theories is displayed.

1.3.2   Video Modeling Systems for ASD: *Simple Social Skills* and *Social Communication Concepts*

According to current diagnostic criteria, children affected by Autism Spectrum Disorders (ASD) are characterized by a strong difficulty in communication and interaction in the social areas, difficulties in maintaining visual contact with people, and limited focus of attention on specific multisensory cues (Association American Psychiatric, 2013). Frequently detected deficits consist of a lack of social initiations and responses, social speech, empathy, and joint attention. In this field, the Video Modeling technologies have been successfully used to capture the attention of ASD children, allowing them new kinds of learning of social skills. Besides, adults with ASD have expressed their confidence in visually based information (Huaqing Qi & Lin, 2012; Welch, Lahiri, Warren, & Sarkar, 2010; Ganz, Earles-Vollrath, & Cook, 2011; Saiano et al., 2015; Porayska-Pomsta et al., 2012).

Video Modeling (VM) is a technological video-based strategy to provide modeling of targeted skills (Bellini & Akullian, 2007). The videos presented through this strategy, which can be either Video Self-Modeling (VSM) that includes the participants or Normal Videos that includes other subjects, have been found effective in teaching new skills. The VM that includes "other" models is easier to produce because these require less editing than the VSM. Implementing the VM with ASD subjects, it is necessary to identify the skills to be targeted, then producing the videos and finally to apply the intervention (Ganz et al., 2011).

Peter Dowrick was one of the earliest researchers to demonstrate the effectiveness of this VM methodology; the main idea was to make videotapes registrations in which a boy would be the model. The assessment revealed that the child achieved a remarkable improvement after several repetitions watching the recorded tape of 5 minutes (Dowrick, 1991). Research has demonstrated that both in-vivo and video modeling are effective not only in teaching new behaviors to children with autism but also in promoting the maintaining of these behaviors. In this way, the VM strategy has been compared with activities of Pivoral Response Training (PRT) to determine the effectiveness of play skills learning in children with ASD. The results were favorable for both methods in the number of game actions in the training environment (Lydon, Healy, & Leader, 2011).

The VM is very useful because it allows performing infinite repetitiveness of the same situations using engaged and amusing contents. This also lets the stimuli presentation inside familiar environments to address social skills deficiencies of children with ASD in a low-cost and unobtrusive fashion (Ganz et al., 2011; Huaqing Qi & Lin, 2012). Also, it promotes independent functioning, and allows address numerous learner objectives, like behavioral, communicational, and social. It consists of a video observation of another person engaged in a target behavior. This activity motivates a subsequent imitation to initiate response chains. It intends gain that the obtained imitation skills can be maintained post-treatment and, to varying degrees, generalized to the imitation of live models (Van Gog, Verveer, & Verveer, 2014; Tereshko, MacDonald, & Ahearn, 2010; Cardon, 2012).

Another advantage also includes the possibility to analyze the expressive language
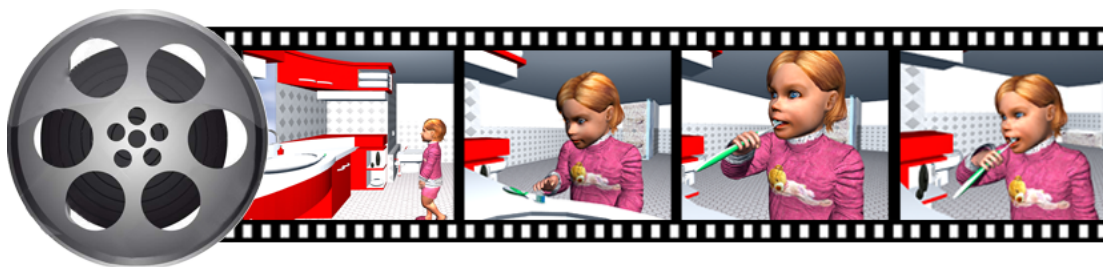
Figure 1.5: Video Modeling of how to brush teeth teaching sequence performed by Olmedo Vizueta et al. (2014).

development skills after exposure to a Video Modeling Imitation Training (VMIT) (Cardon, 2012). Without neglecting the fact that the use of this visually based intervention allows the use of cutting-edge technologies (Alexander, Ayres, Smith, Shepley, & Mataras, 2013). In this way, the Evolutionary Systems Group (ESG) at University of Calabria (UNICAL) has developed an Edutainment Video Modeling system through 3D virtual-modeling situations situated in ordinary environments. It is with the aim of to support and to help psychologists, therapists, teachers and families in showing different social skills to ASD subjects. The educational program is formed by short filmed clips of a virtual agent with targeted behaviors (audio included). For example, in the Figure 1.5, it is shown the 3D Video Modelling teaching how to brush teeth. Hence, some specific skills can be showed and motivate, as the maintaining of the eye contact or daily life communication events (Olmedo Vizueta et al., 2014).

1.4 Some Examples of VALE in Special Education

One of the fields that attract much attention, from both researchers and system developers, is the treatment of people with special needs. Regarding the problem of face recognition, the subjects with ASD have problems understanding the mental and emotional state of other persons around them (Uljarevic & Hamilton, 2013). In order to help them to solve this issue, some tools have been developed to train individuals with High Functioning Autism (HFA) in the recognition and identification of emotions. These tools can be customized to the individual needs and functioning levels, through a basic drill and practice that allows the users to create their personal avatars from a photography (which may be the same user) and also to virtually develop ad-hoc build social situations (F. Bertacchini, Bilotta, Gabriele, Olmedo Vizueta, et al., 2013). In the same vein, a computer-based game called JeStiMulE has been developed, which is targeting both individuals with HFA also as well as persons with a Low Functioning Autism (LFA). This is an individual and a multi-sensory interactive computer game that is played with a gamepad for training in emotion recognition that is including the facial expressions, the gestures emotional, and also the social situations. This tool is intended to help individuals to increase their understanding to the social world (Serret

et al., 2014).

VALE also has been used to develop the social skills and the abilities of young people with ADS. These educational resources facilitate an interaction and behavior assessment in the collaborative activities, by repeating regular tasks (Stichter et al., 2013). It has been shown that these environments provide a virtual social setting that supports the vital learning social skills, and it has become an appropriate intervention that facilitates communication in a socially acceptable manner (Piccin, 2014).

Another varied educational strategies based on technology are those that use video modeling in order to capture the attention and to teach (or revise) some core competencies linked to the three fundamental problems presented by children affected by ASD: language delay, lack of social relationship and stereotyped movements. Specifically, it is a video 3D modeling system, where short videos show reconstructed ordinary virtual environments (i.e. home, school) indicating specific behaviors recreated by virtual infant agents. This system allows infinite repetition of the same situation, and also provides constructive feedback, in order to enable the setting of observational learning, with a strong reinforcing action (Olmedo Vizueta et al., 2014). The video-based intervention allows acquiring relevant academic and functional skills that motivate students with ASD to participate fully in the core curriculum. This also presents a higher concentration both on individual strengths and promoting of the highest level of possible independence (Burton, Anderson, Prater, & Dyches, 2013). 3D modeling may also be employed as rehabilitation system with animated tutoring for children with autism, cybertherapy, and cognitive rehabilitation. This system uses sensors and cameras for analysis of facial expression and gaze tracking that serve as guides to focus the student's attention. Usually, it also includes a biofeedback device to measure stress levels and other input/output parameters for Virtual Reality (Takács, 2005).

Another case of technology-assisted intervention combines the use of robots in teaching social skills for children with ASD, which allows taking advantage of the attraction that these last present by such robots. However, currently, guidelines on how to develop robots socially acceptable do not exist, consequently as a first step it has been investigated and evaluated the design of a system for social interaction with virtual robots. For the assessments two important social parameters were considered to determine which elements cause an emotional reaction; the first one was the eye gaze, and the second one was the social distance. Such results lead to identifying which specific component could be vulnerable during social interaction. This system has effectively contributed to the development of future social robots for children with ASD (Welch et al., 2010).

Moreover, the system developed by Professor Chen-Ching (Samson) Cheung[3] is aiming to improve behavioral therapy for people with autism and related disorders. Since it has been shown that people, with this disorder, present disinterest in social interactions; but they seem to be very interested in their image in mirrors, or similars, imitating their actions. Therefore, the system is a "virtual mirror" that captures the gaze, facial

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[3]Dr, Sen-Ching (Samson) Cheung, Vis Center faculty member, The University of Kentucky Center for Visualization & Virtual Environments (http://vis.uky.edu/blog/2012/09/14/samson-cheung-awarded-nsf-grant-for-autism-therapy-research/)

expression, body movement, and other patterns of human behavior, and with the help of multimedia processing algorithms generating effective models of behavior (Shen, Su, Cheung, & Zhao, 2013).

On the other hand, focusing on children with Down syndrome and cognitive impairment, virtual environments have been implemented to develop reading and writing skills in period's logo visually and aurally. Such therapies have been created because children with this aforementioned syndrome have problems in developing skills in the learning process understandable and quickly. It has been proven that with the help of these innovative therapies, an improvement and great interest in exploring the virtual scenarios of the program is obtained, and also to meet the learning objectives (Santamaría Granados & Torres Gutiérrez, 2013).

Additionally, thinking about people with intellectual disabilities in different ages, a multimodal prototype has been created in the Virtual World of Second Life. This environment is a hospital scenario in order to provide information related to health care. All patients voluntarily agreed and were able to fend for themselves in the environment through assigned avatar. It was shown that this virtual environment helps knowledge retention, and the permanent use promises good results (Hall, Conboy-Hill, & Taylor, 2011).

Each of technological tools presented above provides for direct and immediate patients with various special needs intervention. They are promising strategies that utilize the most innovative technological advances in order to improve the quality of life of each patient. These systems require cooperative and collaborative work of an interdisciplinary and multi-functional team to articulate the pedagogical and technical approaches for optimal development in each treatment.

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Chapter 2

Interacting with Virtual Worlds

2.1 Human Computer Interaction

The Human Computer Interaction (HCI) concept was born with the emergence of the machine itself. The idea of this concept is based on: "most sophisticated machines are worthless unless they can be used properly by men." Consequently, the essential terms in the HCI design are both functionality[1] and usability[2]. In 1996, HCI was defined as "A discipline concerned with the design, evaluation, and implementation of computing systems for human use and with the study of major phenomena surrounding them" (Ritter, Baxter, & Churchill, 2014; ACM SIGCHI, 1997). In this way, HCI is a main interdisciplinary conjunction of several sciences and technologies (Shackel, 2009). Complementary to this HCI is a design that should suit the users, the machine and services, in order to achieve optimum performance in such required services (P. Zhang, Carey, & Te'eni, 2007; Karray, Alemzadeh, Saleh, & Arab, 2008; Fetaji, Loskoska, Fetaji, & Ebibi, 2007).

It has been stated that HCI seeks the human benefit. In fact, the usefully of HCI depends on aspects of human behaviours and needs considered. The user activity can be considered at three different levels. The first one, is the physical level, it determine the mechanics of interaction between human and computer. The second one, is the cognitive level, help the users to understand the system and to interact with it. And the last one, the affective level, encourages the user to continue to use the machine while causing a pleasant experience during interaction (P. Zhang et al., 2007).

HCI stems from a multidisciplinary nature that has developed innovation and creativity in computing field. Around the world, a growing number of general HCI interfaces have been seeing. However, there are some aspects to consider when designing the HCI interfaces. These aspects are the frequent *practice* that improves the performance. The knowledge *transfer* that depends of the user's experience (expert or novice) using the

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[1]Set of actions or services to be efficiently utilized by the user.
[2]The range and degree by which the system can be used efficiently.

interface, in this case can be provided alternative interfaces. The *exploration* performed through factors that facilitate learning. The *vocabulary* adapted to the user target (Zeng, Sun, & Wang, 2012; Fetaji et al., 2007).

2.2   Principles for HCI

Initially, several researchers were agreeing on the main principles to consider during the HCI design (Dumas & Redish, 1999; Shneiderman, 1992; Fetaji et al., 2007; Shneiderman, 1986). The correct application of these main principles for HCI achieves the user satisfaction, optimizes the performance speed, and consequently reduces the error rates (Shneiderman, 1986; Bevan, 2001). These principles are summarized as:

- Give the operations control to the user.

- Maintain consistency in procedures, formats and wording.

- Offer informative and adequate feedback.

- Minimize the operation work, which reduces working memory load.

On the last years, several international standards have been developed to support the general principles of HCI and the correct way to design the user interfaces (Biswas & Langdon, 2011). These international standards specify hardware and software interfaces and procedures for achieving quality. For example, the ISO 9001 explains how the usability of a product can be specified and evaluated as part of a quality system, and the ISO 9241 gives detailed guidance and principles software interface and interaction design, thus permitting a flexibility design. Related to the usability, the standards have been categorized as:

- The user interface and interaction.

- The process used to develop the product.

- The capability of an organization to apply User Centred Design (UCD).

- The use of the product (effectiveness, efficiency and satisfaction in a particular context of use).

Concluding, the usability is the extent to which a product can be used with effectiveness, efficiency and satisfaction by specified users. Therefore, it requires an organizational capability to support UCD (Bevan, 2001).

2.3   Existing Technologies in HCI and Recent Advances

The HCI advances are increasingly natural to use every day, which provides a pleasurable, easier, and satisfying experience for the users. In other cases, this HCI advances have hampered the ability to easily differentiate between what is fiction and what is real (Karray et al., 2008).

As regards existing physical technologies for HCI, the devices are classified according to the relative human sense for which it was designed. Vision, hearing and touch, are the three human senses considered. The systems that are based on only one modality are called unimodal (Dmello, Dowell, & Graesser, 2013; Karray et al., 2008). Therefore, the devices based on vision, are subdivided in output and input devices. The output devices can be any kind of visual display or printing device, instead, the input devices are commonly either switch-based or pointing devices. For example: keyboard and joystick, respectively. On the other hand, the devices based on audition, usually needs some kind of speech recognition. The alarms or navigation commands of a Global Positioning System (GPS) device are some examples. Finally, the haptic devices which functioning through touch, are generally used in virtual reality or disability assistive applications (Lok & Larry, 2004; Fetaji et al., 2007).

At present, the recent methods and technologies in HCI are focused on combining of the common interaction methods with advancing technologies. This combination of multiple modalities is denominated Multimodal Human Computer Interaction Systems (MMHCI) (Pantic & Rothkrantz, 2003; Dmello et al., 2013). The Figure 2.1 shows an example of MMHCI by a innovative projection keyboard interface. This is a virtual keyboard that is made by projecting on a solid surface using a red light. When the user touches the surface covered by the key image, the device records the corresponding keystroke (Brookstone, 2013).

Regarding to the current HCI research advances, they are based on intelligent and adaptive interfaces, and, ubiquitous computing. These interfaces engage the three user activity levels above mentioned. The intelligent and adaptive interfaces depend on the way of interaction with the users according to the used intelligence during the interface creation (Zeng et al., 2012; Karray et al., 2008). The smart interfaces design incorporate intelligence in perception from users' responses. For example Siri Begley app[3] that uses the natural language to interact with the user, answering questions, making recommendations and doing actions by delegating requests to a set of web services. The adaptive HCI designs are based on the cognitive and affective levels in the activity of the user. These interfaces are programed to recognize and to follow the users' interaction way and consecutively delivers interfaces adapted to their shown needs. The websites with regular Graphical User Interfaces (GUIs) for selling various products are a good example. These latter keep a memory of users' searches and purchases and intelligently search, find, and suggest products to them.

On the other hand it is the ubiquitous computing also referred as ambient intelligence. It refers to the ultimate methods of HCI that have replaced the desktops to embed the

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[3]http://www.apple.com/es/ios/siri/

Figure 2.1: Virtual laser keyboard (Brookstone, 2013).

computer in the environments. In this way the computer becomes invisible to humans while around them everywhere in the ambient (Riva, Vatalaro, Davide, & Alcañiz, 2005).

2.3.1 Application of HCI in Disabled People Assistance

The better HCI applications are devoted to assist disabled people who need other kinds of interfaces than ordinary people. Many communication aids have been developed for people with severe physical disabilities as Amyotrophic Lateral Sclerosis (ALS). These systems allow the interaction with the PC through eye-gaze detection, voice and head movement (Biswas & Langdon, 2011; Kiyohiko, Shoichi, & Minoru, 2013).

The operation of this system requires basically of the head or eyes movements and/or the speech of the user. An example of these systems is promoted by LC Technologies, Inc.[4] through the assistive technologies, based on eye tracking systems, for ALS patients as shown in Figure 2.2. Thereby, the head/eyes position indicates the coordinates of the cursor in real time on the screen. The speech indicates the action that must be performed with an object selected by the cursor.

2.4 HCI Devices Used in VALE

As mentioned before, the development of promising technologies is continuously seeking a better stimulation of our senses. The physical technologies for HCI are classified in three types: devices based on vision, devices based on audition and haptic devices. The

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[4]http://www.eyegaze.com/

Figure 2.2: Disabled users navigation with eye tracker point.

conventional input/output devices used are keyboard, mouse, and conventional computer display that are used in command based interactions (Fetaji et al., 2007). Instead, the advanced systems and virtual environments use the newest input and output devices like autostereoscopic displays, 3D virtual reality glasses, haptic sensors, multi touch table and tablets, among others.

In the Virtual Advanced Learning Environments (VALE) that is presented in the next chapters, some of these cutting edge technology devices are utilized. These devices constitute 3D virtual reality glasses for mobile platforms, 3D mouse, 3D sound and television, and touch screens by tablets and blackboards. A brief description of the latter devices is performed below.

2.4.1 3D Mouse Prototype

Massive production of Microelectromechanical Systems (MEMS) sensors has opened a new field of advanced peripherals devices for the nowadays computing systems (Ciuti, Ricotti, Menciassi, & Dario, 2015). In particular, motion tracking sensors based on MEMS (i. e. giroscopes, accelerometers and magnetometers) allow for the development of 3D mouses. The latter are peripheral devices that are useful for interaction in 3D development environments. However, 3D mouses can easily also used in game environments. In fact, due to 3D mouses let an accurate 3-axis movement representation in virtual reality games, these permit to human players to interact inside a virtual world experiencing sensations of reality. For instance, normal tasks with objects, like zoom, drags, rotation, translation among others, can be actioned by effective movements of a 3D mouse. Since a decade, 3D mouses are in commerce as the named *Falcon* presented by Novint Technologies, Inc.[5] (see Figure 2.3).

Furthermore, a 3D mouse prototype was experimented using some scenarios of the VALE described in the next chapters. This prototype was developed using the STM32F

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[5]http://www.novint.com/
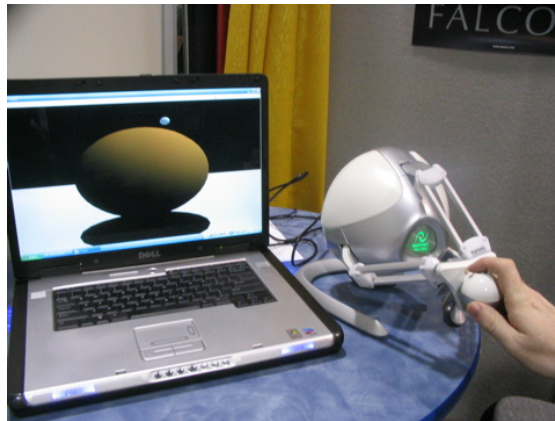
Figure 2.3: 3D haptic device named *Falcon* commercialized by Novint Technologies, Inc.

401RE Nucleo board of STMicroelectronics[6] and a MPU-9150 9-axis MEMS sensor from Invensense[7]. Additionally, a bluetooth HC-05 module for wireless communication with mobile platforms or computer was used. The portability of the 3D mouse prototype is guaranteed through the utilization of a rechargeable battery pack. A click button was also added to the prototype to implement more flexibility of commands to be interpreted in the 3D scenarios of the VALE developed in Unity 3D that is presented in next chapter. The 3D mouse prototype is presented in the Figure 2.4. The programming of the functionalities and operation of the 3D mouse was performed in ARMmbed developer website[8].

The principle of operation of the 3D mouse prototype is to detect the natural movements of rotation and translation (acceleration) that the user can do with the physical board (see Figure 2.4). The 9-axis coordinates (giroscope, accelerometer and magnetometer) are sent as a data frame to a mobile or PC platform through a bluetooh connection. Once the application (3D scenarios of the VALE) receives the data frame, spatial calculation for the representation of movements in the virtual world are performed using the different libraries that Unity implements in its development environment for 3D animation.

2.4.2 VR Glasses for Mobile Platforms

Virtual Reality (VR) experiences are closer to the users through VR glasses that emulate the 3D projection of contents in a portable way. There are a spread vary in VR glasses whose purpose is to allow a media contents side-by-side visualization to render the sensation of being inside the virtual worlds. Famous commercial marks (i.

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[6]www.st.com/stm32nucleo

[7]www.invensense.com/products/motion-tracking/9-axis/mpu-9150/

[8]https://developer.mbed.org/

1) MEMS Sensor MPU-9150   2) Nucleo - 401E Board   3)Battery   4)Bluetooth module   5) Click Button   6) Switch On/Off
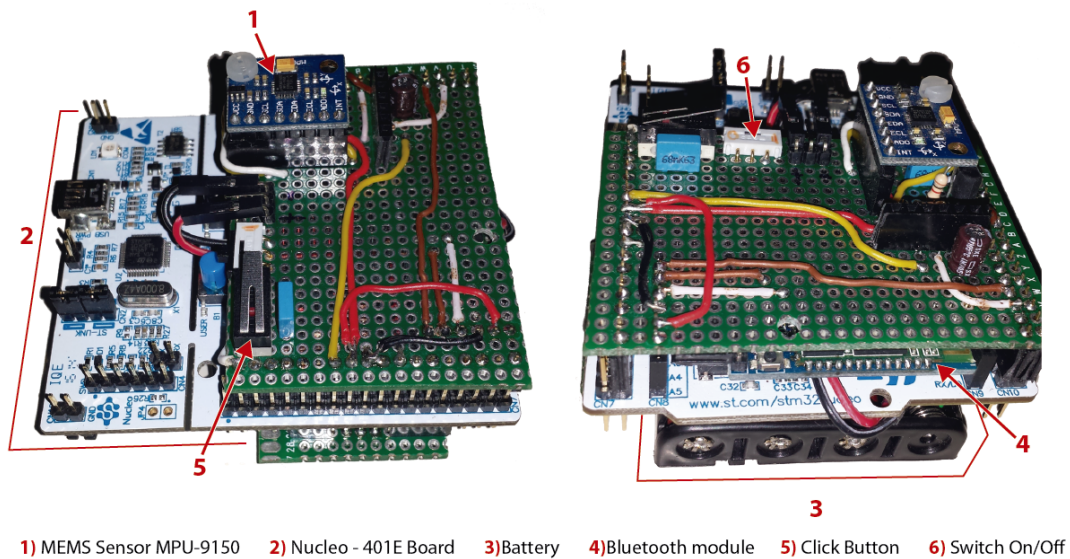
Figure 2.4: 3D haptic mouse prototype developed for the VALE 3D scenarios.

e. Oculus) present VR glasses as a peripheral device for visualization of 3D-games or 3D-films in computers or gaming platforms. Additionally, options like sound, motion tracking and real-time side-by-side visualization are also implemented. Moreover, these kind of devices are expensive and massive diffusion of these of applications has not been possible.

Moreover, alternative projects to render VR glasses more accessible to users have been proposed to use a singular smartphone for the visualization of media contents in a similar manner to those of specific VR glasses before mentioned. The most diffused project is the *Google Cardboard*[9]. The latter is a folded cardboard simple viewer VR glasses for VR experiences through a variety of Android apps. Similarly, other designs of VR glasses structures for smartphones are available in the market for relative lower prices. These VR visors are made in plastic and have a particular lens set to the better visualization of the mobile screen.

In the Figure 2.5, the utilization of a VR glasses visor for the visualization of the 3D scenarios, developed inside the VALE described in the next chapters, is presented. Due to a smartphone is used for the projection of the media contents, some extra functionalities can be associated such as the utilization of the 3D mouse prototype mentioned in the last section. The association of both VR glasses and 3D mouse to the 3D scenarios programmed inside VALE stimulates more realistic interactions of the users with the system. Furthermore, development of 3D environments (games or virtual wanderings) can be developed to use not only the 3D mouse, but also the motion tracking sensors

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[9]https://www.google.com/get/cardboard/

Figure 2.5: Virtual reality glasses implementation for mobile platforms.

inside the smartphone. For instance, visual exploration around of the virtual characters in the scenarios can be performed with the real movement of the player head.

2.4.3   Multitouch Screens: Tablets, Smart Blackboards and Multitouch Tables

The haptic technologies of multitouch allows to the users feeling force and pressure while interacts with the applications environment that is visualized on the surface of a screen. Different devices implement multitouch screens due to the intuitive interaction of users that are each time more attracted since younger ages. Some examples of devices that implement multitouch screens are tablets, smarthphones, laptops, digital information boards among others.

Moreover, tablets are part of a mobile technology that is wide diffused between the collectivity. Tablets are mainly used for media entertaiment and communication. However, tablet devices can also be employed as a learning tool for motor skill development through the interactions of fingers and the screen as shown in the Figure 2.6. Furthermore, due to these devices have the touch recognition ability and support flexible development of apps, logging of touch interaction of users can be stored to evaluate skills performance in a specific ambit.

Therefore, tablets with Android OS system have been used in the experimental part of this work with applications developed inside the ambit of VALE, which will be described in the next chapters. Additionally, a smart blackboard and multitouch digital table were also used for the socialization of certain VALE applications as shown in Figure 2.7.
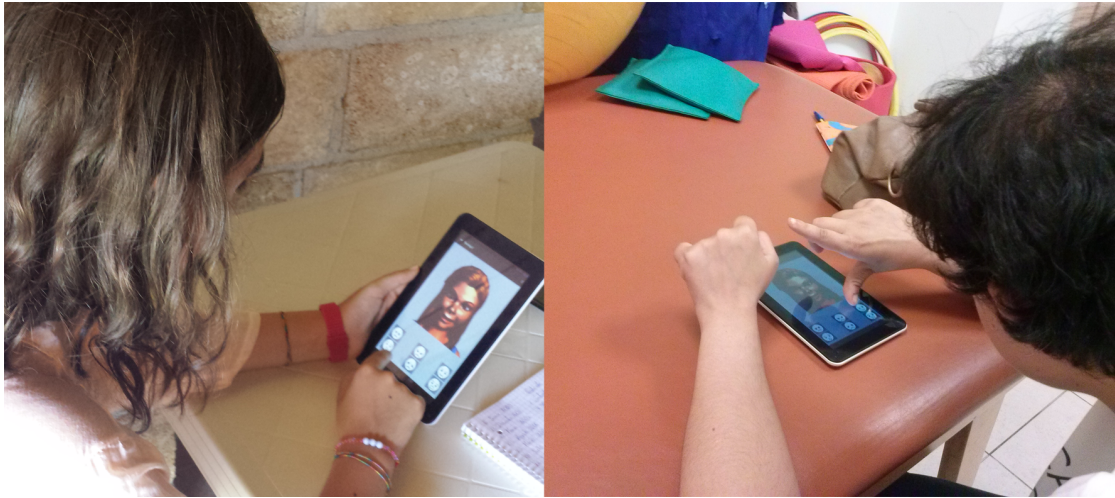
Figure 2.6: Interaction with VALE-Emotions app using a multitouch screen Tablet.
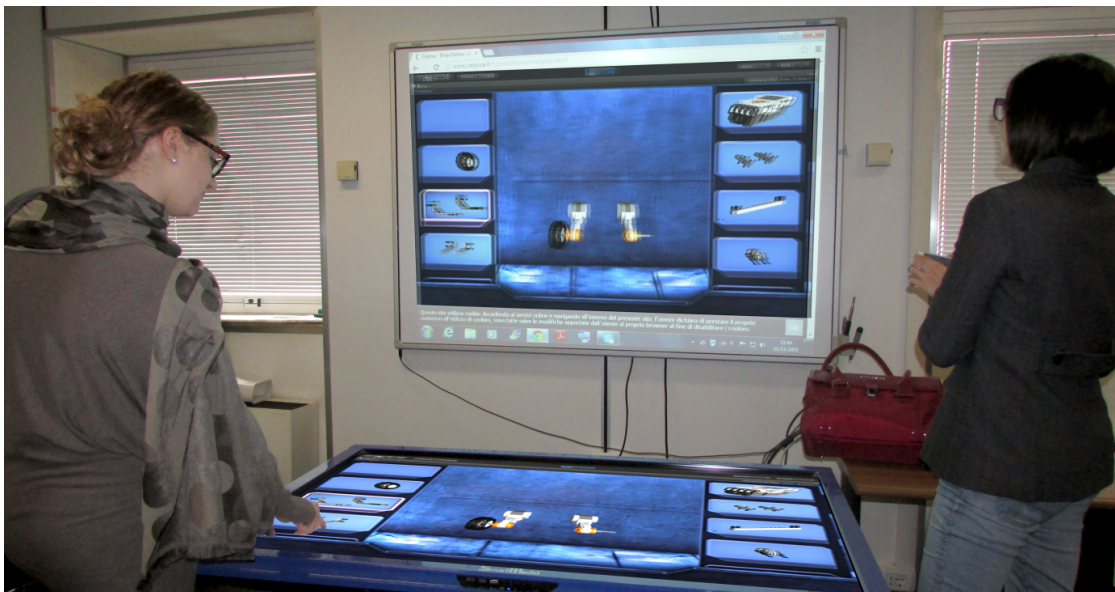
Figure 2.7: Interaction with VALE robotic app using a blackboard with multitouch screen.
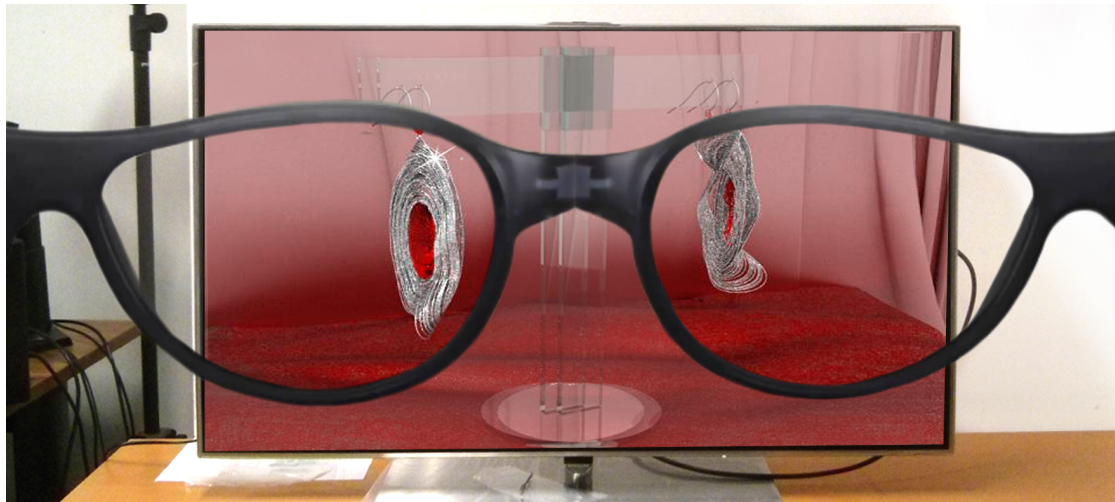
Figure 2.8: Visualization of 3D material of VALE using a 3D-TV Full HD-LED.

2.4.4   3D Television

The term *3D television* refers to a TV that can display images/video formatted with effects of three dimensions. Various techniques are used to achieve the illusion of depth such as video syde-by-side among others. To complete the requirements for 3D visualization with depth effects is necessary 3D viewer glasses that can be pasive or active.

Any process for creating 3D images from a stereo pair is known as stereoscopic and basically relies on the natural principle of human vision, where each of our eyes at the same moment captures an image slightly different from the other eye, due to the distance between them. Both images are processed by our brain, allowing us to see the world in 3D, as we know.

For socialization of some of certain VALE applications, a 3D-TV Samsung Full HD-LED was used as shown in Figure 2.7.

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Chapter 3

Techniques and Tools for Building the VALE

Contents

3.1 Design of the 3D Learning Environment

As mentioned in the first chapter, a 3D learning environment is basically the representation of the real world or abstract environments, used as locations to broadcast knowledge. These environments exist only in the computer's memory but allow users to experience the feeling of being physically present in that location or space. Sometimes it is even possible to interact in real time with the various elements of these environments.

The 3D objects that form part of such environments are originated through a process of mathematical calculations. These calculations are performed on three-dimensional geometric entities produced on the computer. Each object is a mere representation of coordinates. These coordinates form structures which are wrapped by a texture. The trick is to make the mesh as simple as possible. Then, the material through which the

object acquires the characteristics can be assigned. These 3D objects are created by graphical software and then modified and reproduced frame by frame (Serrano, Botella, & Baños, 2012). Next, the interactivity, the possible navigation mode, the automatic tour, the points of view as well as the management of input devices are programmed (Laria, 2014; F. Bertacchini, Bilotta, Laria, & Pantano, 2013). Some of the software used for the development of Advanced Virtual Learning Environments (VALE) are described below.

3.2 Technical Characteristics: Software Used in Creation of 3D Virtual Learning Environments

3.2.1 3ds Max®

Modelling, as its name suggests, is the phase in which it is built and generates the model itself. It represents the central stage of development and also the largest temporary stage that consumes resources. There are many 3D modelling tools on the market; each has its strengths depending on the field of action. Undoubtedly, the most widely used tools and both projects medium or large scope are those submitted by the company Autodesk. In fact, one of the most used software of this family of Autodesk is 3ds Max®[1]. This latter offers a great potential for the creation of the characters and some environments. 3ds Max has a single interface from which it is possible to create objects before animate them. Some graphical interfaces of this 3D modelling software are shown in the Figure 3.1. Even if the work space of the graphical interface is divided in four quadrants by default, the designer can define the level of detail of each one. It has solid editing capabilities, ubiquitous plugin architecture and a long tradition in Microsoft Windows platforms. 3ds Max is used more by game developers, but also in developing animation projects like movies or TV commercials, special effects and architecture projects.

3.2.2 Unity 3D

Unity 3D[2] is a powerful game engine with some tools that allow creating environments for real-time navigation. Unity also has the support of 3D standards formats for exchange. In addition, this software possess Editor Mod Tools through which it is possible to program the behaviour of objects in the scenes, using popular languages programming such as C++, C# and JavaScript. The development interface of Unity 3D is shown in Figure 3.2.

One of the potential of Unity 3D is that generates high-quality products by creating compelling physical behaviours. This means that an object in the game should adequately accelerate and be affected by collisions, gravity and other forces. The physics

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[1]http://www.autodesk.es/products/3ds-max/overview

[2]http://docs.unity3d.com/es/current/Manual/UnityManualRestructured.html
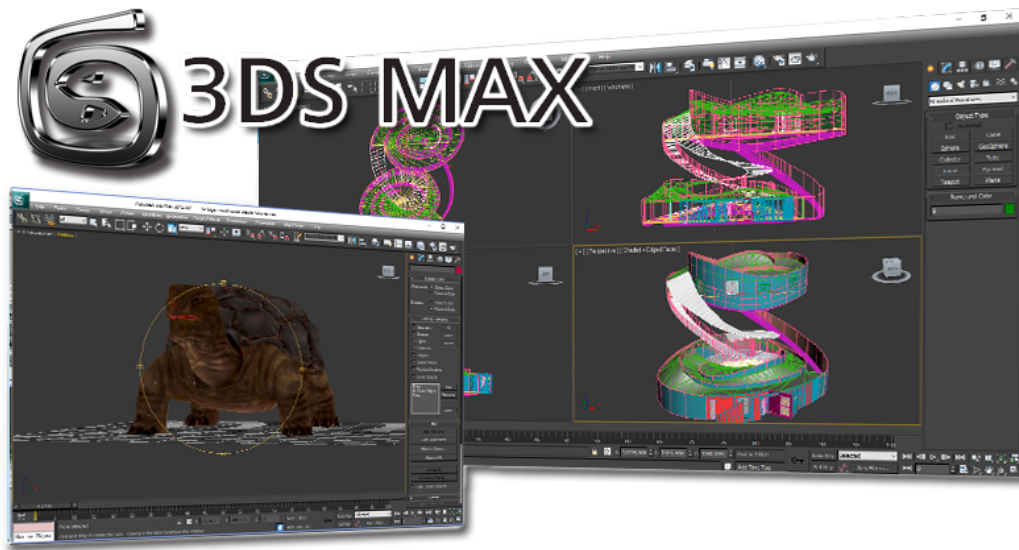
Figure 3.1: Graphical development interfaces of 3ds Max.

Figure 3.2: Graphical development interface of Unity 3D.

engine integrated into Unity provides the components that handle the physical simulation. Also, the programmer can set the range of influence of obstacles.

Unity 3D provides also the user with a powerful tool for terrains generation and also

it can customize the height, and texture in a simple way. The land generated can be manipulated to manually modify the topology thanks to an interactive brush. Also, the instrument of terrain generation allows the incorporation of several materials and effects applied with the interactive brush. Consequently, the final object will appear composed of grassy areas, rocky, sandy, etc., denoting the morphological characteristics of a real ground.

Another feature that makes a powerful Unity 3D game engine is the cross-platform support for running applications, including mobile phones, websites, desktops and consoles. Therefore, Unity is available as a development platform for Microsoft Windows and OS X, and allows the creation of games for Windows, OS X, Linux, Xbox 360, PlayStation 3, PlayStation Vita, Wii, Wii-U, iPad, iPhone, Android and Windows Phone.

3.2.3   iClone

In all related fields with computer graphics, animation is probably one of the most difficult. The developer must not only have the technical ability to create, draw and drop characters, but also a developed sense of time and movement observation. In other words, the developer needs to be like an actor to have a sense of what makes to anything become alive and natural. With all these skills, the animation developer can achieve something magical living up 3d inanimate objects. In this ambit, iClone is one of the software that gives a whole support to animate 3D objects by creating an unlimited number of facial and body movements. These movements give personality to the characters and can be controlled during playback or recording in real time. Development interfaces of iClone are shown in the Figure 3.3.

Most of the expressions and emotions of a character is reflected on his face. Regarding the latter, iClone 3D facial animation determines the level of control and style appropriate for the character animation. In particular, animation of the eyes should to pay special attention and iClone has tools for controlling the movement of the head and eyes of the actor when looks at a moving target. In addition, clicking during recording, blinking eyes can be easily recorded as clips on the track of expression.

As regards the body animations, iClone allows creating movement and add puppet behaviours, while the animations During Real-time playback or recording are controlled. On the other hand, in iClone is also possible to combine movements from different sources, for it must seek a rapprochement between realistic and cartoon animation. Before the production, should be defined a clear style of movement and animation. If is used motion capture, the actors need to add intention to their movements.

The developer animator can have absolute control over the movement and position of cameras enhancing the film animation. Finally, iClone allows a particular attention to the scene lighting because it has a huge impact on the animation and in the final rendering.

Figure 3.3: Graphical development interface of iClone.

3.2.4 Scratch

Scratch[3] is a new programming language that allows the creation of several applications like interactive stories, games and animations in a simple and fun way. This new programming language is a project of the Lifelong Kindergarten Group at the MIT Media Laboratory. Scratch presents an intuitive and attractive environment. The programs are formed by just dragging command blocks from a palette into the scripting panel to assemble stacks blocks, like puzzle pieces. Through these blocks, the instructions that the characters must perform are programmed. These blocks represent the statements, expressions, and control structures and the same shapes of these blocks suggest how they fit together. Development interfaces of Scratch are shown in the Figure 3.4.

Regarding to the data used in this programming language, there are three first-class data types: boolean, number, and string. The objects that interact inside of the created projects are known as Sprites. This last, encapsulate state (variables) and behaviour (scripts). In this way, the programming basis are easy to learn for children (Maloney, Resnick, & Rusk, 2010).

With this programming language, the users can learn to think creatively, reason systematically, and work collaboratively. In addition, the free accessibility of Scratch, enable sharing applications created with other users in the on-line community.

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[3]https://scratch.mit.edu/

Figure 3.4: Graphical development interface of Scratch.

3.2.5   Adobe Photoshop

Adobe Photoshop[4] is one of the most popular tools and is endorsed by hundreds of professional experts in computer graphics. It is essentially a computer application in form of painting and photography workshop working on a "canvas". It is intended for editing, retouching and paint bitmap images (or raster graphics). Photoshop has become, almost from its inception, in the standard in photo retouching. It is also used extensively in many disciplines in the field of design and photography, as web design, composition of bitmap images, digital fashion design, video editing and basically any activity that requires the processing of digital images. The development user interface of Adobe Photoshop is shown in Figure 3.5.

In a first version, Photoshop worked in a bitmap space formed by a single layer, where the application a range of effects, text, trademarks and treatments was possible. Somehow, it had much resemblance to several traditional and basics software like Paint. He now works with multiple layers which is useful at the time of working with multiple images simultaneously.

3.2.6   Adobe Illustrator

Adobe Illustrator is essentially an application for the creation, and the vector manipulation, like in an art workshop. It works on a drawing board, known as "worktable". It is intended to artistic creation drawing and painting for Illustration (technical illustrations, graphic design, among others). Illustrator has creative options, easier access to

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[4]https://helpx.adobe.com/photoshop/tutorials.html
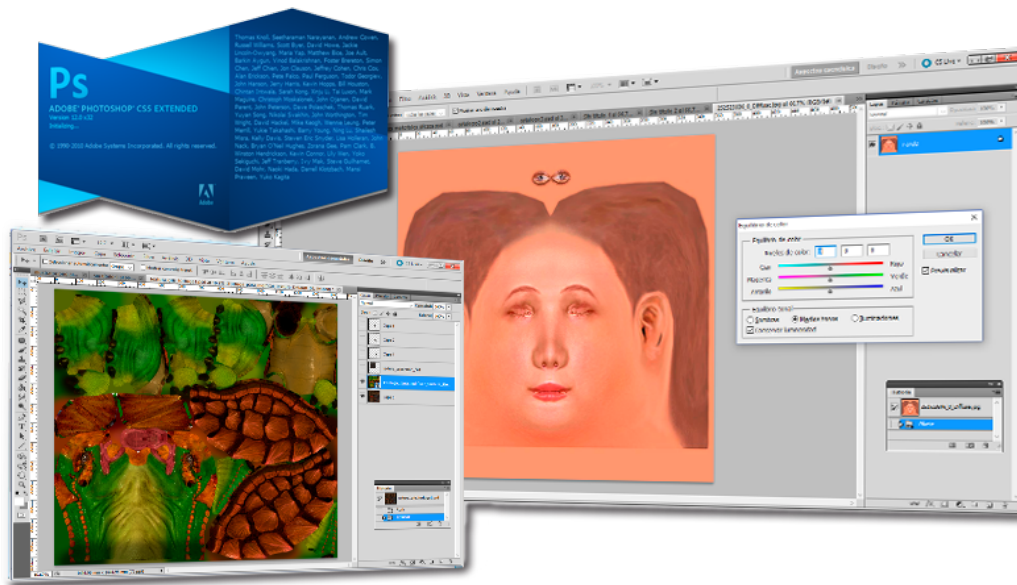
Figure 3.5: Graphical development interface of Adobe Photoshop.

tools and versatility to quickly produce flexible graphics. The development user interface of Adobe Illustrator is shown in Figure 3.6.

The stunning illustrations that are created with this program have given fame to this application of vector management between digital graphic artists around the globe. It belongs to the family of Adobe Creative Suite. The extension of his files is (.ai). This application allows graphic artists to see on the screen a preview of the result as it will be printed.

3.3 Rendering Process

When a three-dimensional object is modelled, its contents only can be seen in the program in which it was created. To allow a different user can view it, should be performed a process called Render or Interpretation. The seconds in a film are translated in computer animation as frames (fps) (in the PAL video system there are 25 fps and the American NTSC has 30 fps). The computer must calculate each of these images and create animation. In the rendering process, the system interprets the ambient light, shadows, reflections, textures and views to a specified format. This process can take from minutes to hours, to days or months. It depends on the complexity of the model, animation, sequence and characteristics of the computer in which the Render is performed.

Once the "Basic Render" was created (either video or graphics) the user can see only the sequences, views or elements that have been previously prepared. For example, if a

Figure 3.6: Graphical development interface of Adobe Photoshop.
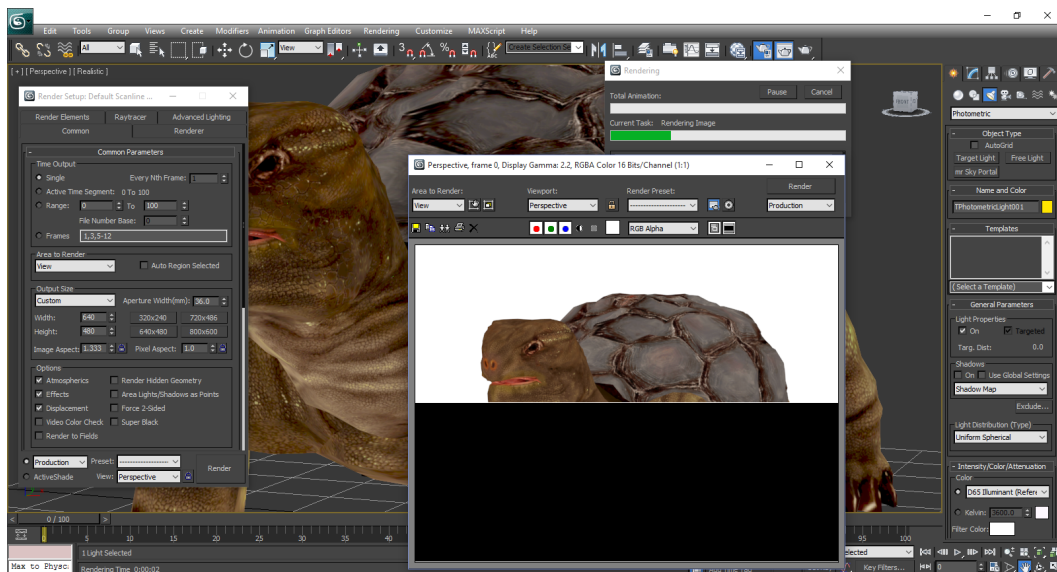
Figure 3.7: Graphical development interface of 3ds Max for rendering task.

building is modelled with a visit to one of the rooms, the users don't can see the other rooms, or turn in the environment when he wants. By contrast, when it is used the "Real-time Render", a previous render is not generated. In this way, the user can go

to the rooms like he wish, turn around whenever you want and even interact with the pre-set animations like in the games. The development user interface of 3ds Max during the rendering process is shown in Figure 3.7.

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Chapter 4

VALE-STEAM Education: Implementation

Contents

4.1 Introduction

The current graphics technology allows the combination of 3D environments and scientific content to convey complex concepts in a simple, fun and understandable way. This fusion of learning through entertainment is known as "Edutainment" (Bilotta, Gabriele, Servidio, & Tavernise, 2009; F. Bertacchini, Bilotta, Pantano, & Tavernise, 2012; Webster, 2015). In fact, since the work of Piaget (1952), it has been recognized at the play as a decisive role in the process of internal development of intelligence through several cognitive stages classified by age. In the light of this, regarding the new forms of education, a VALE for educational game-based has been designed. It consists of different virtual scenarios inspired by the famous Galapagos Islands. These virtual environments will be focused on Science, Technology, Engineering, Arts and Mathematics (STEAM) education. Thus, this system is named VALE for STEAM education. The main aims
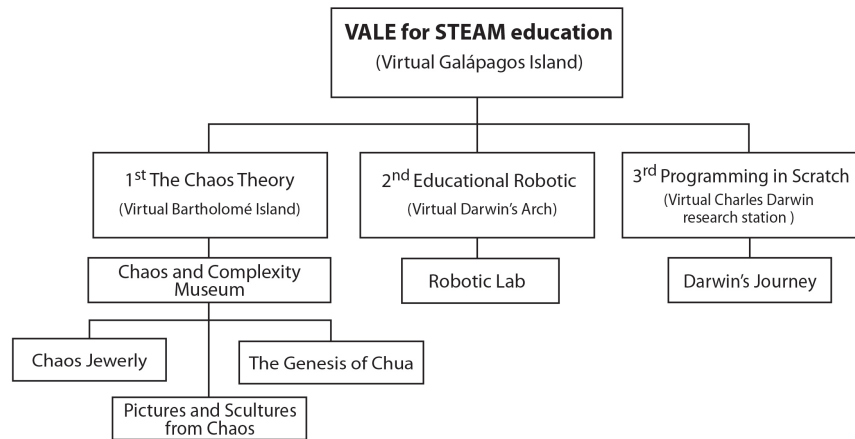
Figure 4.1: Structure from VALE-STEAM education

Figure 4.2: Interaction in the environment of VALE-STEAM education

are to strengthen learning skills, improving the ability to interpret and solve problems, and at the same time, developing creativity in students. In the Figure 4.1, the schematic organization of the VALE-STEAM education is presented.

Among the scenarios that integrate the VALE-STEAM education, the Galapagos Islands of Ecuador is the main one. The Galapagos Islands were chosen as the main scenario because of its scientific and historical background that the naturalist Charles Darwin gave to this beautiful place. Moreover, just like in 1835 it was the scene of important discoveries, today too in the XXI century, it intends to become, virtually, in a scenario where teaching activities for elementary school students could be implemented (see Figure 4.2). The most representative islands have been selected as virtual learning stage for each topic treated in the VALE-STEAM education: Chaos Theory, Educational Robotics, and Programming with Scratch (see Figure 4.1).

Such islands have been fully modelled in 3D, considering the real geographical characteristics of the place. Such scenarios are assigned to the different topics mentioned before. The first scenario is the "Bartolome Island" characterised by its beauty and distinctive landscape. In this scenario, the user can visit the "Chaos and Complexity Museum". The second level is the "Darwin's Arc", called in this way in honour of Charles Darwin. This arc is the gateway to the second virtual environment dedicated to educational robotics. For the third virtual scenario, the Isla Santa Cruz has been used as a virtual location. On this island, the famous scientific Biological Research Station Charles Darwin[1] is situated. This research station becomes the entry to the game named "Darwin's Journey", which was fully developed in Scratch. It is an educational journey to discover biological evolution through challenges.

In this way, interactive educational games, virtual museums and laboratories can be used as a teaching supplement in the classroom, which can be executed on both PCs and mobile applications. The VALE-STEAM education incentives to freely discover and learn interesting concepts in a fun way while developing knowledge. Furthermore, the applications and environments of the VALE-STEAM education have been developed on the Unity 3D platform with the support of other programs for 3D design and animation, and programming as well.

4.2 Main edutainment topics inside VALE-STEAM education

Inside of the virtual learning environment inspired by the Darwin's voyage, some of the places visited by the naturalist during his trip around the world have been reconstructed virtually. This reconstruction has been used as the virtual location of an interactive video game. In this game, it is possible to learn about "Chaos Theory", "Educational Robotics" and "Programming with Scratch", these last ones can be framed inside of STEAM study as presented in the Figure 4.1 (Vaca Cárdenas et al., 2014; Vaca Cárdenas, Bertacchini, Tavernise, et al., 2015). These issues are not introduced at the level of basic education, due to their complexity or in some cases to lack of resources and/or physical space. However, with a proper and dynamic presentation of contents through virtual environments like the presented in this work, it could become a tool to develop and potentiate skills in the students forming solid basis for future engineers and scientists.

4.2.1 The Chaos Theory: Chaos and Complexity Museum

As regards to the Chaos Theory, along history have been reported only the incomprehensible aspects that tend to complicate it. On one side, there are ineffective traditional teaching methods to illustrate these particularly complex concepts. This limitation is related to the utilization of complicated mathematical formulas and systems that are well

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[1]http://www.darwinfoundation.org
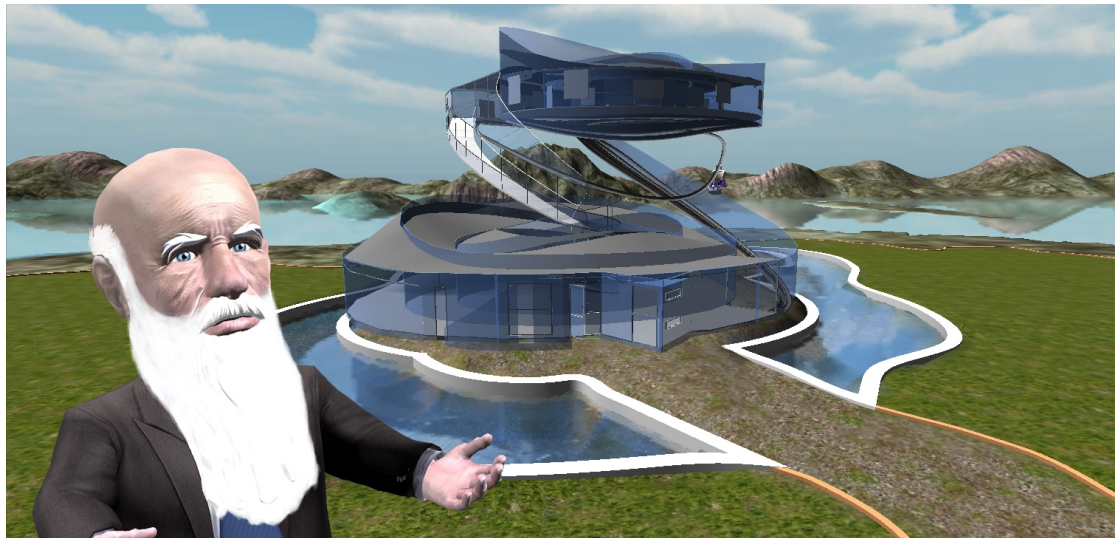
Figure 4.3: The Chaos and Complexity Museum inside of Bartolomé virtual Island

understood only by experts in the field. On the other side, there is the strong attention to the unpredictability of such systems. However, this famous theory also presents other aspects of prediction, knowledge and developments that make it attractive, interesting and with multiple possibilities of application.

On the other hand, museums can be benefited from the development of a large number of projects and edutainment products. In fact, the museum is an institution with multiple functions: the acquisition and conservation of works of art, research and communication.

For these reasons, into VALE-STEAM education, a virtual environment for the teaching of Chaos Theory has been developed. This environment is a virtual museum known as *"Chaos and Complexity Museum"* (F. Bertacchini, Olmedo Vizueta, Pantano, & Bilotta, 2013), which is presented in Figure 4.3. The aim of this museum is to teach the aforementioned scientific contents concerning to the Chaos theory in a readily understandable manner. Also, it intends to demonstrate that the chaos can generate beauty, and can be used to create artistic compositions not only aesthetically nice but also with a scientific background.

During the virtual tour inside of the *Chaos and Complexity Museum*, the user can watch a collection of pictures, sculpture and jewellery pieces of art inspired in the attractors. At the beginning of the visit, the user can find several sculptures wearing attractor jewels. Such sculptures are inspired by the cultural renaissance movement. In this way, a symbolic fusion between Ecuador (location) and Italy (culture) can be virtually stated. In the tour, the user could arrive at the top level of the museum to watch a collection of paintings based on the Chaos and Complexity. A peculiarity of the tour is the possibility to admire the virtual outdoor landscape of the Bartolomé Galápagos Island through the crystal walls of the museum (see Figure 4.4). Finally, the user can participate in the

Figure 4.4: Exhibition inside the museum with a view of the outside environment

Figure 4.5: Painting's collection by Eleonora Bilotta inspired on the Chaos theory.

presentation of the video named "Genesis of Chua," which explains the theory and the invention of the Chua's circuit in an illustrated way (F. Bertacchini, Bilotta, Laria, & Pantano, 2013).

In the artistic world, there is a strong relationship between aesthetics, art and the search for meaning, which can be attributed to the chaotic ways. For instance, Kandinsky showed in his paintings a preference for an imagination that leads to the chaos. In this way, the collection of paintings inspired in the fractals from the Chaos theory, which were created by Eleonora Bilotta, are exhibited in the internal structure of this virtual museum as shown in Figure 4.5. This paintings collection is the ideal complement for the thematic museum.

These artistic expressions have already been presented successfully in the exhibition entitled *"Dall'ordine al Caos"* at the Aula Magna of the University of Calabria. The contents of the event have been reconstructed in virtual reality by Evolutionary System Group (ESG) and are freely available in internet[2]. It is noteworthy that currently this collection is also shown in physical and permanent in the ESG department.

This museum is linked with several works that have been developed by the ESG,

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[2]http://museomg.unical.it/scienar

which have integrated this famous theory in the educational field. In this ambit, the video *"Genesis Chua circuit"* transmits scientific concepts of the Chaos Theory. In this manner, even spectators unrelated to this particular disciplinary sector can understand the basis of this thematic. This compression is possible thanks to the animated presentation of the story describing how the circuit Chua was born. This illustrative video combines the teaching of scientific concepts, 3D modelling techniques, theatrical communication forms, animation, and virtual simulation. The result of this work has already been reported by F. Bertacchini, Bilotta, Laria, and Pantano (2013), and it is still very useful in the work done by the ESG department in this particular field. Another conducted study in the internal of the ESG has developed a model of teaching and learning in schools aimed to explore the chaos by creating digital images and sounds (F. Bertacchini, Bilotta, Carini, et al., 2012; F. Bertacchini et al., 2007, 2008; F. Bertacchini, Bilotta, & Pantano, 2011; F. Bertacchini, Bilotta, Pantano, & Tavernise, 2012). This particular approach is based on the idea that digital creations, obtained by the manipulation of the Chua circuit, can motivate students stimulating the learning and creativity processes. It is an edutainment that allows for physically building and testing the Chua circuit. In this way, students learned to build the circuit by manipulation of the electronic components understanding the connection diagram. Furthermore, through the Chaos Explorer software (also developed by the ESG), the students got a deep understanding of the evolution of dynamical systems through computer simulations, creating attractor patterns derived from the Chua circuit (F. Bertacchini, Gabriele, & Tavernise, 2011; F. Bertacchini, Bilotta, Gabriele, Pantano, & Tavernise, 2013; Bilotta et al., 2007; F. Bertacchini, Tavernise, et al., 2013).

4.2.2   Educational Robotic: Robotic Lab

Due to the great potentiality in the use of the Lego® MindStorms™ robots as a didactic tool, the first part of a virtual robotics lab has been created in 3D. This lab allows for building and programming virtual robots. Following with the virtual Galapagos' Islands, the *"Darwin's Arch"* has been replicated inside this environment representing the virtual door to access at the laboratory (see Figure 4.6). The aim is to apply the robotics in an educational context to study the cognitive skills of the students linked to the manipulation of these virtual tools.

Once in the laboratory, the user can intuitively select the individual parts available on the sides of the screen. The selected part is placed in the right position to build the robot in the centre of the main screen (see Figure 4.7). During the construction, the user can interact with the robot performing actions as rotation, displacement, and zoom. Thus, the user may have a comprehensive view of the robot and its parts while the assembly process is performed. Moreover, a more engaging experience was obtained through a version of the virtual laboratory with 3D visor and the prototype of a 3D mouse before detailed in the second chapter. Further works are in progress to extend the functionalities of this laboratory regarding robot customization, movement programming among others.

This initiative related to robotics is supported in studies already successfully un-

Figure 4.6: Virtual Darwin's Arc representing a simbolic gate to enter at the Darwin's Jorney game.

Figure 4.7: Lego® MindStorms™ robot modelling and assembly process inside of Robotics lab.

dertaken by the ESG. So far, these studies have been conducted with the Lego kits in physical form. As a reference, we can mention the *"Edutainment Robotics as Learning Tool"* (Bilotta et al., 2009), where the knowledge acquisition of a Lego Robotics system was investigated. In the same vein, the work presented by P. Bertacchini, Bilotta, Gabriele, Pantano, and Servidio (2003) allows for programming real robots, previously assembled. This project was characterized by letting the students operate in the real world, during experimental research on robotics and learning processes.

4.2.3 Programming in Scratch: Darwin's Journey

In the third chapter, Scratch was presented as a new programming language and environment that allows for the creation of interactive applications in an intuitive and easy way. In fact, Scratch adds programmability of media-rich and network-based activities. In this way, Scratch supports new paradigms and activities within the field of programming, attracting the attention of ever younger generations to instil in them a taste for careers related technologies (Maloney et al., 2004; Vaca Cárdenas, Bertacchini, Tavernise, et al., 2015). Even if for kids, Scratch is a game; indeed, it represents the possibility that they become familiar with programming logic, being conditioned to choose related careers in the future.

Consequently, the programming environment of Scratch has been used to design a game named *"Darwin's Journey"* (Figure 4.8). The aim is to introduce the users to the world of Scratch while dynamically they learn about some important events that occurred during the voyage of the naturalist Darwin.

Following with the virtual Galapagos' Islands, the Charles Darwin Research Station building has been virtually replicated (see Figure 4.9). The game begins when the user enters in the virtual research station where the user can find a link that drives the user to play the game in Scratch. Hence, the users can access to the "Darwin's Journey" game. This app allows the user to travel virtually from Plymouth (UK) to the Galápagos Islands in Ecuador. Thus, the game is started by clicking on the green flag at the top-right of the main screen, while it can be stopped by clicking on the next located red button.

It is worth to mention that the old Darwin character is the users' guide in the virtual environment of the Galapagos' Islands (see Figure 4.9). He explains the different scenarios, shows the educational activities, and gives instructions. Instead of this, the young Darwin is the character of the game. The character travels on the ship Beagle around the world inside the game.

Since the aim of the game is to learn about the Darwin's discoveries and the elements that allow developing his famous theory of Species evolution. In different and graphical scenes, the user can collect the objects necessary for Darwin's theory formulation. In this game, the challenge is to recognize which objects are according to the Darwin's Journey; otherwise it causes the loss of the game. In Figure 4.10, the young Charles Darwin and the Captain Fitz Roy start the game, sailing from Plymouth (UK) with the Beagle ship.

Next, Charles performs an introduction and explains the below instructions:

Figure 4.8: Scratch interface during the development of Darwin's Journey game.

Figure 4.9: The virtual Charles Darwin's Research Station.

Figure 4.10: Darwin's Journey game start screen.

Figure 4.11: Map of the Darwin's Journey.

"Hi, my name is Charles Darwin. I will guide you in this wonderful adventure around the world on the Beagle. Press play to start the game",

then, in the next scene, the player has to surf with the Beagle inside of the map to continue the game; the map allows the player to develop spatial skills and to recognize the full tour of Darwin (Figure 4.11).

Surfing inside the map, the user arrives at the Brazilian rainforest scene. The player has to collect some species of plants, insects and other animals such as the blowfish that takes considerable attention of the naturalist. Another important aspect to consider in this scene is Darwin's disagreement with slavery. In the game, a slave represents this argument. The player must not select him; otherwise, the user lose the game (Figure 4.12a). Regarding the learning aspects, in this game application, the students discover with Darwin one of the hypotheses on the marine geology origin (Charles, 1842). The greater incentive to continue the exploration of the places visited by Darwin through experience is to solve the different problems to access from one scene to another.

Going on in the game, the player arrives into Montevideo, Punta Alta (see Figure 4.12b). Here, the user can collect fossilized bones of large mammals, noting the difference between savage and civilized man. In the meantime, the user can continue to collect birds and reptiles, discovering new knowledge.

Then, in the next scene, the player is in the Andes (Chile) when the earthquake and Osorno volcano eruption occurred (see Figure 4.12c). Here, Darwin receives information about other earthquakes, so he hypothesizes that could be an underground communication between volcanoes (Darwin, 1844).

Finally, Darwin arrives at the beautiful Galápagos Islands (see Figure 4.12d). In this scene, he finds an unusual flora and fauna, many unique species in the world, the famous finches, and giant tortoises, among others. All of these species contributes to his theory of natural selection that shows the mechanism by which species evolve to adapt to their environment. Each scenario of the game has different distractors activities that greatly
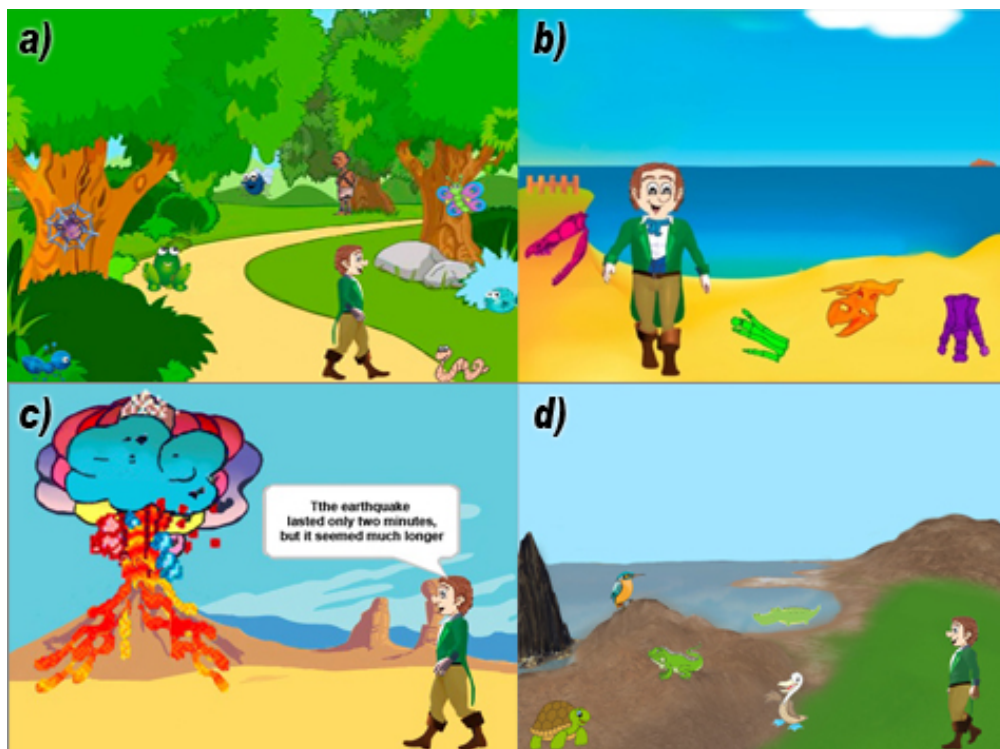
Figure 4.12: a)Brazilian rainforest scene; b) Montevideo fossilized bones scene; c) Osorno volcano eruption scene; d) Darwin arrives to the Galápagos Islands.

improve the opportunity of embedding learned contents into long-term memory.

4.3 Modelling and programming of VALE for STEM education

For the realization of the VALE for STEM education, organization of work into two different areas was required. The first one was the creation and animation of characters and environments across multiple graphics software. The second one was the programming of interactions and events in the different scenarios using the programming language of Scratch and JavaScript for Unity.

As mentioned in last sections, the scenarios that were visited by Darwin in the Galapagos' Islands compose the different stages of the VALE-STEAM Education reported in this work. A complex modelling and animation process for characters, buildings and objects was necessary to recreate each scenario. In this way, different design software, described in the previous chapter, were used. Such software has allowed the modelling of objects to obtain easily manageable structures within each of the 3D scenes.

4.3.1 Texture Mapping

Adding details, color or surface texture to 3D models in a computer is performed through the texturing mapping method. In this work, images were used for the texturing surface of the different 3D characters, buildings and objects created for each scenario. Such texturing images can be created through image edition software (i.e. Photoshop). In the slang of texture mapping, these images are called "bitmaps," and it is crucial to control the resolution quality.

During the modelling phase, a Surfacing operation performs the subdivision of the 3D model surface in polygons, which will subsequently be treated with different characteristics according to the materials desired. Through mathematical techniques implemented in 3D software edition, the coordination between the texturing image and the polygon surfaces of the 3D model can be performed. In our case, the mathematical technique UVW mapping, inside 3ds Max Studio, was used. A UVW map applies coordinates of correspondence between the image and object surfaces to control how the materials appear therein. The coordinate's correspondence specifies how they are projected into a bitmap object. Inside 3ds Max Studio, before the assignation of a material to a particular object, this material must be created in the Slate Material Editor. This last assigns a bitmap in a Diffuse Colour option (see Figure 4.13a).

Furthermore, the bump-mapping method was also used to texture the uneven surfaces given the effect of roughness (i.e. skin of a turtle). In fact, a relief image (see Figure 4.13b) is created from the normal texture image through applying techniques of desaturation and high-pass filter reaching this effect. Then, the relief image is applied to the object not as a texture, but as a bump-map. A third image texture in grayscale can be loaded in the Specular Colour option as shadow (see Figure 4.13c) to obtain a more realistic effect. This particular shade makes that the angles of the reflected normals light
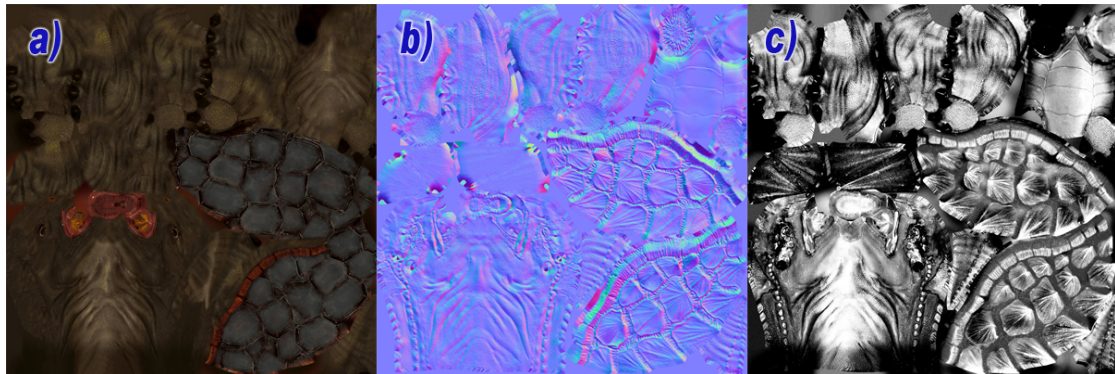
Figure 4.13: Images used for texturing of George through UV-maping.

Figure 4.14: Image map for the texturing of skin of Darwin's face.

rays from the object are modified locally based on the intensity of the pixels of the image used, allowing to obtain an artifice with the rippling effect of the surface.

When this texturing process is applied to organic models, complex and irregular meshes are faced. Therefore, it is necessary to proceed to connect the points of the image to those of the mesh being able to change the performance details using UV-mapped techniques. Also, the 3D modelling program allows obtaining the exploded from the model that can be used to draw textures (see Figure 4.14). It was necessary to use the UV-mapping from the software to create the texture on the Darwin's face character, which has created a "spread" of the 3D model on a two-dimensional surface.

Furthermore, obtain transparent surfaces, such as the windows of the museum, it was necessary to set different parameters including color, specularity coefficients, the intensity of the reflection coefficient of transparency, refractive index, according to the optical characteristics of the material that must be simulated (see Figure 4.15).
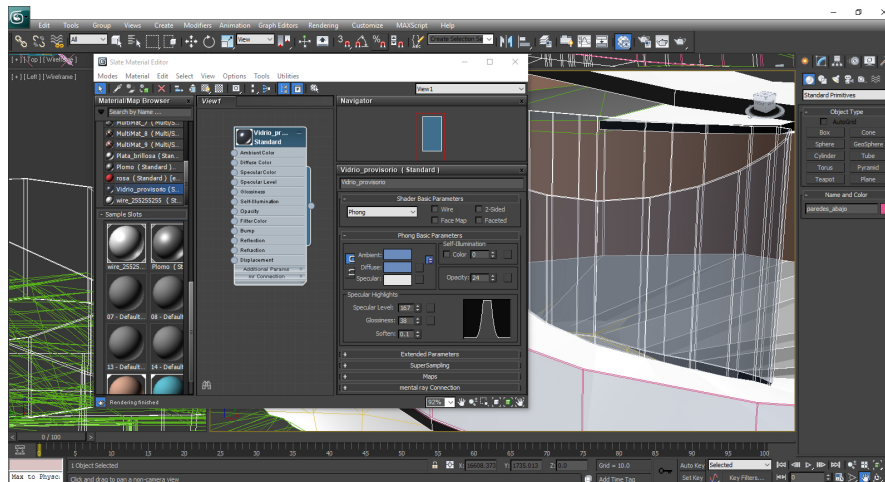
Figure 4.15: Creation of glass material in 3ds max studio.

4.3.2 Characters Creation

The creation of characters was completely based on an organic modelling. This type of modelling is used to create "natural" 3D models such as humanoids, animals, plants, rocks. In this case, the models must be very detailed and preserve every particularity. The result is a considerable increment in the number of polygons that make up the model, and, therefore, their digital weight. Advantageously, there are several techniques for lightening the model and conserve the topological characteristics by eliminating useless polygons.

In the initial phase, the avatars, employed in the journey of Darwin, have been modelled. For this purpose, a collection of photographs and material was collected from the internet. This task was the biggest challenge due to the lack of Darwin photographs in different profiles. This aspect is significant to perform a more accurate reconstruction of the 3D model. However, after many hours of working on the information obtained, the avatar of the famous Charles Darwin was built (see Figure 4.16).

The complete modelling of Darwin was conducted using 3ds max because of the powerful suite release 4.2 of Character Studio. The latter allows using predefined skeletons of bones with the possibility to link them to the model and generate some movement characteristics of the real person (see Figure 4.17). This software also allows for importing animation files from other scenes, motion capture systems, and even downloaded from repositories.

Another important character in the game is the lonesome turtle "George" (see Figure 4.18). It was the last Galapagos turtle of the species denominated "Chelonoidis Abingdoni", but, unfortunately, the species was extinct with the die of "George". In this learning environment, it has been thought to acknowledge this famous turtle, which was part of the adventure of Darwin. The modelling of this turtle has also been possible thanks to 3ds max, and its movement's animation was generated in iClone.
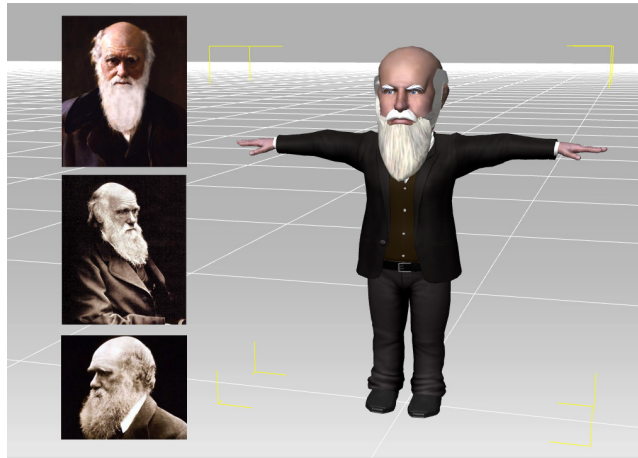
Figure 4.16: Reconstruction of the avatar of Charles Darwin using his photographs.

Figure 4.17: 3ds max GUI showing the skeletons tool applied to the Darwin's avatar.

Figure 4.18: Internet picture of the lonesome George Pinta giant tortoise Santa Cruz.
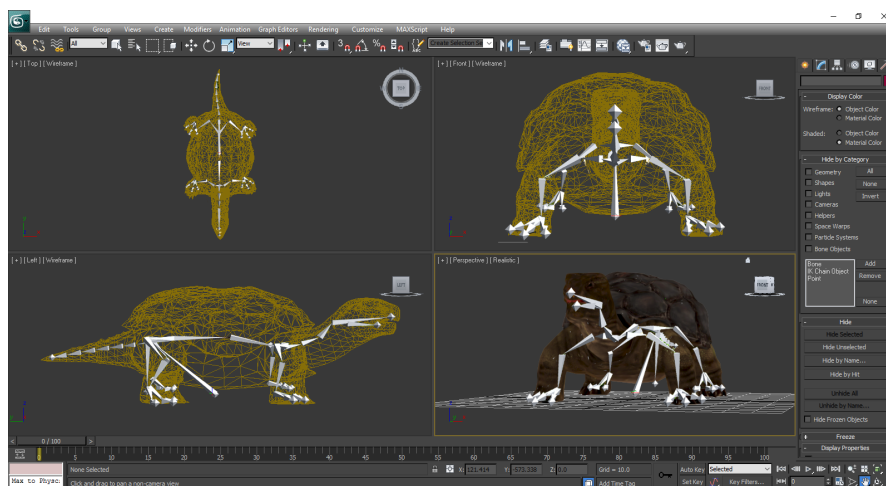
Figure 4.19: George turtle modelled in 3ds max studio.

Through the "Helpers" tool, inside 3ds max studio, was possible to add bone's structures in the turtle George (see Figure 4.19). Once created the internal structure of the skeleton with all its hierarchies, the limits of the movements were defined. The indexes' friction and viscosity determine the possibilities of movement that may have each part. Finally, the effects of the different internal parts of the structure in the "skin" were defined. For example, for bending a turtle paw is necessary a fold occurrence in the skin and a fattening of the muscles.

With these perfectly organized structures, the animating process started allowing that each element can move at the right pace, controlling the curves velocity. Thus, George acquires a certain personality. A very accurate series of pre-set animations also can be imported; in this case, it is possible to generate instantaneously complex rigging to adapt to the character.
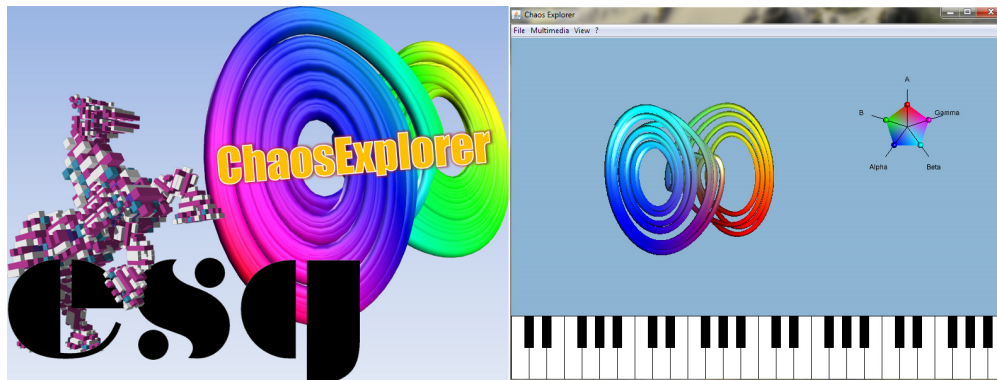
Figure 4.20: Chaos Explorer software developed by the ESG.

4.3.3 Buildings and objects creation

For modelling of buildings, it has also been used 3ds max studio, which lets the creation of three-dimensional models through views or visors (plan and elevations). Also, 3ds Max allows easy visualization and representation of models, which can be exported in formats supported by Unity3D software for the creation of the environment interaction through Java Scripts.

Chaos and Complexity Museum

In the creation of the museum, it sought to replicate the trends and the most innovative architectural forms concerning to the chaotic dynamics virtually. Through the knowledge on computer graphic, it has been possible to leave the world of mathematics to enter into a genuine virtual artistic dimension. In this activity, the Chaos Explorer tool, developed by the ESG, was used to generate 3D objects known as "attractors" through mathematical models extracted from the Chua circuit (see Figure 4.20). Since these objects are generated in Chaos Explorer software through the manipulation of set parameters, different 3D attractors can be exported as 3D objects.

In the Figure 4.21a, the selected attractor to serve as the base structure for the museum is shown. Then, in 3ds max, the phase of the walls design started, in which the shape of the attractor was conserved (see Figure 4.21b), while wave unevenness of the walls were created (Figure 4.21c). Subsequently, the stairs snail-shaped and the cover for the connection between the levels were modelled (see Figure 4.21d and Figure 4.21e, respectively).

Afterwards, were placed several complementary components of the museum such as pictures, spotlight and exhibition stand (Figure 4.22). At the end of the modelling process were placed various textures and the different environments to make realistic virtual museum as shown in the Figure 4.22.

After finishing the physical modelling of the museum, the virtual interaction was programmed in the development environment of Unity 3D (see Figure 4.23). The addition of vital aspects of a virtual tour (e.g. lighting effects, terrain plains, physical simulations,
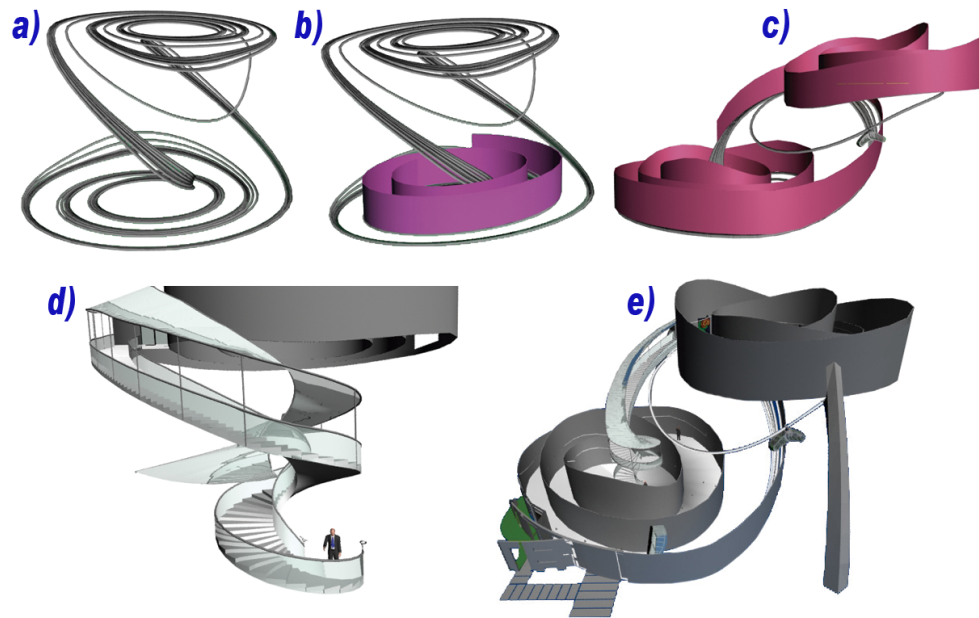
Figure 4.21: Chaos and Complexity museum building proccess.
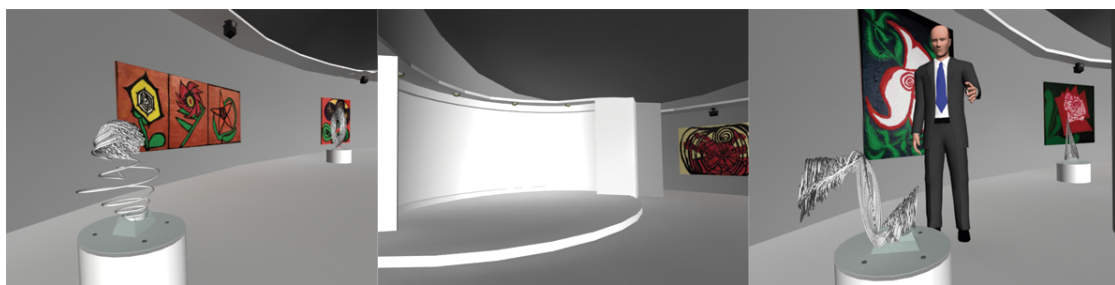
Figure 4.22: Digital artworks inspired of chaos attractors.
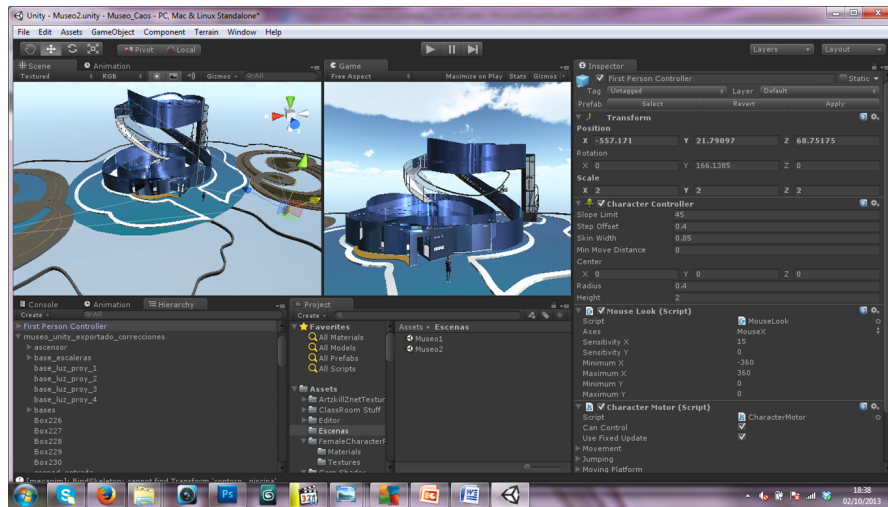
Figure 4.23: Museum interaction created in Unity development environment.
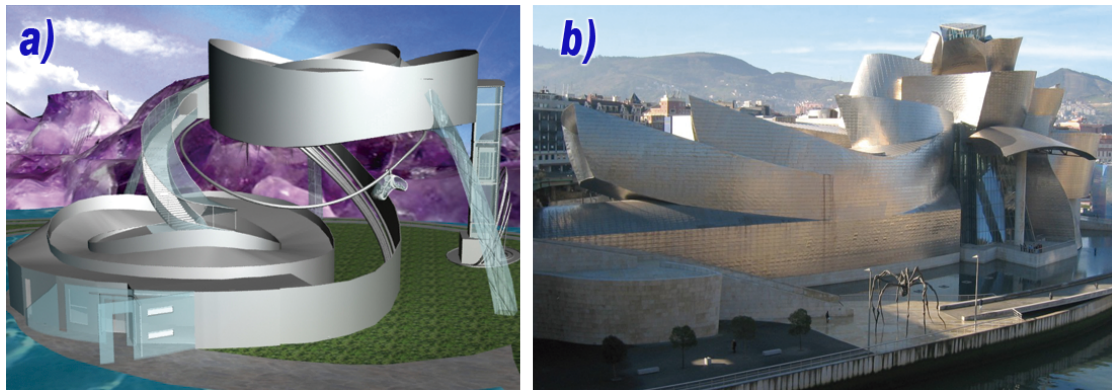
Figure 4.24: a) Chaos and Complexity Musum, b) Photograph of the Guggenheim Museum in Bilbao, Spain.

audios, network operability among other functions) were implemented using JavaScript code to customize the museum.

Finally, the Chaos and Complexity Museum implementation is dominated by curvilinear forms features that alter the structure of the building. This virtual architectural design is characterized by generating a sense of controlled chaos and unpredictability stimulation (Figure 4.24a). The result of this process converges with architectural designs known as "Deconstructivism" movement. A clear example is presented at the Guggenheim Museum in Bilbao, Spain, by Frank Gehry (see Figure 4.24b[3]).

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[3]Photograph of the «Guggenheim Museum in Bilbao, Spain» taken by MykReeve on 14 January, 2005. – distributed with licence CC BY-SA 3.0 via Wikimedia Commons.
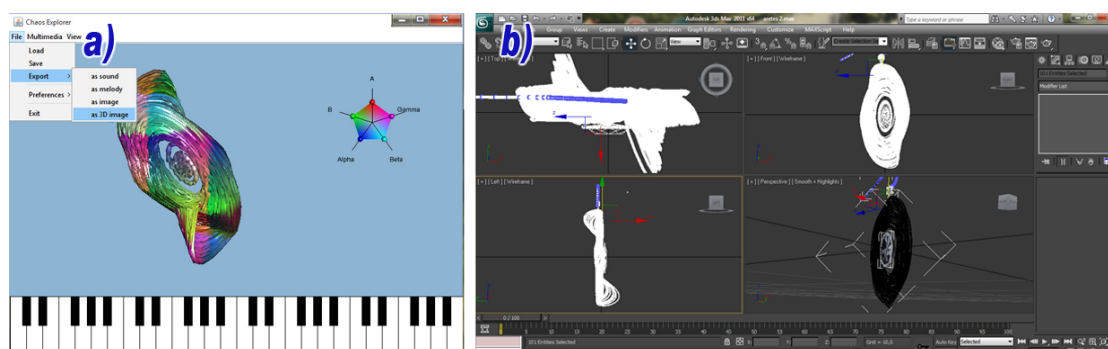
Figure 4.25: Jewel creation process. a) Exporting from Chaos Explorer. b) Manipulation in 3ds max studio.

Chaos' Jewelry

One of the most important sections of the museum is dedicated to the collection of jewellery inspired by the attractors. This collection has been called "Chaos' Jewelry", and it has been created fully in a digital way. Its process of realization is described below.

The first part in the creation of these jewels is the generation of different 3D attractors through the software Chaos Explorer (Figure 4.25a). After a selection process, and with the help of the software 3ds max (Figure 4.25b), these images have been manipulated and modified to achieve the desired shape and piece into jewellery such as necklaces, earrings, rings, bracelets among others.

Later, details were added such as frames of embed precious stones, pearls and pins (Figure 4.26a), and at the same time, the proper material was suitably chosen such as silver, gold and copper (Figure 4.26b).

Then, ambiance and decorative elements, such as textiles, furniture, and wallpaper, were created according to the Renaissance theme (Figure 4.27). For this reason, it was also necessary to deepen the study of this cultural movement, to identify its characteristic features and incorporate them into each composition. Another area of research was on engine V-Ray Render used in 3D animation. This particular engine manages to render the 3D models with more realistic effects. For instance, the Figure 4.28 shows, the materials used in the Chaos Jewellery that looks much realer than using traditional render engines.

After the completion of the models, a 3D animation has been performed to allow for viewing the final prototypes in all its dimensions. With this exhibition of digital art, it has been demonstrated that even beauty can generate chaos and that it can use to manifest in artistic compositions a more impressive scientific background.
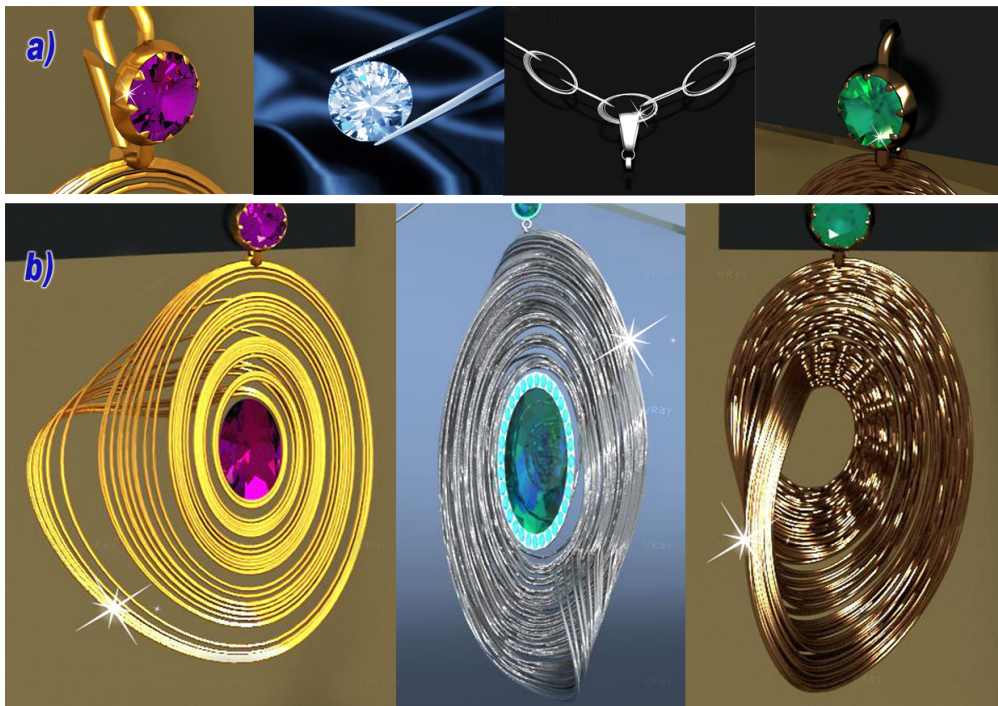
Figure 4.26: a) Decorative elements and b) Materials from the Chaos Jewerly.
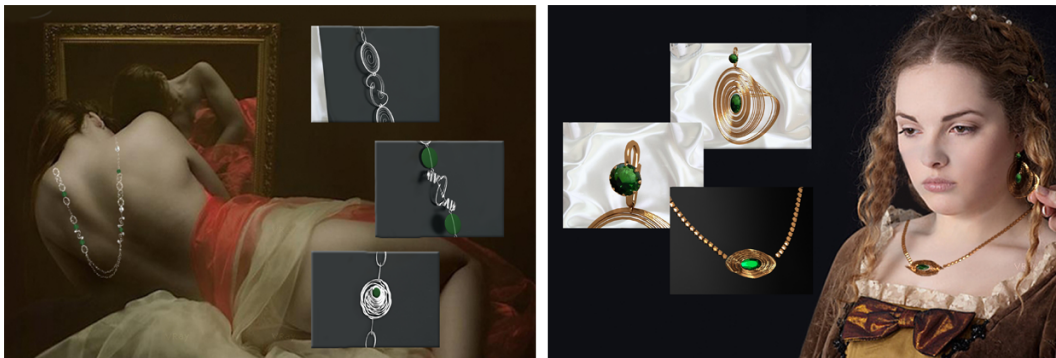
Figure 4.27: Artistic compositions linking the Renaissance cultural movement and the Chaos Jewerly collection.

Virtual kit for the Robotic Lab

The modelling of each part of the kit Lego® MindStorms™ in 3D was required to make this three-dimensional virtual game. Therefore, the online gallery Google SketchUp has been used to obtain some of the still existing 3D models (Paytonrwhite, 2007). However, some unavailable parts were modelled in 3ds max (see Figure 4.29). Then, the whole pieces were exported individually, keeping the features supported by Unity software for the future animation.
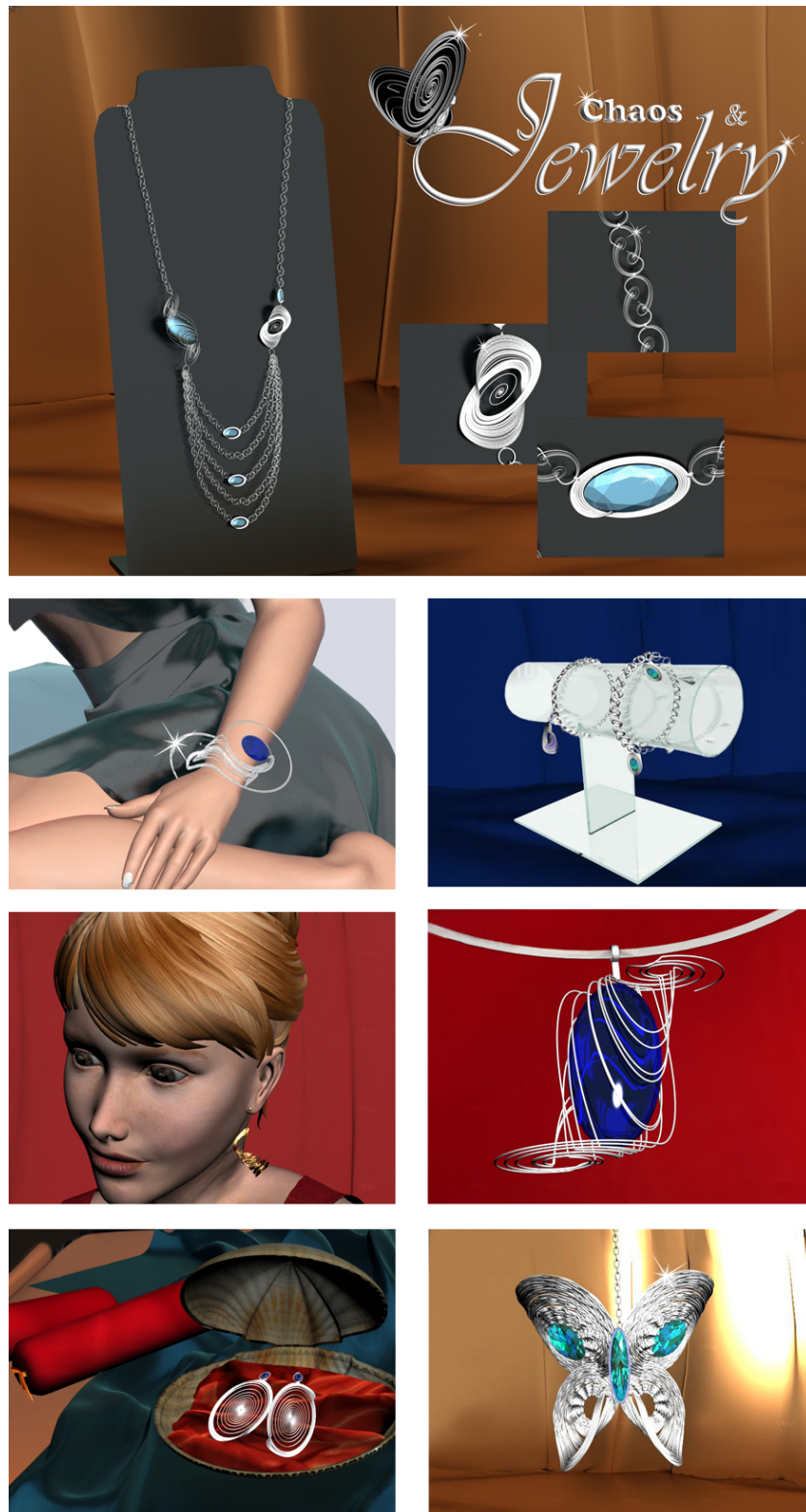
Figure 4.28: Chaos and Jewerly collection exhibited in the Chaos and Complexity museum.
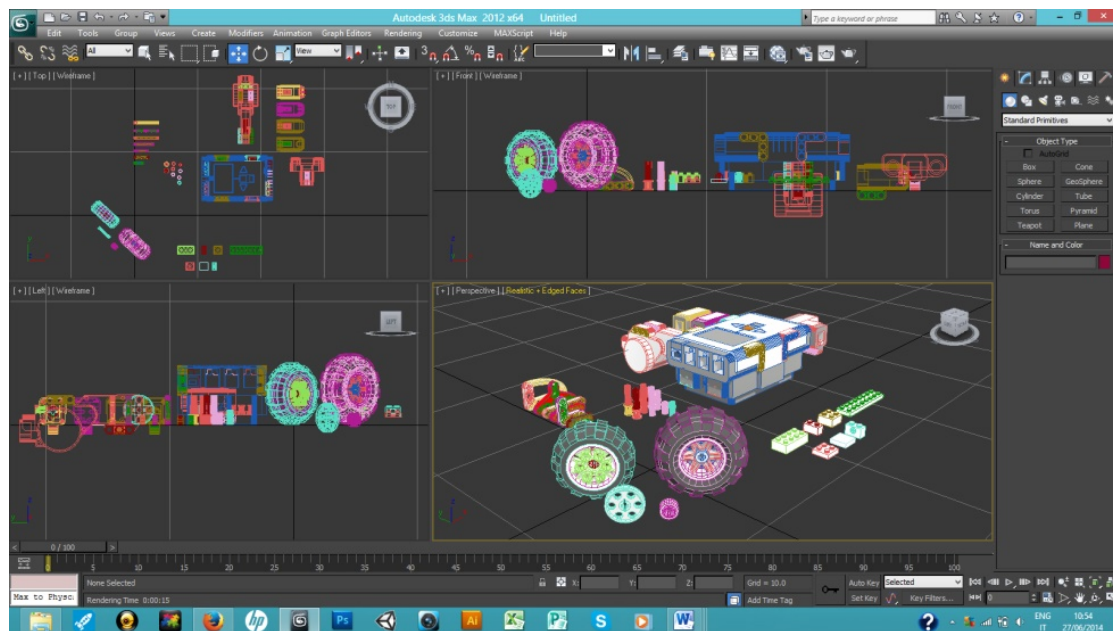
Figure 4.29: Kit of pieces from Lego® MindStorms™ modelled in 3ds max for the Robotic Lab.

Charles Darwin Research Station

This section describes the programming activities performed in the development of the game "Darwin's Journey" created in Scratch version 1.4 (see Figure 4.30). The didactic transposition was made taking into account the age of the users. This task required a simplified approach looking for rendering all fun. For this purpose, the programmed scenarios used coloured backgrounds and funny animations to motivate the young users.

For the navigation between the scenarios of the game, a counter variable, called "background", was used to keep track of the steps taken by the user. A script that manages the forward walk in the scenarios via a mouse click was also added. Subsequently, two scripts to handle navigation forward and backward through the keyboard buttons "m" and "n" were programmed. Moreover, other scripts that are activated by sending an event by a sprite to change the scene have been added. In the Figure B.1 of the Appendix B, the scripts here described are presented.

- **Implementation module: "England".-** This module begins with the presentation of Darwin inviting the user to join the adventure with him. The script developed for this module is presented in Figure B.2 of the Appendix B.

- **Implementation module: "Travel through the map".-** The player has to surf with the Beagle inside of the map. The scrip used for the Beagle's movement is shown in Figure B.3 of the Appendix B.

Figure 4.30: Development of the programming code in Scratch.

- **Implementation of the modules: "Brazilian rainforest", "Montevideo" and "Darwin arrives to the Galapagos Islands".-** In these modules, the player has to collect some objects. In Figure B.4 of the Appendix B, the script used for the actions taken by each of the elements of this scene is presented.

- **Implementation modulo: "Osorno volcano eruption".-** For this module, it has been created an animation to show the eruption of Osorno volcano (Chile). The script created to run this animation is presented in Figure B.5 of the Appendix B.

4.4 Future developments

Advanced environments presented in the previous items have been designed with the intention of integrating them into a system of IoT. This system is being developed by ESG members with experience in Computer Programming. This project of IoT consists in to create a virtual platform that will serve as host for the presented VALE-STEAM education. This platform shall have a standardized and flexible architecture that will allow the interconnection of multiple devices such as tablets, PC, cell phones, digital whiteboards, smart TVs among others. All these devices will be used for pedagogical purposes, being accessed for the future generations of devices to integrate contents related to STEAM teaching (see Figure 4.31).

Currently, existing online platforms enable for programming objects (microcontroller) to be used to control other objects such as wearable microdevices or robots. In fact, Architectural Reference Model (ARM)[4] has launched the "IoT EMBED" Operational System as a platform that seeks to facilitate the acceleration of IoT devices.

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[4]http://www.iot-a.eu/arm
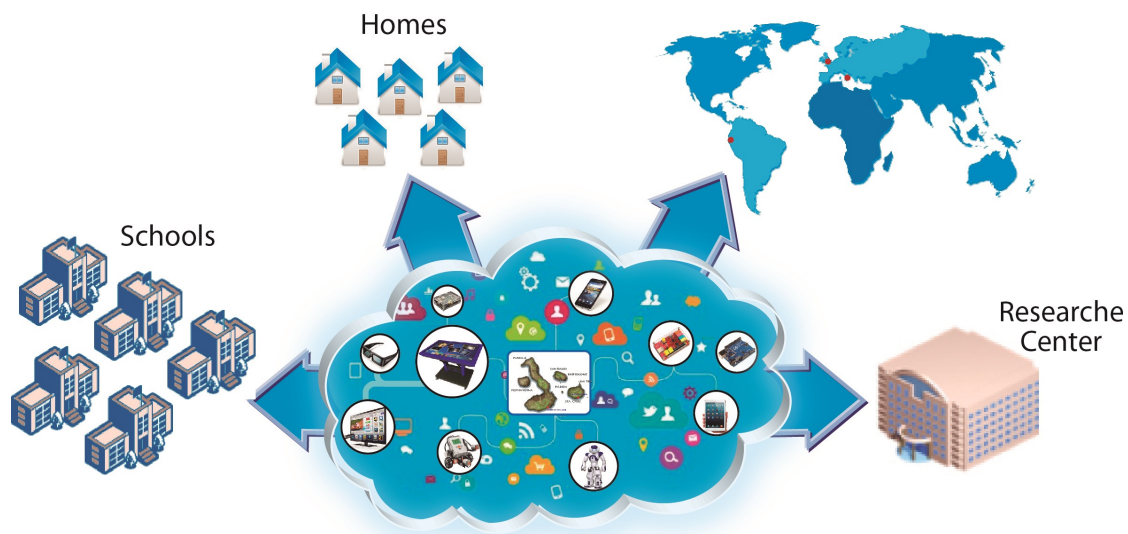
Figure 4.31: Managed cloud Image Service and Remote Session Storage for IoT.

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Chapter 5

VALE-Emotions Application Implementation

Contents

5.1 Introduction

As mentioned in the first chapter, the technology is a useful tool referred to special education. Also, as noted in the first chapter, the persons with ASD and Mental Retardation have certain difficulties to understand the emotional expressions. In the particular field of teaching and training of emotion recognition by this kind of subjects, several studies and papers have already been completed (Bilotta et al., 2010; Serret et al., 2014; Fernandes, Alves, Miranda, Queiros, & Orvalho, 2011; Silver & Oakes, 2001; Miranda, Fernandes, Sousa, & Orvalho, 2007). However, most of these studies have been tested up to 10 levels of intensity for each studied emotion. These intensities usually range from neutral to the strongest expression (K. Kim et al., 2014; Thomas et al., 2012; Y. Zhang & Wei, 2012; Dailey et al., 2002; Harms, Martin, & Wallace, 2010).

In the light of this, through the collaboration between doctoral students from the
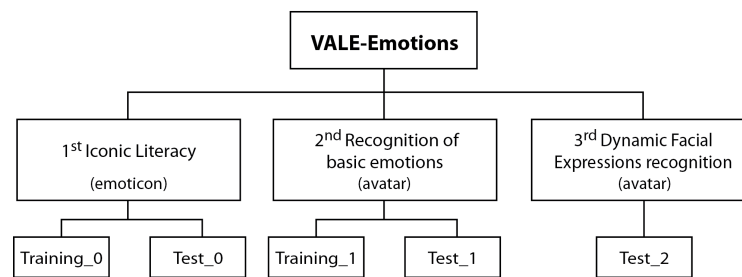
Figure 5.1: Schematic organization the VALE-Emotions App tools.

Dipartimento di Ingegneria Informatica, Modellistica, Elettronica e Sistemistica (DIMES) and the Laboratory of Psychology in the Università della Calabria (UNICAL), a system aimed to support individuals with a diagnosis of ASD and other disorders in both emotions recognition and empathy enhancement has been developed. This environment is comprised of several activities enclosed in an Applications (Apps) developed for Android mobile platform, which have been reported by F. Bertacchini, Bilotta, Gabriele, Olmedo Vizueta, et al. (2013), Olmedo Vizueta et al. (2014). This section is focused on the VALE-Emotions App that consists of three tools schematized in the Figure 5.1. This App is aimed at stimulating and facilitating the understanding and recognition of the six basic facial emotions: Joy, Sadness, Anger, Fear, Disgust, and Surprise. These emotions have been well studied by Paul Ekman (1999a, 1992). Such studies have been considered to promote learning processes through training following the program developed by Valenti (2007).

The emotions, considered in the development of the App here reported, has been modeled following an experimented set of parameters proposed in this section, which is based on settled codifications of Motion Picture Experts Group - v4 (MPEG-4) and Facial Action Coding System (FACS). In a certain case of this study, each emotion presents a sequence of 100 pictures (intensity levels) of the emotional expression within the Dynamic Facial Expressions (DFE) level (see Figure 5.1).

These learning and training processes can be used on mobile devices as tablets or smartphones, allowing the portability and access to touch sense interaction experiences. In fact, with this last, another key force can be individuated, since it has been demonstrated that these technologies enhance manipulation, eye-hand coordination, perception and intuition (Porayska-Pomsta et al., 2012; K. Kim et al., 2014; F. Bertacchini, Bilotta, Gabriele, Olmedo Vizueta, et al., 2013).

5.2   Users Requirements: User Centred Design

User Centred Design (UCD) is a design philosophy that incorporates the user perspective (needs, wishes, and limitations) in the software development process to achieve an easily usable system. In this philosophy, the HCD is also described as a multidisci-
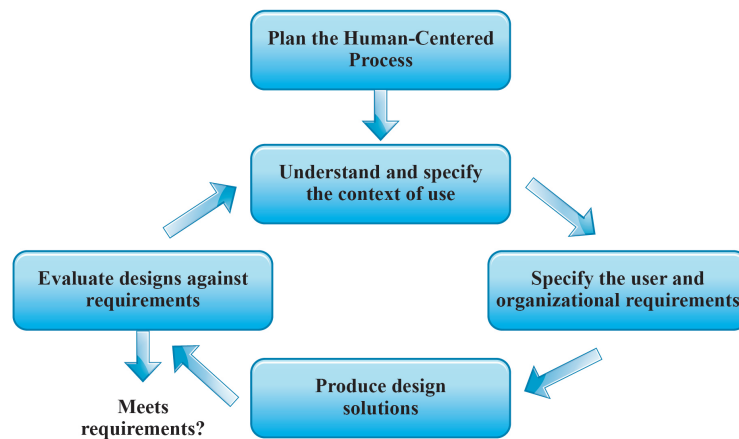
Figure 5.2: The Human-Centred Design cycle (from ISO 13407).

plinary activity that incorporates human factors, techniques, and knowledge. Moreover, the HCD determines five steps in the design cycle processes as shown in Figure 5.2. A study case using HCD was presented by Lai, Honda, and Yang (2010). The contents of this section are based on the HCD methods presented by Maguire (2001).

Such a design cycle has been considered to ensure both the usability of the App and effective representation of users throughout the design process. This later is also collected in the ISO-13407 standard for HCD (ISO-13407, 1999), which is detailed in Table 5.1. The sequence in which the processes and the level of effort are made varies depending on the environment and the performance stage within the design process. The following table explains, in summary, the process that has been achieved with the approach mentioned above.

5.2.1 Planning

After conducting an extensive literature review concerning the recognition of emotions in subjects with ASD and other developmental disorders, and analysing this information, it has initiated the planning phase to determine the grounds upon which develop the system, as well as the team and the stakeholders with whom it will interact throughout the process. The team includes an engineer with programming skills and management capacity of Android Studio development environment. This engineer is the responsible for the implementation and testing of the computer system. Also, a graphical engineer was necessary, who creates all the visual elements. The work has been performed in conjunction with a student of "Education Sciences" in the testing stage of the developed App. The team has been under the supervision of a full professor of Cognitive Psychology, who gave the guidelines to carry out this system.

Also, it has been considered the low economic cost that is intended to characterize the application, so it has been designed for use by any device with Android operating

Table 5.1: Methods of every step in the cycle HCD.

Planning	Using Context	Requirements	Design	Evaluation
1. Usability planning and scoping 2. Usability cost-benefit analysis	1. Identify stakeholders 2. Context of use analysis 3. Survey of existing users 4. Field study user observation 5. Diary keeping 6. Task analysis	1. Stakeholder analysis 2. User cost-benefit analysis 3. User requirements interview 4. Focus groups 5. Scenarios of use 6. People 7. Existing system/competitor analysis 8. Task/function Mapping 9. Allocation of function 10. User, usability and organizational requirements	1. Brainstorming 2. Parallel design 3. Design guidelines and standards 4. Storyboarding 5. Affinity diagram 6. Card sorting 7. Paper prototyping 8. Software prototyping 9. Wizard-of-Oz prototyping 10. Organizational prototyping	1. Participatory evaluation 2. Assisted evaluation 3. Heuristic or expert evaluation 4. Controlled user testing 5. Satisfaction Questionnaires 6. Assessing cognitive workload 7. Critical incidents 8. Post-experience interviews

system, easy to acquire and install.

5.2.2   Using Context

The system has been used in two specialized treatment institutions:

- "Associazione Autismo KR", located in Crotone (IT), which is aimed to support people with High Functioning Autism Spectrum Disorder (HFASD).

- "Centro Socioeducativo servizio di Neuroriabilitazione – Calabria", placed in Rende (IT), which is aimed to people with another kind of neurological disorders.

The objective was to stimulate and facilitate the understanding and recognition of the six basic facial expressions. So with this clear understanding of the context of use, the basis for the identification of needs and assessment system has been obtained. The tasks to be performed, the technical, physical and social conditions are described in the Table 5.2.

5.2.3   Requirements

The next step is the identification of user requirements as well as its limitations, so that the designer can consider them within the system development process. The Following, some general methods that have been used in the specification of these requirements are described.

Table 5.2: Summary of the Using Context factors.

User Group	Task	Technical environment	Physical environment	Organizational environment
System skills and experience: ability to use a tablet **Task knowledge:** Indicate the correct answer by touch **Training:** before each activity by the person supplying the app **Qualifications:** visual and sound stimuli that indicate the successes and failures **Language skills:** listening, speaking, reading, and writing **Age and gender:** from 4 years of age for both sexes **Physical and cognitive capabilities:** Motor skills to manipulate Tablet **Attitudes and motivations:** electronic devices attraction and acceptance of interpersonal interaction	**Task list:** receive instructions, running consecutively the Training and Test activities **Goal:** identify and learn the six basic emotions **Output:** virtual avatar expressing different emotions **Steps:** show emotion, listen nominative, identify, choose correct answer **Frequency:** once for each activity **Duration:** 20 min maximum **Dependencies:** have the company of specialists during the supply	**Hardware:** tablet 10" **Software:** Android operative system **Reference materials:** Facial Action Coding System **Other equipment:** notebook for recording observations	**Auditory environment:** normal **Thermal Environment:** tempered **Visual environment:** neutral without distractions **Space and furniture:** therapy room **User posture:** seated	**Work practices:** perform several therapeutic, educational and recreational activities in individual and group way **Assistance:** there are several specialists such as psychologists, doctors and therapists who are responsible for the well-being of patients **Interruptions:** each activities take place at set times **Management and communications structure:** centres run by specialists in the field of special needs **Organizational aims:** Autism KR.- provides educational paths and integration activities for children and young people with ASD. Centro Socioeducativo.-

Stakeholder analysis

In our particular case, the system will be used as a training tool for the assessment and recognition of the six basic emotions in children and adolescents diagnosed with HFASD and other disorders. It has been considered that not all these users have reading skills, for that reason, each interface has only iconic information, supported by sound stimuli for a better understanding of the activities. Also, it is anticipated that the system is used by the specialized staff of each institution, for that reason, the interface is simple and intuitive. While developers of the system and those carrying out the research will continue to provide support and monitor the proper use of the system.

User Requirements Interviews

Through a first contact made with the Centre's staff, valuable information on the needs and requirements of the patients was obtained, as well as on psychological tests that have been provided to them, which turns out to be advantageous as it provides relevant information such as the Intelligence Quotient (IQ) and reasoning ability of

Figure 5.3: GUI from MARA3D (Mobile Art Reference App).

patients.

Existing Competitor Analysis

In order to determine possible unique benefits of our system, two applications already existing on the market have been evaluated. Thus, possible problems of usability have been identified and taken as the baseline for the proposed new system. The evaluated applications were: Mobile Art Reference App 3D (MARA3D)[1][2](Figure 5.3), and, Facial Expression Recognizer v1.2 (FER)[3] (Figure 5.4). The first application is used to study facial expressions. This version features a stunning face model with two texture modes. This model expresses the six basic emotions, with pinch & zoom options. The second application allows discovering the hidden emotion behind a selfie, using photos from personal gallery or takes one instantly. Through these images, it is possible to discover the expressions that the picture shows. Seven possible facial expressions recognized in the picture are displayed (in percentage): neutral, happy, surprise, anger, fear, sad and disgust. The Table 5.3 shows a comparative diagram of the two applications discussed in comparison with the App here reported.

In the Figure 5.5, additional benefits that the new application could offer in comparison with existing applications are displayed.

Task and Function Mapping

In this step, the functions that each user must perform during the execution of each system tasks are specified. Besides the functions that are essential to the task and those

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[1]http://www.mara3d.com/

[2]https://play.google.com/store/apps/developer?id=MARA%203D&hl=en

[3]http://www.appszoom.com/android-app/facial-expression-recognizer-mpckp.html
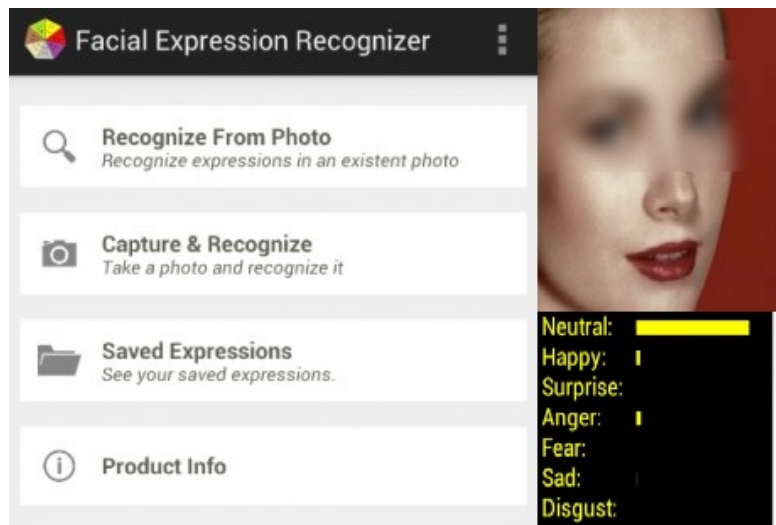
Figure 5.4: GUI from Facial Expression Recognizer App v1.2.

Table 5.3: Comparison between the two analysed applications vs. VALE-Emotions App.

Features	MARA3D	FER	VALE-Emotions
Beautiful real-time morphing	√		√
Dynamic Facial Expressions			√
Intuitive Gesture-Based Navigation	√	√	√
Comlete emotion presets	√		√
3D real-time orbiting	√		
Portrait Modes	√	√	√
Zoom (in / out)	√		
Interface Tools	√	√	√
Database stored			√
Training	√	√	√
Assessment Test		√	√
Auditory stimuli			√
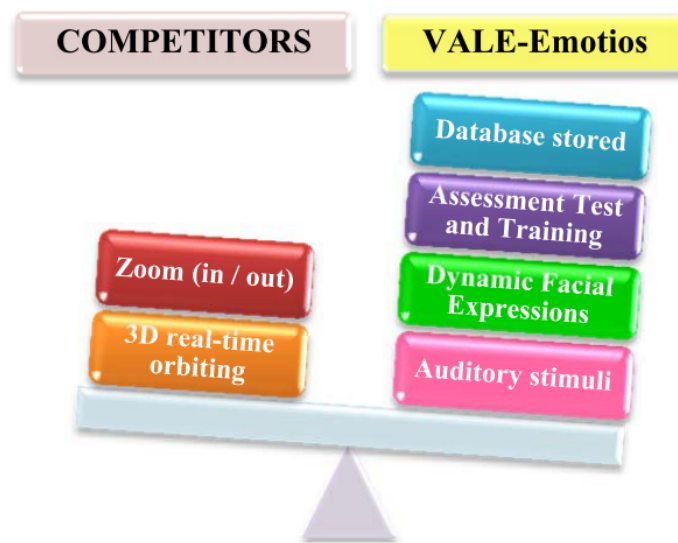
Figure 5.5: Differential characteristics between applications analysed.

that are only occasionally used are identified. The Table 5.4 presents this information using the Structure of Functionality Matrix.

Allocation of Function

It consists of specifying the tasks performed by humans and that which will be carried out by technology. The diagram of Figure 5.6 shows how this process is accomplished in two major enforcement activities.

5.2.4   Design

At this stage, the user interface based on a flexible and iterative approach is developed. For this purpose, several previous sketches have been made. These sketches indicate the possible distributions of each of the elements, functionalities features, and links. The final result of this stage is shown below in the next section.

5.2.5   Evaluation

The designs have been tested throughout development. The main factor was the usability qualifies based on the criteria of both experts and users, through testing performed by several volunteers inside suitable locations. It is noteworthy that, thanks to the feedback received in the various interactions, several versions of the application have been conducted. The final result was the version v10.0, which is amply described in successive section.

In order to get success during the development of the process described above the following principles should take into account:

Table 5.4: Structure for functionality matrix of the VALE-Emotions App.

Users and Tasks	Functions within App									Comments
	F1	F2	F3	F4	F5	F6	F7	F8	F9	
Researcher/Specialist										
• Patient data storage	x									
• Interaction data storage		x								
• Patient Iconic Literacy				x						
• Configuration of parameters			o							Lenguage, Time, Number images
• Dynamical emotions generation					x					Random displayed images.
• Intuitive Interface								o		
• Portability									x	Install for Smarthphones.
Patient										
• Highly Accessibility						x				Easiness interaction.
• Intuitive Interface								x		
• Stimulation							x		x	Sounds and Images
Function selection	Medium priority	Medium priority	Low priority	Medium priority	Medium priority	Medium priority	Medium priority	High priority	High priority	x = Critical to task o = Occasional use

F1: Patient Data Storage.
F2: Evaluation data storage.
F3: Setting Menu.
F4: Iconic Literacy (Training/Test).
F5: Random Emotions Generation.
F6: Touch Screen Interaction.
F7: Feedback Notifications.
F8: Intuite Graphic Interface .
F9: Android Cross-platforms.
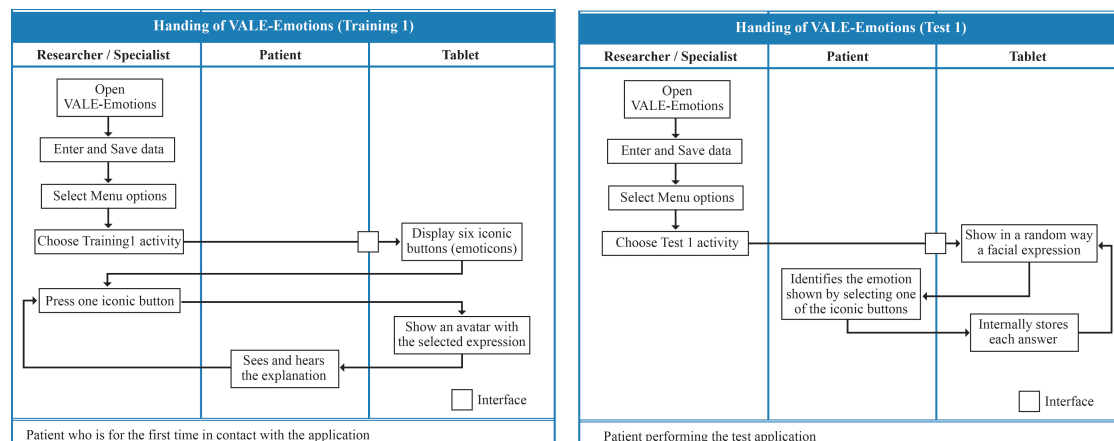
Figure 5.6: Allocation of function chart from Training and Test activities in VALE-Emotions App.

- The active involvement of users and clear understanding of user and task requirements.

- An appropriate allocation of function between user and system to refine the requirements and design.

- Active Iteration with the users for assessment the designs.

- Integration of a multi-disciplinary design teams.

5.3 Framework of codification models for emotional expression

In this section, two codification models for the body and face of human avatars are reviewed. The first one was developed by MPEG-4 and the second one was proposed by Paul Ekman (1999a, 2003, 1999b, 1992). Such codifications have been intrinsic used for the modeling of emotional expression in the two avatars shown in Figure 5.7. Below, it is presented the procedure and description of the before mentioned codification standards that were applied in the modeled avatars.

5.3.1 MPEG-4 Codification System

The human avatars, presented in the Figure 5.7, have been linked to the Face and Body Animation (FBA) international standard as part of the MPEG-4 ISO/IEC-14496 (1999). In fact, the MPEG-4 FBA provides the details for the animation of human or human-like characters through the Face Animation Parameters (FAPs) and Body Animation Parameters (BAPs).

Figure 5.7: Virtual avatars modelled for the VALE-Emotions App.

Continuing with the FAPs, these are composed by two high-level FAPs and 66 low-level parameters drawn from the study of minimal facial actions (movement of facial parts). In fact, these parameters are closely related to facial muscle actions (Technologies, n.d.; Giacomo, Joslin, Garchery, & Magnenat-Thalmann, 2003). In the AppendixA, it is summarized the FAPs and their respective parameter range value used in the virtual animation of human faces through the MPEG-4 standard. Thus, these parameters control and describe the movement of facial parts in virtual human or human-like animation. Moreover, these parameters are represented computationally by I-Frames in a sequence of movement of face parts and gesture generation.

Moreover, the MPEG-4 includes the Facial Definition Parameters (FDPs), which in turn describes the Feature Points (FPs) related to the human face. Such a FPs is the vertex codification of a settled mesh in the face of a virtual human representation. For instance, the Figure 5.8 presents the FPs applied to the girl face avatar modeled for this study. It is worth to mention that according to the MPEG-4 FBA standard, the FAPs control the key FPs action, which are used to produce animated vises and facial expressions, as well as head and eye movement (Moussa & Kasap, 2010).

Due to the FAPs are applied in a broad range of facial animation characters with different sizes and proportions, the FAPs are also expressed regarding the Face Animation Parameter Units (FAPUs). These last are computed from the spatial distances between the major facial FPs on the model in its neutral state as illustrated in Figure 5.9. Such
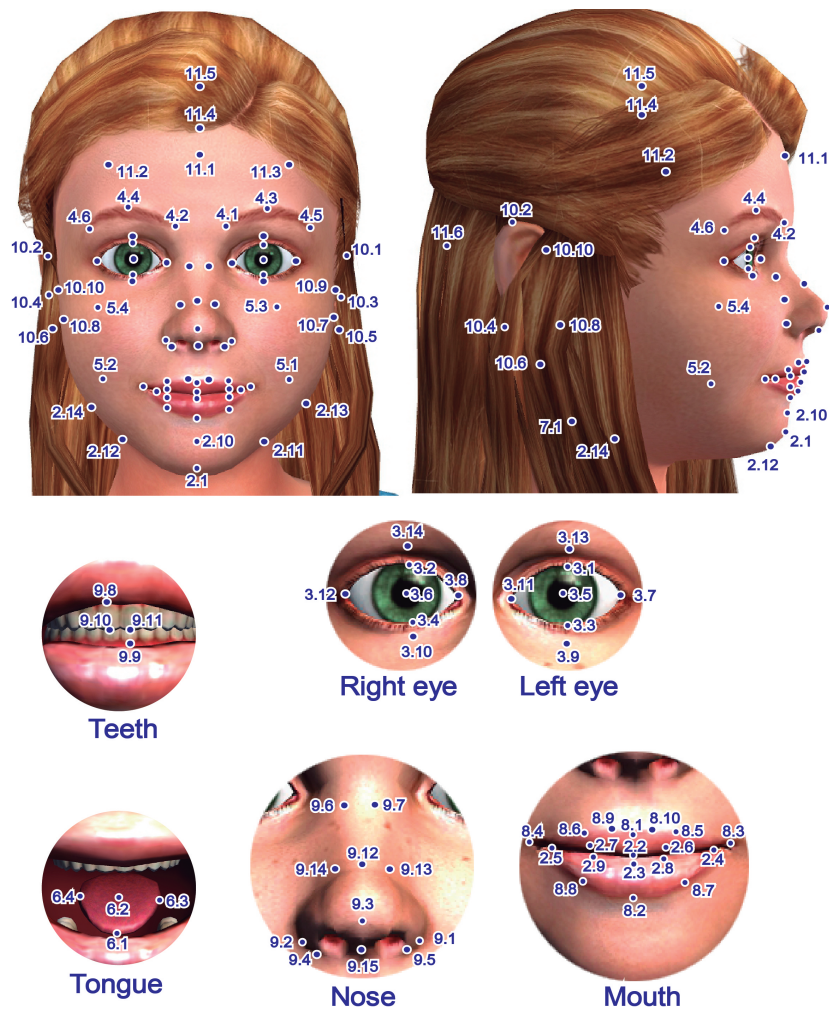
Figure 5.8: Facial Feature Points (FP) applied to the avatar.

a FAPUs values are listed in the Table 5.5. The FPs and spatial direction (x or y) that were related to obtaining the FAPUs are also shown.

5.3.2   Facial Action Coding System

Other well diffused and practiced codification system used for representing natural expressions of human faces has been taken from the known studies of Paul Ekman (1999a, 2003, 1999b, 1992). In such studies, the encoding of 44 facial muscle's movements that serve to generate any emotion are described. In order to detect such movements, Ekman has been developed a human-observer-based system known as Facial Action Coding System (FACS). This coding system encodes muscles individually calling them Action Units (AUs). In the Table 5.6 is presented the summarized application of the Ekman's
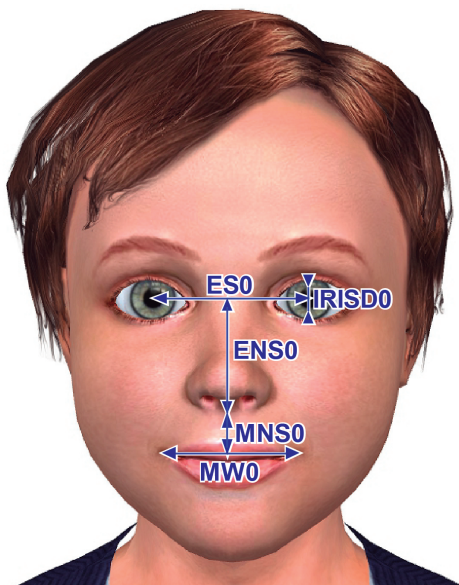
Figure 5.9: FAPUs applied to the modelled boy avatar.

Table 5.5: Facial Animation Parameter Units (FAPUs) of the modelled boy avatar .

Equation	Description	Value
IRISD0 = 3.1.y–3.3.y = 3.2.y–3.4.y	Iris diameter	97 px
ES0 = 3.5.x–3.6.x	Eye separation	375 px
ENS0 = 3.5.y–9.15.y	Eye - nose separation	270 px
MNS0 = 9.15.y–2.2.y	Mouth - nose separation	100 px
MW0 = 8.3.x–8.4.x	Mouth width	325 px
AU	Angle Unit	0 rad

AUs on the six base emotions analyzed in this thesis work.

5.4 Proposal of a parametrization model for the Dynamic Facial Expression (DFE) generation

In this section, a parametrization model for emotional expression in virtual human faces is proposed. This model is based on frameworks of the FACS and MPEG-4 through the AUs and the FAP, respectively. For the implementation of such a model, the animation software called iClone[4] has been used to animate the six basic emotions through a virtual girl avatar. In fact, the different sections of the avatar face are defined through iClone in a similar way that FACS as shown in Figure 5.10.

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[4]http://www.reallusion.com/iclone/default.html

Table 5.6: Facial Action Coding System (FACS) and Action Units (AUs) from Ekman's study.

Emotion	AUs	AUs Description	Final Expression
ANGER	4+5+7 +23	AU4: brows lowered and drawn together AU5: upper eyelids are raised AU7: lower eyelids are raised AU23: lip tightener	
DISGUST	9+15+16	AU9: nose wrinkler AU15: lip corner depressor AU16: lower lip depressor	
FEAR	1+2+4 +5+7+20 +26	AU1: inner portion of the brows is raised AU2: outer portion of the brows is raised AU4: brows lowered and drawn together AU5: upper eyelids are raised AU7: lower eyelids are raised AU20: lip stretcher AU26: jaw drop	
JOY	6+12	AU6: cheeks are raised AU12: lip corner puller	
SADNESS	1+4+15	AU1: inner portion of the brows is raised AU4: brows lowered and drawn together AU15: lip corner depressor	
SURPRISE	1+2+5B +26	AU1: inner portion of the brows is raised AU2: outer portion of the brows is raised AU5B: upper eyelids are raised AU26: jaw drop	
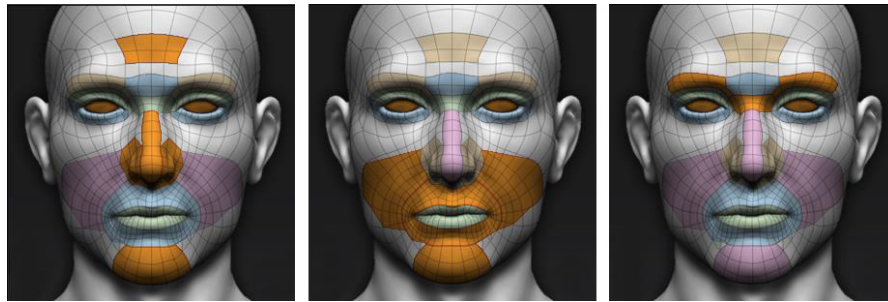
Figure 5.10: Face manipulation during the expression creation process in iClone.
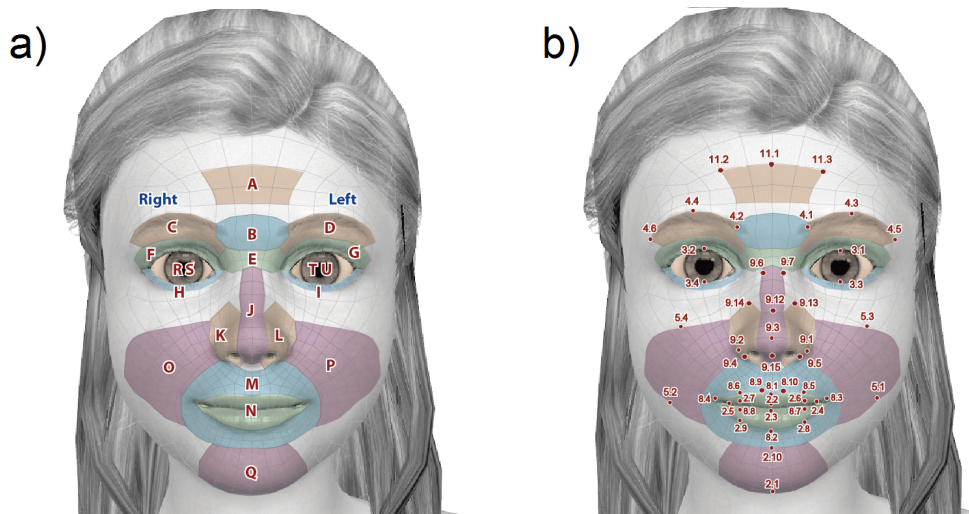
Figure 5.11: Female avatar in iClone, showing the merge of the a) AUs of the FACS and b) FAP of the MPEG-4 codification systems.

The result of merging the two standards (AUs and FAP) was accomplished through iClone as shown in Figure 5.11. Thus, in the Figure 5.11a is possible to observe the face sections of the avatar manipulated in iClone. Each one of these sections has been related to specific AUs of Ekman, but they have been identified using the characters from "A" to "U". On the other hand, certain FPs have been linked to the movement of every feature point enclosed by the AUs as shown in the Figure 5.11b.

Hence, a resumed codification is attributed to each FPs enclosed by each new AUs as shown in the Table 5.8. Through iClone, a ranges values was defined for every parameter represented by the degree of freedom of every FP. Such degrees of freedom may be defined as the independent way in which the AU can move either in translation or rotation mode. Finally, the parameter range values adopted for the generation of the six different basic emotions animated in this study are shown in Table 5.8.

Finally, based on the parametrization before presented and with the support of iClone, the generation of the Dynamic Facial Expressions (DFE) for each emotion has

Table 5.7: Proposed face parametrization model on AUs and FAPs applied through iClone.

Emotion	iClone Animation	AUs used	Section Face (Figure 5.11)	FPs used (Figure 5.11)	Effective Parametrization Range through iClone
ANGER		AU4 + AU5 + AU7 + AU23	A+B+C+D F+G F+G N	(11.1)-(11.3),(4.1)-(4.6) (3.13)-(3.14) (3.13)-(3.14) (2.2)-(2.9), (8.2)-(8.10)	$[0,-450],[0,-180],[0,-450],[0,-450]$ $[0,108],[0,108]$ $[0,108],[0,108]$ $[0,-450],[0,180],[0,180],[0,180],[0,180],[0,360]$
DISGUST		AU9 + AU15 + AU16	E+J N N	(9.6),(9.7),(9.3),(9.12),(9.15) (2.2)-(2.9),(8.2)-(8.10),(8.4) (3.13)-(3.14) (2.8),(2.9)	-408, 360, -327
FEAR		AU1 + AU2 + AU4 + AU5 + AU7 + AU20 + AU26	A+B A A+B+C+D F+G F+G N Q	(11.1),(4.1),(4.2) (11.2),(11.3) (11.1)-(11.3),(4.1)-(4.6) (3.13),(3.14) (3.13),(3.14) (2.2)-(2.9),(8.2)-(8.10) (2.1)	180, 90, -450, -135, -180, -180, 540, 540, 540, 540, 300, -540
JOY		AU6 + AU12	O+P N	(5.1)-(5.4) (8.3),(8.4)	360, 300
SADNESS		AU1 + AU4 + AU15	A+B A+B+C+D N	(11.1),(4.1),(4.2) (11.1)-(11.3),(4.1)-(4.6) (2.2)-(2.9),(8.2)-(8.10),(8.4)	225, -450, -90, -225, -225, -240
SURPRISE		AU1 + AU2 + AU5 + AU26	A+B A F+G Q	(11.1),(4.1),(4.2) (11.2),(11.3) (3.13),(3.14) (2.1)	900, 630, 216,-1080
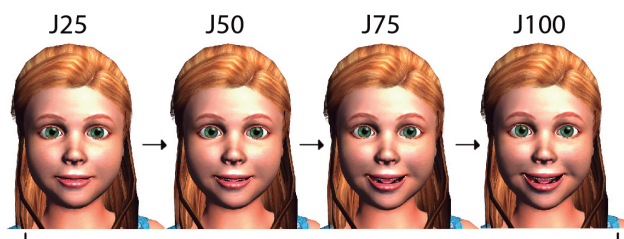
Figure 5.12: Samples of the joy emotion sequence generated with the Dynamic Facial Expression parametrization (DFE) within iClone.
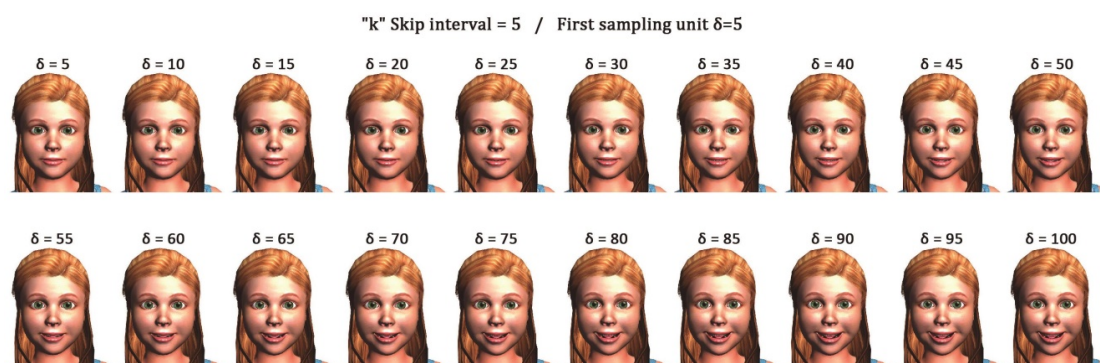
Figure 5.13: Sampling of twenty pictures of the Joy Dynamic Facial Expression.

been obtained. For instance, the Figure 5.12 presents some picture samples of the generated joy emotion sequence.

The parametrization presented before has been used to create the various intensity level of the six emotions within the Dynamic Facial Expressions (DFE) implemented in the girl avatar. Such a parameterization was used for the generation of 100 pictures sequence of the six emotional expressions in iClone. However, in this study, a group of 20 images from each emotion generated through the DFE has been chosen. A systematic sampling method was used for the selection of such images. Such a sampling method is expressed as

$$k = \frac{N}{n} \tag{5.1}$$

where, the value of k defines the skip interval, N is the population of pictures sequence, and n is the sample size (e.g. k=100/20). Thus, a random number δ between 1 and k has been chosen. This number allows for the first sampling unit. Then, taking a leap of k units from the position δ, we get the following sample units to complete a group images sequences of 20 facial expressions for each basic emotion. In Figure 5.13, the whole group of pictures sequence for the Joy emotion is presented as an example. Also, in the Figure 5.14, the six final emotions are presented, which represent the highest intensity level emotion pictures of the sequences.

| **Anger** | **Disgust** | **Fear** | **Joy** | **Sadness** | **Surprise** |
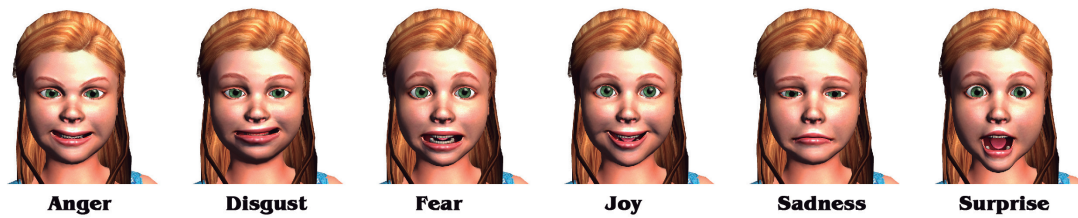
Figure 5.14: Highest intensity level of the six emotions generated with the DFE.

Furthermore, the thorough parametrization set of the twenty selected pictures is presented in the Table 5.8. The emotion encoded as 005 represents the lowest level of intensity, in other words, an almost neutral expression. Instead of this, the parameters corresponding to the expression 100 allows for the generation of the final and highest intensity level expression.

5.5 VALE-Emotions App Description

The VALE-Emotions App has been created with the development environment Android Studio (see Figure 5.15). Usually, an App consists of Layouts that describes the interface organization of the App and Activities that describe the actions and event necessary for the interaction of the user with the App. The Layouts are XML files, and the Activities are Java Scripts. More details about the development of Android applications can be found in (Meier, 2012).

In particular, five different layouts have been programmed for the VALE-Emotions App. Every layout has associated one activity that has also been programmed. Below, a description of the different layouts and activities that form the user interface of the VALE-Emotions App will be described.

5.5.1 Launcher Icon and Main Interface

A Launcher Icon is a particular direct access to the App that appears in the menu of installed applications of an Android device. The launcher icon of the VALE-Emotions App is shown in Figure 5.16a. Once the user enters to the App, the main interface of the VALE-Emotions App is displayed on the screen as shown in the Figure 5.16b. The layout of this interface is formed by text and number fields to enter the patient data to be stored in the output data results file (e.g. Code, Name, Age, and Sex). Due to the filling of these data is a critical task for the research and diagnosis purposes, the activity of this interface controls that the data have been saved by the user before to launch the training or tests activities.

Table 5.8: Parametrization of the twenty selected picture for each emotion generated through the DFE and iClone.

Emotion Cod	ANGER	DISGUST	FEAR	JOY	SADNESS	SURPRISE
005	-22.5, -9, -22.5, -22.5, 9, 9, 9, 9, 18	-24, 18, -16.35	9, 4.5, -22.5, -6.75, -9, -9, 27, 27, 27, 27, 15, -27	18, 15	11.25, -22.5, -4.5, -11.25, -11.25, -12	45, 31.5, 10.8, -54
010	-45, -18, -45, -45, 18, 18, 18, 18, 36	-48, 36, -32.7	18, 9, -45, -13.5, -18, -18, 54, 54, 54, 54, 30, -54	36, 30	22.5, -45, -9, -22.5, -22.5, -24	90, 63, 21.6, -108
015	-67.5, -27, -67.5, -67.5, 27, 27, 27, 27, 54	-72, 54, -49.05	27, 13.5, -67.5, -20.25, -27, -27, 81, 81, 81, 81, 45, -81	54, 45	33.75, -67.5, -13.5, -33.75, -33.75, -36	135, 94.5, 32.4, -162
020	-90, -36, -90, -90, 36, 36, 36, 36, 72	-96, 72, -65.4	36, 18, -90, -27, -36, -36, 108, 108, 108, 108, 60, -108	72, 60	45, -90, -18, -45, -45, -48	180, 126, 43.2, -216
025	-112.5, -45, -112.5, -112.5, 45, 45, 45, 45, 90	-120, 90, -81.75	45, 22.5, -112.5, -33.75, -45, -45, 135, 135, 135, 135, 75, -135	90, 75	56.25, -112.5, -22.5, -56.25, -56.25, -60	225, 157.5, 54, -270
030	-135, -54, -135, -135, 54, 54, 54, 54, 108	-144, 108, -98.1	54, 27, -135, -40.5, -54, -54, 162, 162, 162, 162, 90, -162	108, 90	67.5, -135, -27, -67.5, -67.5, -72	270, 189, 64.8, -324
035	-157.5, -63, -157.5, -157.5, 63, 63, 63, 63, 126	-168, 126, -114.45	63, 31.5, -157.5, -47.25, -63, -63, 189, 189, 189, 189, 105, -189	126, 105	78.75, -157.5, -31.5, -78.75, -78.75, -84	315, 220.5, 75.6, -378
040	-180, -72, -180, -180, 72, 72, 72, 72, 144	-192, 144, -130.8	72, 36, -180, -54, -72, -72, 216, 216, 216, 216, 120, -216	144, 120	90, -180, -36, -90, -90, -96	360, 252, 86.4, -432
045	-202.5, -81, -202.5, -202.5, 81, 81, 81, 81, 162	-216, 162, -147.15	81, 40.5, -202.5, -60.75, -81, -81, 243, 243, 243, 243, 135, -243	162, 135	101.25, -202.5, -40.5, -101.25, -101.25, -108	405, 283.5, 97.2, -486
050	-225, -90, -225, -225, 90, 90, 90, 90, 180	-240, 180, -163.5	90, 45, -225, -67.5, -90, -90, 270, 270, 270, 270, 150, -270	180, 150	112.5, -225, -45, 112.5, -112.5, -120	450, 315, 108, -540
055	-247.5, -99, -247.5, -247.5, 99, 99, 99, 99, 198	-264, 198, -179.85	99, 49.5, -247.5, -74.25, -99, -99, 297, 297, 297, 297, 165, -297	198, 165	123.75, -247.5, -49.5, -123.75, -123.75, -132	495, 346.5, 118.8, -594
060	-270, -108, -270, -270, 108, 108, 108, 108, 216	-288, 216, -196.2	108, 54, -270, -81, -108, -108, 324, 324, 324, 324, 180, -324	216, 180	135, -270, -54, -135, -135, -144	540, 378, 129.6, -648
065	-292.5, -117, -292.5, -292.5, 117, 117, 117, 117, 234	-312, 234, -212.55	117, 58.5, -292.5, -87.75, -117, -117, 351, 351, 351, 351, 195, -351	234, 195	146.25, -292.5, -58.5, -146.25, -146.25, -156	585, 409.5, 140.4, -702
070	-315, -126, -315, -315, 126, 126, 126, 126, 252	-336, 252, -228.9	126, 63, -315, -94.5, -126, -126, 378, 378, 378, 378, 210, -378	252, 210	157.5, -315, -63, -157.5, -157.5, -168	630, 441, 151.2, -756
075	-337.5, -135, -337.5, -337.5, 135, 135, 135, 135, 270	-360, 270, -245.25	135, 67.5, -337.5, -101.25, -135, -135, 405, 405, 405, 405, 225, -405	270, 225	168.75, -337.5, -67.5, -168.75, -168.75, -180	675, 472.5, 162, -810
080	-360, -144, -360, -360, 144, 144, 144, 144, 288	-384, 288, -261.6	144, 72, -360, -108, -144, -144, 432, 432, 432, 432, 240, -432	288, 240	180, -360, -72, -180, -180, -192	720, 504, 172.8, -864
085	-382.5, -153, -382.5, -382.5, 153, 153, 153, 153, 306	-408, 306, -277.95	153, 76.5, -382.5, -114.75, -153, -153, 459, 459, 459, 459, 255, -459	306, 255	191.25, -382.5, -76.5, -191.25, -191.25, -204	765, 535.5, 183.6, -918
090	-405, -162, -405, -405, 162, 162, 162, 162, 324	-432, 324, -294.3	162, 81, -405, -121.5, -162, -162, 486, 486, 486, 486, 270, -486	324, 270	202.5, -405, -81, -202.5, -202.5, -216	810, 567, 194.4, -972
095	-427.5, -171, -427.5, -427.5, 171, 171, 171, 171, 342	-456, 342, -310.65	171, 85.5, -427.5, -128.25, -171, -171, 513, 513, 513, 513, 285, -513	342, 285	213.75, -427.5, -85.5, -213.75, -213.75, -228	855, 598.5, 205.2, -1026
100	-450, -180, -450, -450, 180, 180, 180, 180, 360	-480, 360, -327	180, 90, -450, -135, -180, -180, 540, 540, 540, 540, 300, -540	360, 300	225, -450, -90, -225, -225, -240	900, 630, 216, -1080
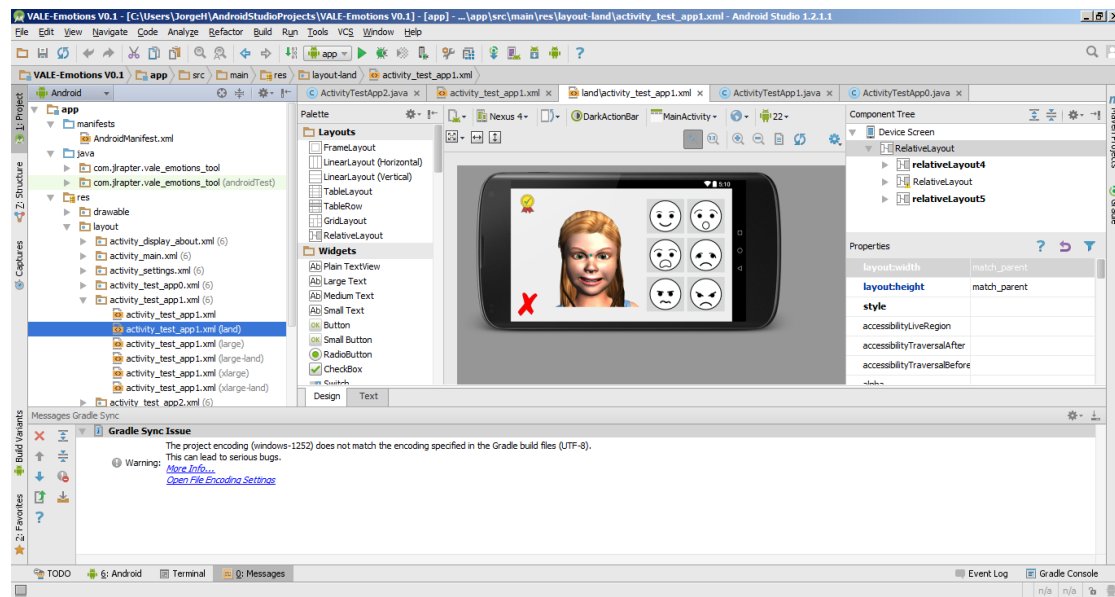
Figure 5.15: Development interface of the Android Studio used for the VALE-Emotions App.

5.5.2 Menu and Settings Interfaces

The main interface displays the button "Menu" in the top-right corner as shown in the Figure 5.17a. The principal activities of the App can be accessed through this menu. One of the activities is the "Settings" option, which screen capture is shown in Figure 5.17b. In this activity, the language of the audio feedback for the training and test activities can be set among Italian, Spanish, and English, as well as the audio activation/deactivation. Also, it is possible to customize the visualization time of each emotion expression that is displayed in the next activities. The last option is the configuration of the number of pictures generated by the Dynamic Facial Expression (DFE) that are displayed in the training and test activities.

5.5.3 Interfaces of the Training and Test activities

As mentioned at the beginning of this chapter, three different activities are enclosed into the VALE-Emotions App (see Figure 5.1). The first one activity is aimed for Icon Literacy of the patient (see Figure 5.18a), since these certain set of icons is further used for the interaction of the patient with the next two activities. The idea of using standard icons for the interaction with ASD subjects is not new. In particular, a Europe Union project named ARASAAC[5] from the Government of Aragon (Spain), offers online graphics resources and materials to facilitate the communication between subjects with communicational limitations. This project is based on the denominated Sistemas Au-

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[5]http://arasaac.org/index.php

(a) Launcher icon

(b) Main interface
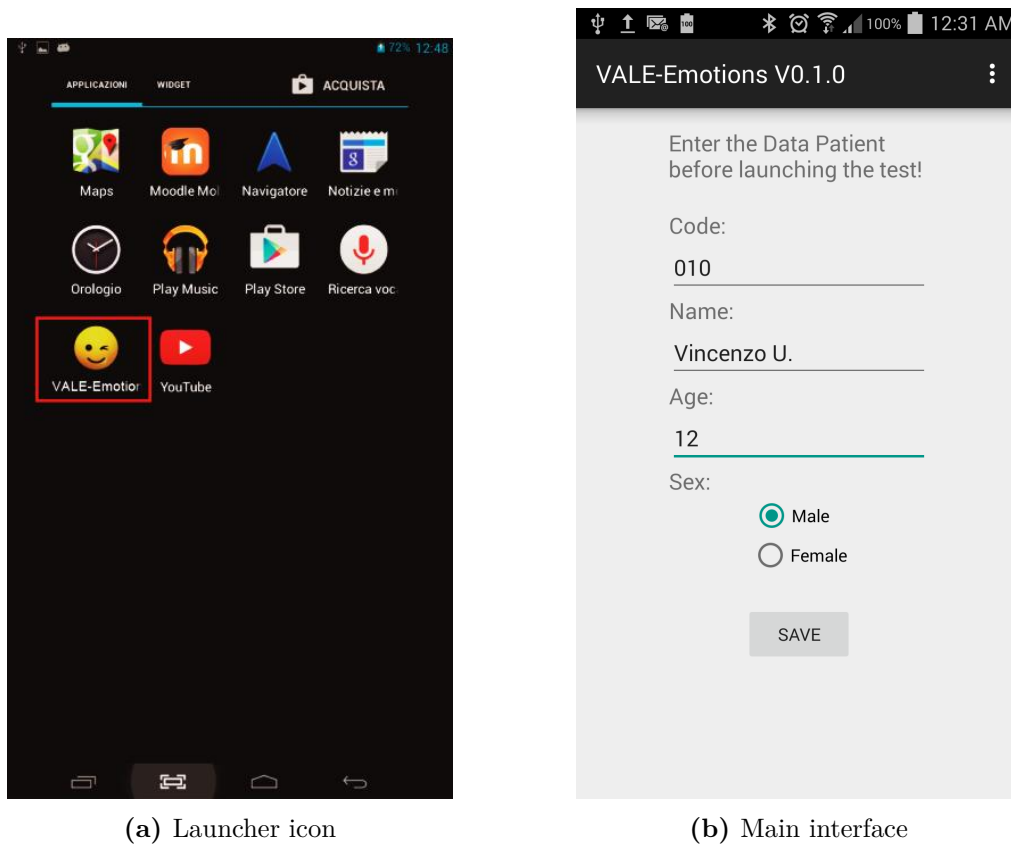
Figure 5.16: Screen captures VALE-Emotions App

(a) Menu interface

(b) Setting interface
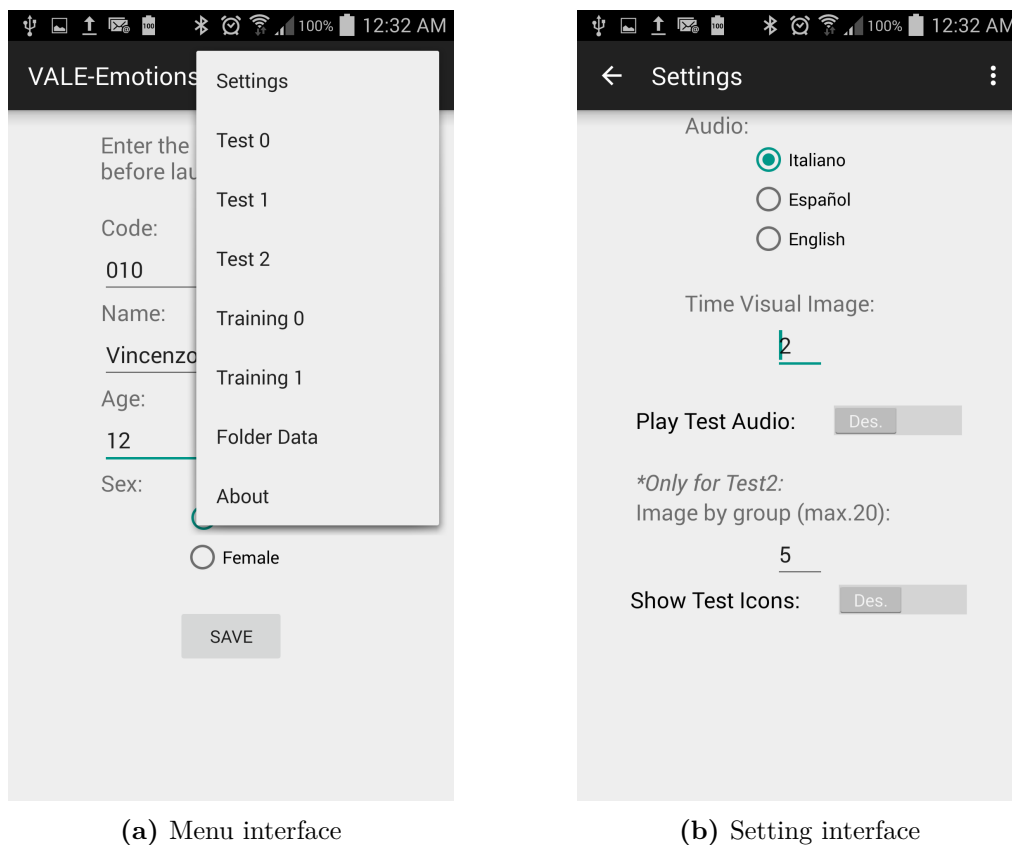
Figure 5.17: Screen captures VALE-Emotions App

(a) Interface for Iconic Literacy.

(b) Interface for Recognition of basic emotions.

(c) Interface for Dynamical Facial Expression recognition
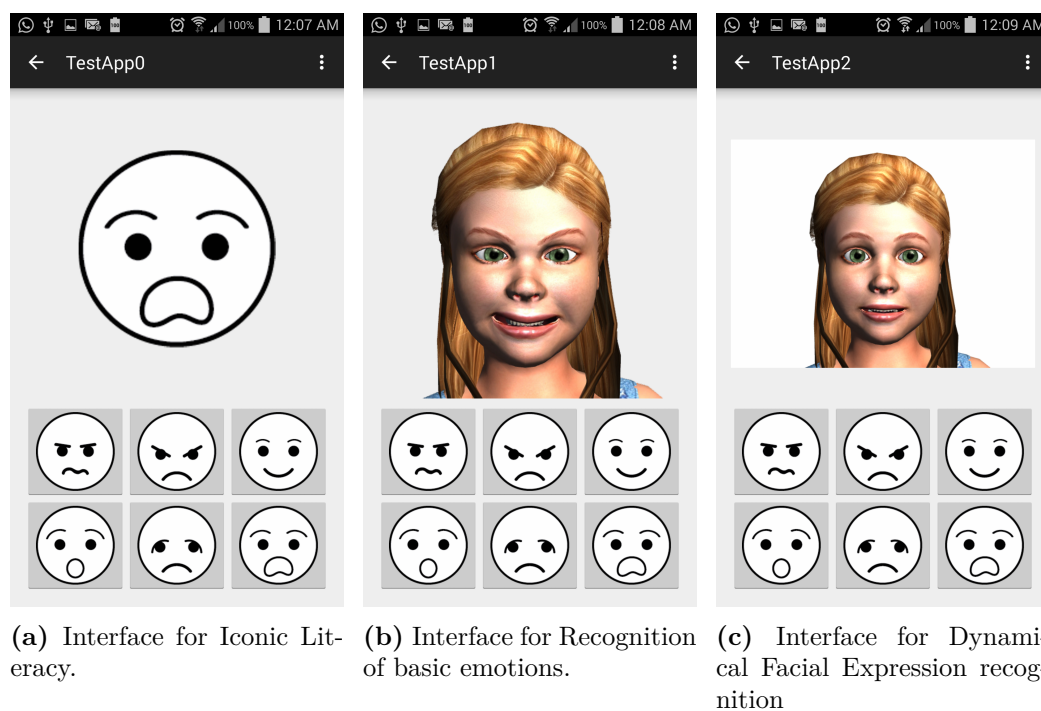
Figure 5.18: Screen captures VALE-Emotions App

mentativos y Alternativos de Comunicación (SAAC) by its meaning in Spanish. Thus, the "Training 0" activity trains on the Icon Literacy, supported by the audio feedback. Then, the "Test 0" activity evaluates the icon-emotion recognition of the patient quantitatively. It is worth to note that the six basics emotions, analyzed in this work, are associated with specific and unique icons as shown in Figure 5.18a.

Based on the activities before mentioned, the "Traning 1" and "Test 1" are aimed to practice and evaluate the recognition of emotions expressed by the virtual avatars described in the last sections as shown in the Figure 5.18b. It is worth to mention that the pictures involved in these activities represent the highest intensity level of the six basic emotions generated through the DFE described in the last section.

Finally, the activity "Test 2" is shown in the Figure 5.18c. This activity is oriented to assess the recognition level of the patient among the set of twenty pictures for each basic emotions obtained through the Dynamic Facial Expression (DFE) parametrization model presented in the last section. It is worth to mention that the images are randomly displayed to avoid any particular relation between the order presentation of the emotions and pictures sequence.

5.5.4 Information Interface and Data Format Storage

A complementary interface is displayed when the option menu "About" is selected (see Figure 5.19a). This interface shows a summary information of the App like aims,

(a) App information

(b) Folder data storage
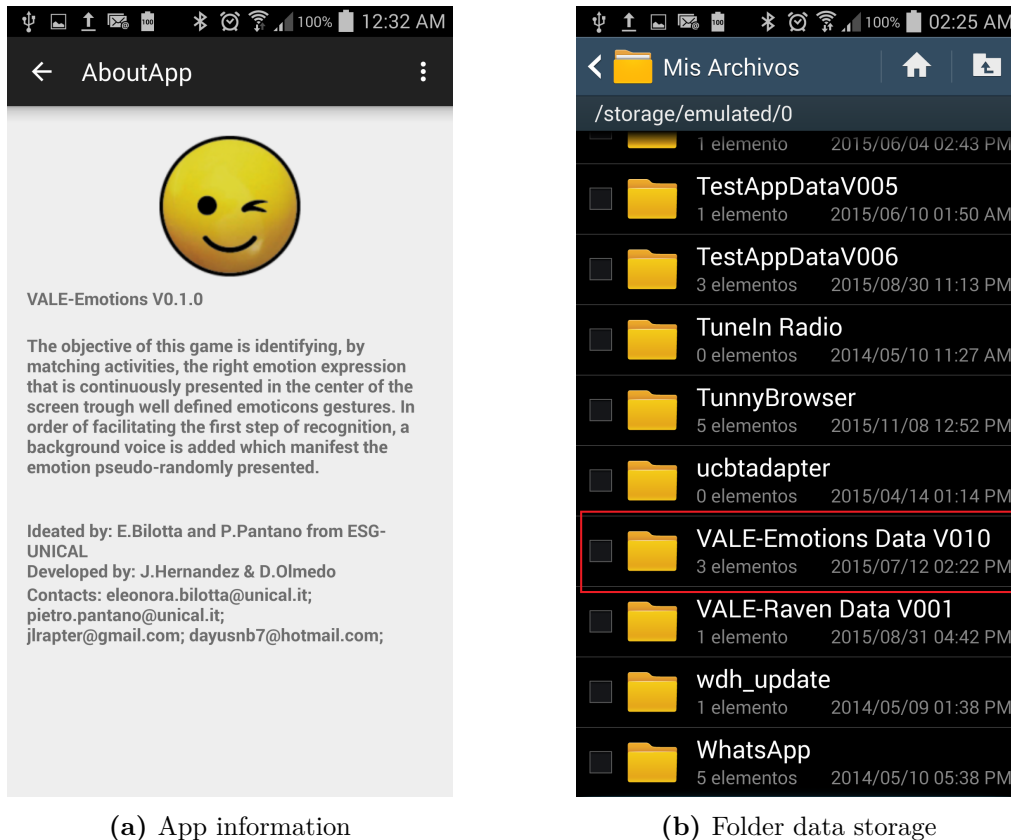
Figure 5.19: Screen captures VALE-Emotions App

version, and contacts. It is worth to mention that the data generated from the interaction of the training and test activities is saved in CSV files, categorically ordered into the folder "VALE-Emotions Data V010" as shown in Figure 5.19b.

5.5.5 Format the output datafile

As mentioned before, the output datafile is stored in CSV format to facilitate the portability of the collected information to data analysis software. In this section, a description of the organization of the data inside the output file is performed.

Header of the datafile

The header starts with the data file title, which also shows the date of the initialization of the training/test expressed as yyyy-mm-dd_hh-mm-ss. The header of the file also presents the personal data of the patient entered into the main activity.

Figure 5.20: Open mouth sequence.

Column headers

- **Reg_n.-** The number of the register entry in the file record.

- **Emotion_Code.-** It is the code of the image presented identifying the emotion expressed.

- **Time_Image.-** This is the relative timestamp in seconds at which the emotion picture was presented on the activity.

- **Button_Code.-** It shows the answer that was selected by the user.

- **Time_Answer.-** This column presents the relative timestamp in seconds registered when the patient selected the answer on the touch-screen.

- **Result.-** Here, the evaluation of the patient answer is registered by the App. Weights of the response are: T (true)=1 and F (false)=0.

- **Time_Response.-** In this column, the differences between Time_Answer and Time_Image is registered for every entry in the data file.

Tail of the datafile

Summary information about the App execution and patient answers registered are presented in this section. For instance:

- Total time test expressed in minutes.

- Number of total right answers evaluated by the App.

- Respective percentage of the right answers related to the total number of entries in the data file.

5.6   Future developments

In future assessments, it would be interesting to consider reinforcing each expression by body gesture and addition lip-synch animation in agreement with the displayed emotion, with the aim of giving greater emphasis to every emotion (K. Kim et al., 2014).

Furthermore, working on incorporating avatars that represent each of the family members will complete the generalization of the emotion recognition activities.

Further work in this ambit could include individual workout muscle movements (e.g., only the mouth) to help familiarization with the sequences of movements of each face part as shown in Figure 5.20.

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Chapter 6

VALE Experimentation

Contents

In this chapter, the experimental processes and results of different VALE environments developed. This chapter is divided into two parts. The first one is oriented to the presentation of a training program to teach Scratch programming language to pre-service teachers of the UNICAL. The second part is formed of statistical results gathered from experimental application of the VALE-Emotions described in the chapter 5.

6.1 Experimentation 1: VALE-STEAM Education

The VALE for STEAM education was experimented through a training teacher program organized by the ESG research group. The training program was focused on the utilization of Scratch within a STEAM education approach. This program was called "Scratch Days" and was offered for pre-service teachers of the UNICAL. The main goal of the program was to share advanced current contents for enabling the attendees to realize their own projects. Moreover, the contents shared in Scratch were useful for the future teachers to learn basis for programming and structured thinking. The organization program and evaluation to the attendees were reported in the work presented of

Figure 6.1: Advertisement flyer for the teacher training program called "Scratch Days".

Vaca Cárdenas, Bertacchini, Tavernise, et al. (2015).

6.1.1   Subjects

The participants of this study were 58 pre-service teachers which are enrolled in a physical education Science course, Science of Primary Training, at University of Calabria (Italy).

6.1.2   Methodology

This study was conducted for two months research. According to study stages, four mentors for instructional interventions have been involved. Each session was led by mentors who have specific skills and also programming experiences. Experience of the mentors involves Scratch projects and the other similar projects before (Olmedo Vizueta et al., 2014; Vaca Cárdenas et al., 2014; Vaca Cárdenas, Bertacchini, Gabriele, et al., 2015). Two of the mentors are expertise in Educational Technology, Edutainment and Psychology Programming. The third expertise mentor with a formation education in computer engineering and the last mentor is a graphic design engineer. All these team had been worked together in order to offer a constructive instruction for these future teachers. The previous diffusion of the program was carried out by a flyer (see Figure 6.1) sent by via e-mail to the other course participants.

The Scratch Days activities inside a STEAM education approach followed the frame-

Figure 6.2: Workshop and Training during a Scratch Days encounter.

work of Human Centred Design (HCD) that was described in the chapter 5 (see Figure 5.2 and Table 5.1). Furthermore, the concept of the comprehensive creative design education was introduced (Hong & Hwang, 2013; Y. Kim & Park, 2014).

In the first meeting, a brief introduction for the graphical interface and the use of Scratch was performed. Then, a demonstration workshop and training program were been conducted (see Figure 6.2).

In the next meeting, the participants were grouping by affinity in work teams of five members. Altogether 15 groups were formed, and each one developed different Scratch application during the course. Thus, the different applications are listed in the Table 6.1.

During the course, each of team work was requested to take notes about the design-process decision that is referring to the application's development. Furthermore, each group had to submit a detailed report. Regarding to the decision-making process, the first part of the report must contain:

- Name and position of the group members.

- Objective and working hypothesis.

- Detailed description of all the steps in every meeting group performed.

- Drafting a brief user manual of the Project, with images and text.

- Table Final Summary.

It is noteworthy that participants could seek for mentor advices and give suggestions to be applicable for their projects.

6.1.3   Materials

The main requirement for the course participants was to have at least a laptop per group. Instead, mentors developed various supporting materials such as video tutorials

Table 6.1: Applications developed during the Scratch Days course.

Group	Application Name	Ability to Develop	Score
1	"Vocali in scena"	Recognize the voice in a playful way but also at the same time interesting and captivating.	5
2	"Una settimana in fondo al mar"	Learning in a fun and an interactive way all of the days of the week.	5
3	"Le mie prime parole in inglese"	Teaching simple words in English.	5
4	"Impariamo le addizioni"	Learning of the additions.	5
5	"Alfabetolandia"	Learning about the vowels.	4
6	"Alla conquista del cinque"	Transmission of the concept of quantity, linguistic and iconographic strengthening of numbers, starting from one up to five.	5
7	"Le stagioni di Scratch"	Learning "the seasons"	5
8	"Un arcobaleno di frutti e verdure"	Understanding that every colour of fruits and vegetables is associated with a specific benefit	5
9	"I numeri che magia"	Using correctly the vocabulary related to the numbers from zero to nine in English.	5
10	"Fare musica con Scratch"	Knowing and discriminating of the primary colours.	5
11	"Contamelando"	Strengthening the concept of numbers from 1 to 10 having as a prerequisite the "Knowing Count"	4.75
12	"Quatro zampe"	Learn by playing the names of animals in English.	4.75
13	"Gatti incontra cat"	Learn colors in English. 3.75	
14	"Fruits & colours"	Recognition of the primary colours, the subsequent formation of the secondary colours.	4.5
15	"Movimento della mano"	Developing eye-hand coordination	4

and PowerPoint presentations (see Figure 6.3). In addition, participants were guided to use tutoring online help[1][2][3] provided by the software Scratch. The versions that used in this course were Scratch 1.4 for PC and the online Scratch 2.0 launched in 2013.

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[1]http://learn.code.org/hoc/4

[2]http://code.org/learn

[3]http://scratch.mit.edu/

Figure 6.3: Image sequence of Scratch Video Tutorial.

6.1.4 Results

Each of the projects in Scratch has been evaluated in a comprehensive manner using the *rubrics* methodology (Goodrich Andrade, 1997). The latter describes the criteria that is used to evaluate such kind of projects (Randall & Rusk, 2009). Rubrics has also served as a guideline to compare the user's own progress in the implementation of programming projects. Thus, the value of "1.00" is the highest score that is given for each stage and it is equivalent to 100% of the score. Such stages represented the main aspects of the project evaluation. Therefore, the scale of values for this course, based on the rubric criterion, was as follows:

- Excellent = 1.00

- Good = 0.75

- Average = 0.5

- Needs to improve = 0.25

The description of each ratings assigned for the 15 projects is described below in Table 6.2.

6.1.5 Discussion

In Figure 6.4, it is possible to observe the best stage performed in a general level by the pre-service teachers which was the analysis of the user requirements. The pre-service teachers have been successfully understood the instructions that is given during the initial training. Basically they received a guideline for the analysis of possible user interfaces based on the objectives proposed for them. Also they are clearly achieved to identify the functional for the application that should be possessed. Moreover, in the stage of the approach for the problem, the pre-service teachers have been proven successfully. Through a discussion and exchange of the ideas, they are generating a new knowledge and at the same time they are strengthen their skills in a collaborative work.

However, the stages that need to be strengthened are the context of use and the designing process. In the first, we should put more emphasis on the development of each

Table 6.2: Qualifications obtained in each of the HCD stages for each group.

Group	Planning	Context	Requirements	Design	Evaluation	Score
1	1.00	1.00	1.00	1.00	1.00	5.00
2	1.00	1.00	1.00	1.00	1.00	5.00
3	1.00	1.00	1.00	1.00	1.00	5.00
4	1.00	1.00	1.00	1.00	1.00	5.00
5	1.00	1.00	1.00	0.50	0.50	4.00
6	1.00	1.00	1.00	1.00	1.00	5.00
7	1.00	1.00	1.00	1.00	1.00	5.00
8	1.00	1.00	1.00	1.00	1.00	5.00
9	1.00	1.00	1.00	1.00	1.00	5.00
10	1.00	1.00	1.00	1.00	1.00	5.00
11	1.00	0.75	1.00	1.00	1.00	4.75
12	1.00	0.75	1.00	1.00	1.00	4.75
13	0.75	0.50	1.00	0.75	0.75	3.75
14	1.00	1.00	1.00	0.50	1.00	4.50
15	0.75	0.75	1.00	0.75	0.75	4.00
Media	0.96	0.88	1.00	0.85	0.90	4.67

tasks that have been performed by the application and also consider all of the technical aspects. The second should be a deeper into the advanced understanding of the blocks and process, as well as achieve the generation of logical and well organized programming threads.

It should be considered that the pre-service teachers were not computer apprentices. Thus, the apps that they realized is showed not only for the possibility to learn the program without a complete background of knowledge, but they are proving the great motivation of the pre-service teachers to the challenge for future works (Vaca Cárdenas, Bertacchini, Tavernise, et al., 2015).

This program "Scratch Days", that carried out within a STEAM education approach like those presented by Oh et al. (2013), F. Bertacchini, Bilotta, Gabriele, Pantano, and Tavernise (2013), Vaca Cárdenas et al. (2014), was stimulated curiosity and creativity of pre-service teachers who were motivated to create tailored qualities and desired jobs. As the pre-service teachers were created their Scratch projects learning important computational principles and go beyond the processes of creative thinking and systematic reasoning.

The mentors were listened and encouraged by the pre-service teachers in develop their own programming projects. They also used several examples available on the Scratch web site, and used all the accessible information that has been vehicles to carry out the process and finished with success for all the projects.

For the expected result, the satisfaction of the participants and also the intention to
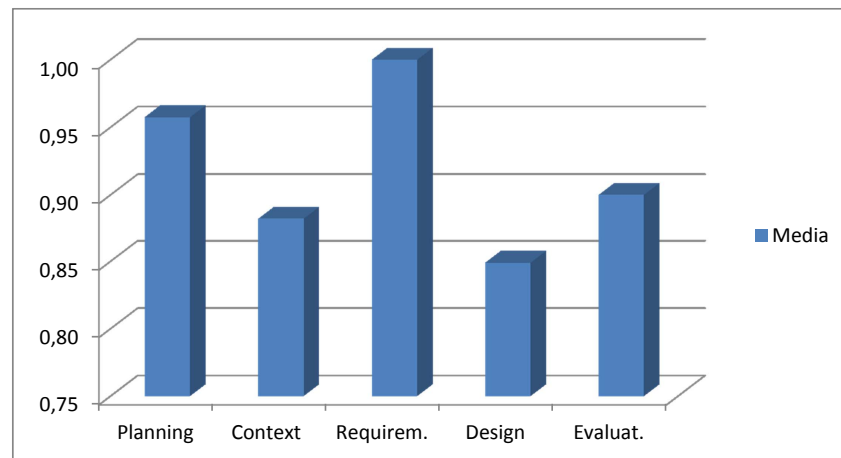
Figure 6.4: Average evaluation results of Scratch projects using Rubrics methodology.

apply and transfer the knowledge learning during the "Scratch days" are the factors that indicate the success of the program.

6.2 Experimentation 2: VALE-Emotions in Special Education

The main objective of this study has been to identify the recognition of the six base emotions studied by Paul Ekman and Friesen (1971), Paul Ekman (1992), Paul Ekman and Davidson (1994), Paul Ekman (1999a, 1999b). This recognition has been evaluated inside a Dynamic Facial Expressions (DFE) presented in the chapter 5. Such DFE is generated by different intensity levels of each emotion.

This study has been carried out thanks to the collaboration of two assistance centres in the south of Italia aimed to support people with special needs such as *High-Functioning Autism Spectrum Disorder* (HFASD) and *Mental Retardation* (MR). Several work meetings with these groups were maintained during one month through personal interaction with the participants (see Figures 6.5 and 6.6)

Two hypotheses have been proposed during this experiment. The first assumes that the general success emotions recognition of the HFASD participants in the tests would be higher than that performed by the MR participants. The second one assumes that is possible to determine the intensity level at which the recognition of emotions inside the DFE series occurs, assuming an effective recognition from 50%.
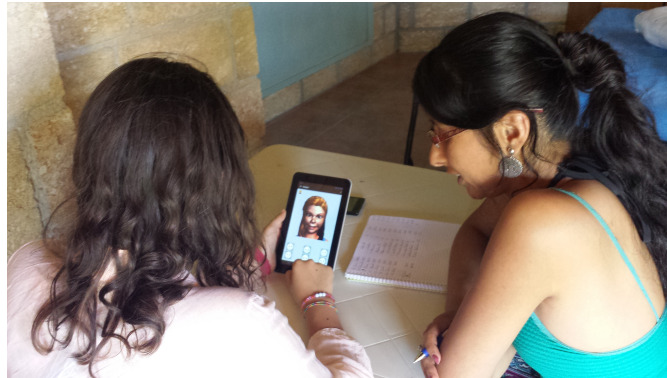
Figure 6.5: Interaction with a participant from the "Associazione Autismo KR" with HFASD diagnostic.

Figure 6.6: Interaction with a participant from the "Centro Socioeducativo servizio di Neuroriabilitazione – Calabria" with MR diagnosis.

6.2.1   Subjects

First group of participants in this study were 19 subjects (15 males (78.9%) and 4 females (21.1%)) of the *"Associazione Autismo KR"* of Crotone (Italy), aged between 5 and 18 years (M=10.58, SD=3.68). They received a clinical diagnosis of HFASD. Second group of participants were 11 subjects (7 males (63.6%) and 4 females (36.4%)) of the *"Centro Socioeducativo servizio di Neuroriabilitazione"* of Rende (Italy), aged between 25 and 44 years (M=33.91 (SD=6.82), ICD 10: M=7.18 (SD=2.40)). They received a clinical diagnosis of Mental Retardation (MR). Finally, the third group of participants were 20 *Typically Development* (TD) as control group (11 males (55%) and 9 females

Table 6.3: Patients' score of "Centro Diurno" in the Wais-IV and CPM Psicodiagnostic.

Code	Partic. Initials	Age ICD 10	Age	Sex	ICV	IRP	IML	IVE	IQ CPM
010	VV	6	29	m	94	78	85	74	80
011	RP	6	42	f	68	65	46	59	70
012	LP	7	32	m	62	58	46	71	70
013	RR	6	36	f	98	74	46	65	70
014	GU	6	37	m	106	67	49	68	70
015	GF	6	25	m	104	58	64	56	70
016	AR	12	35	f	154	130	91	141	130
017	WR	6	26	m	100	61	49	59	70
018	RB	6	41	f	82	52	46	47	70
019	GE	12	26	m	128	74	106	100	100
020	GM	6	44	m	108	80	49	47	70

Table 6.4: Mean Age and IQ of the participant groups.

Variables	TD (Control)	HFASD	MR
N	20	19	11
Age	3.75 (0.7)	10.58 (3.7)	33.91 (6.8)
IQ	115.2 (10.3)*	110.6 (15.3)*	79.1 (19.2)

*(K. Kim et al., 2014)

(45%)), aged between 3 and 5 years (M=3.75 (SD=0.72)).

It is worth noting that the children of the first group received the clinical diagnosis of HFASD from their assistance centre. Instead, patients from the second group (Figure 6) received the clinical diagnosis of MR through the evaluation with Psicodiagnosis clinical instruments of our research group. The latter instruments were Wechsler Adult Intelligence Scale (WAIS-IV) and Coloured Progressive Matrices (CPM). The first one is a clinical tool used to assess the cognitive abilities of adolescents and adults aged between 16 and 90 years, while the second one is a set of visual tools used for the measurement of intelligence "fluid". This evaluation was conducted prior to the administration of VALE-Emotions app that was detailed in chapter 5. The results obtained in the Psicodiagnosis are shown in Table 6.3.

The requirements for the selection of patients in each diagnostic group were: to have the consent of parents or guardians, not suffer any significant sensory or motor impairment, and a full scale IQ greater than 70. Unfortunately, IQ data of the TD and HFASD groups were not available until the redaction of this work. However, to complete the analysis below presented, IQ values reported in literature of works performed with similar characteristics groups were used. The data mentioned is summarized in Table 6.4.

6.2.2 Materials

Hardware

For the experimentation, hardware consisted of a Tablet Kraum of the line Ktab 7008dX2 was used. Specific characteristics of this tablet are: display of 7 inch, capacitive multitouch screen, 1024x600 px resolution, 1.2 GHz Cortex processor dual-core, WiFi 802.11 b/g/n and Android OS 4.2.

Software

VALE-Emotions app has been developed in Android Studio. Therefore, the app is only able to run in devices with Android platforms. VALE-Emotions app is a Training/Test program with multi-sensory activities. Visual, tactile and auditory stimulations are involved during the interaction performance. The app consists of three stages: Iconic Literacy, Recognition of basic emotions and DFE recognition. Specific details about these stages and app development were widely described in chapter 5.

6.2.3 Methodology

Participants have been assessed individually and in similar conditions. All sessions were conducted by a researcher and took place in a family room for them. The room was equipped with adequate light conditions and without distractions. A professional by each centre (educator or psychologist) was present during the experimentation to avoid stress on the participants for being in front of people unfamiliar to them. Participants were asked to sit in a chair in front of a table upon which it was placed the tablet containing the app (see Figure 6.7). In this experiment, the participants were asked to recognize six basic emotions (Anger, Disgust, Joy, Fear, Sadness and Surprise) each time these were displayed on the screen. The selection of the desired answer from the participants was done through iconic buttons pressing. The experimentation activities were performed in three stages (Iconic Literacy, Recognition of basic emotions and Dynamic Facial Expressions recognition). The first and second stages consisted of Training and Test phases, while the third one only presents a Test phase. Each Training/Test stage lasted 15 minutes maximum. The full description of each stage is presented in the next paragraphs.

Iconic Literacy Stage

The main scope was to identify whether the user known the basic emotions represented in its simplest form called "emoticons". These latter become the communication language used in this app to determine the recognition of emotions as shown in Figure 6.8. This stage consisted of two parts: "Training-0" and "Test-0". During the Training-0, the user pushed each of the six emoticon buttons found on the bottom of the screen (see Figure 6.8). An enlarged image corresponding to the selected button was displayed on the centre of the screen. At the same time, an auditory stimulus saying the emotion's

Figure 6.7: Participants during a Training phase with the VALE-Emotions app.
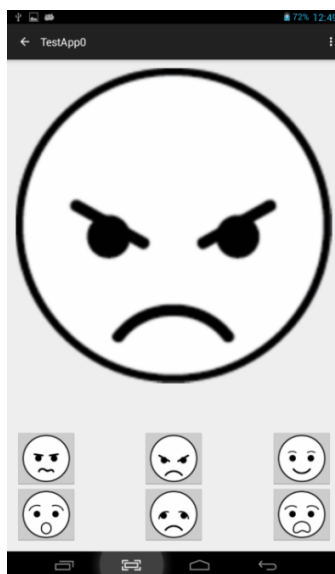
Figure 6.8: VALE-Emotions app interface of Test-0 used for the Iconic Literacy stage.

name was listened from the app. To complete this activity, the evaluator explained to the participant every expression shown in a detailed way. Thus, only in this Training part, the participant received a gesture or physical guidance.

Recognition of Basic Emotions Stage

The purpose of this activity was to link the displayed emotion picture on the screen center with the corresponding iconic button as shown in Figure 6.9. This phase also consisted of two parts: "Training-1" and "Test-1." During the Training-1, the user pushed each of the six buttons found on the bottom of the screen. At this time, an avatar face expression corresponding to the selected button was displayed, while an auditory stimulus saying the emotion's name was listened. Also in this phase, the evaluator explained to the participant every expression displayed.
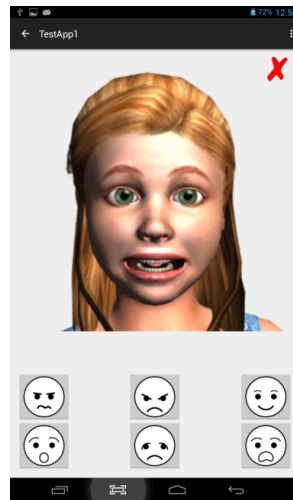
Figure 6.9: VALE-Emotions app interface of Test-1 used for the Recognition of Basic Emotions stage.

Afterwards, in the Test-1 phase, the app displayed the six avatar face emotions in a random way. The auditory stimulus was deactivated to permit an intuitive recognition of the emotions. The user was required to identify the emotion presented through the corresponding button pushing. If the user correctly identified the emotion, a visual stimulus symbol of victory appeared, and another random emotion was visualized. Conversely, if the button selected was incorrect, a visual stimulus symbol "X" appeared and the same emotion picture was visualized again until it was correctly identified. Also the results and the interactions were stored automatically in the system too. It is worth mentioning that at this stage only the maximum emotional intensity of the DFE was presented for each emotion.

Dynamic Facial Expressions Recognition Stage

It is intended to determine from which level of intensity were correctly recognized the emotions generated by the DFE. These mentioned intensities correspond to each of the parameterized images representing facial actions process to form a natural facial expression described in chapter 5. Series of maximum 20 intensity images per emotion (max. 120 intensity emotion images) were randomly displayed on the center of the tablet screen (see Figure 6.10). The participant was required to recognize each emotion picture having only one chance to do it. Visual and audio stimulation were deactivated to assess the intuitive emotional recognition of the patients. This level of the test was applied only to patients who achieved more than 50% correct answers in Test-1. It is worth mentioning that in this phase, VALE-emotion tool controls that emotions images were not repeatedly presented. The tool also permitted to the evaluator to determine how many images will be randomly presented by each basic emotion.

Figure 6.10: VALE-Emotions app interface of Test-2 used for the DEF Recognition stage.

6.2.4   Results and Discussion

The current study provides data on the identifying the level of intensities in the base emotions (Anger, Disgust, Fear, Joy, Sadness, Surprise), through an Android's app called VALE-Emotions developed by our researcher group. The analysed groups brought to light interesting results, the hypothesis established as a therapeutic Training-Test application based on the recognition of emotions has achieved statistically significant results.

A descriptive analysis of data from the three stages (Iconic Literacy, Recognition of basic emotions and Dynamic Facial Expressions recognition) presented inside of VALE-emotion app have been conducted. The main dependent variable from the VALE-emotion has been the percent of emotional success recognition scores. This variable was individuated from the rights and wrongs answers obtained during each Test. Thus, the value "1" corresponds to the right answers and the value "0" corresponds to the wrongs. Therefore, for every participant, all values 1 obtained were selected. Thus, the percentage of emotion success recognition of the six basic emotions analysed for TD, HFASD and MR groups will be analysed in detail in the following sections through summarized tables, graphs and figures. Moreover, comparison of the average percentage of success recognition of emotions between the participant groups is performed. Furthermore, based on the experimental data, a generalized calculation of the intensity level of emotional expressions generated by DFE is presented together with a comparison of the results between the participant groups.

Table 6.5: Results obtained in the *Tests-0* of VALE-Emotions app.

Emotion	TD		HFASD		MR	
	Success %	SD	Success %	SD	Success %	SD
ANGER	96.93	9.3	91.05	22.33	64.58	32.35
DISGUST	87.87	22.57	86.55	24.08	56.21	37.39
FEAR	95	16.31	82.22	26.14	66.46	35.34
JOY	92.11	19.54	87.52	26.1	79.44	26.59
SADNESS	94.44	17.15	86.2	21.65	62.12	33.41
SURPRISE	96.05	17.21	92.13	15.78	61.47	37.73
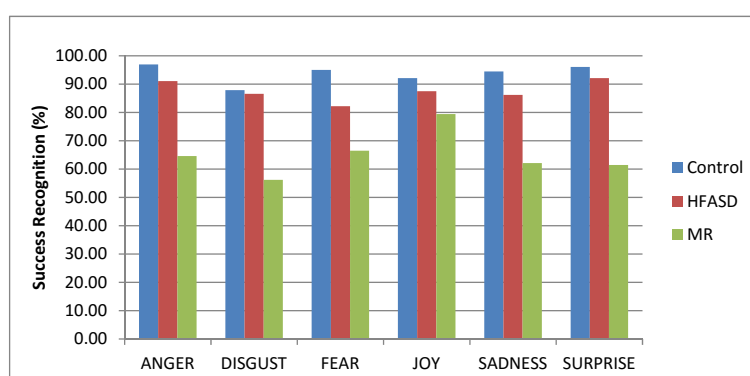
Figure 6.11: Correct recognized obtained in the *Test-0* of VALE-Emotions app.

Iconic Literacy Results

The average percentage of success recognition of the six basic emotions represented by emoticons, for each group, obtained in the *Tests-0*, are summarized in the Table 6.5 and graphically represented in Figure 6.11. These results revealed significant differences between HFASD and MR groups. A high recognition of emotions in HFASD group represented through its simplest such as "emoticons" form had been observed. This high recognition was higher than 80 % for all emotions. This means that the iconic literacy was not extensive for the participants of this group. Such iconic literacy was the main objective of this first stage since these images (visual non-verbal code) were the principal language used by the participants during the whole process of running the application.

Instead, MR group showed an average between 56 % and 80 % of accuracy recognition. In some individual cases with identification problem, only outcomes around 12 %, 25 % and 40 % of success were obtained (see Table C.3 in the Appendix C). For this reason, it was necessary to devote more individual Training time to the participants from MR group that demonstrated greater iconic recognition difficulty, as shown in Figure 6.12. In this graph, the average time devoted to *Training-0* in the group of participants
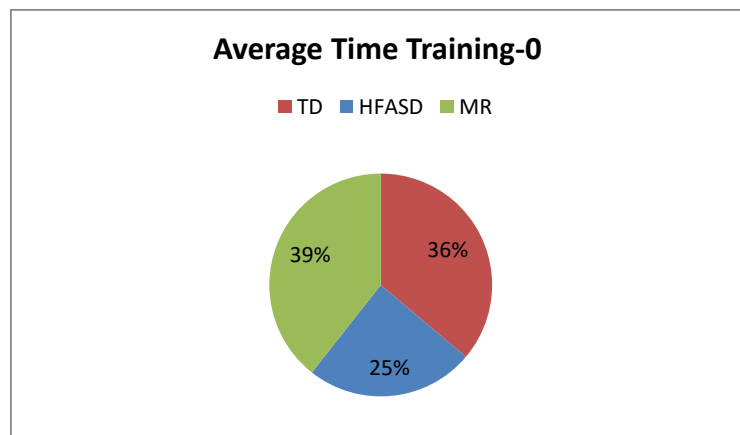
Figure 6.12: Time training average for the Iconic Literacy stage of TD, HFASD and MR groups.

with MR is greater than the average time of the other two groups. It should also be considered that this value is still high even when the number of participants in this group is lower.

Recognition of Basic Emotions Results

Regarding to this stage, the average percentage of success recognition of the six basic emotions, represented by final intensity level of DFE, obtained in the *Tests-1* for each group, are summarized in the Table 6.6. The latter is also graphically represented in Figure 6.13.

Certain differences are evidenced between the participant groups as shown in the Figure 6.13. For the HFASD group, the greater recognition was for the Joy (M=92.11, SD=19.54) emotion was observed, near followed by Anger (M=87.81, SD=28.12) and Surprise (M=85.09, SD=26.45). In contrast with the latter results, the Fear (M=75.39, SD=31.79) emotion was the least identified expression. These results show a strong congruence with the works performed by K. Kim et al. (2014), Serret et al. (2014). This suggests that HFASD subjects often seem relatively similar to their peers regarding the recognition of emotions (Harms et al., 2010). This last statement is against the belief that children with HFASD often show impaired in emotion recognition (Kanner, 1943; K. Kim et al., 2014; Uljarevic & Hamilton, 2013).

Due to the inconsistencies presented by several researchers regarding the recognition of emotions in subjects with Autism, in the work entitled "Review of Behavioural and Neuroimaging Studies" (Harms et al., 2010), it has been conducted detailed research that seeks to explain these conflicting results. The key seems to be in the use of compensatory mechanisms used by individuals with ASD (Grossman, Klin, Carter, & Volkmar, 2000;

Table 6.6: Success results obtained in the *Test-1* of VALE-Emotions

Emotion	TD		HFASD		MR	
	Success %	SD	Success %	SD	Success %	SD
ANGER	74.92	32.36	87.81	28.12	76.67	26.29
DISGUST	66.88	33.48	84.91	21.47	53.00	41.77
FEAR	61.47	34.68	75.39	31.79	56.36	30.09
JOY	93.86	14.92	92.11	19.54	66.79	40.71
SADNESS	93.52	19.08	81.49	24.46	67.71	29.02
SURPRISE	84.38	30.10	85.09	26.45	53.56	26.44
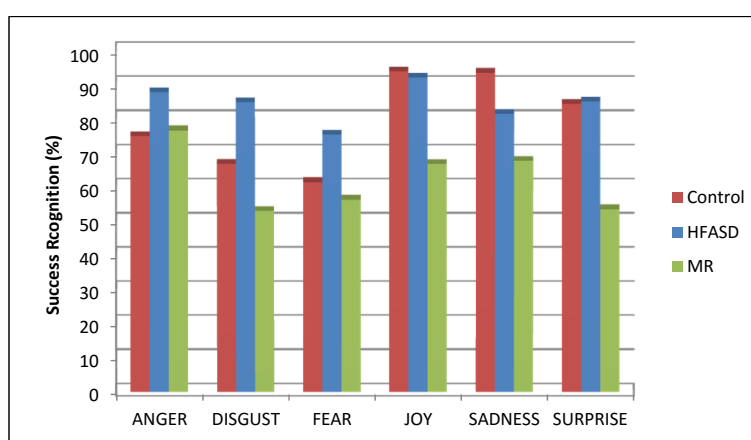
Figure 6.13: Correct recognized obtained in the *Test-1* of VALE-Emotions app.

Vesperini et al., 2015). These mechanisms can be verbal mediation or feature-based learning. This is supported by the evidence found that people with ASD decode facial expressions differently than individuals Typically Developing (TD) (Fink, de Rosnay, Wierda, Koot, & Begeer, 2014). In this way, the greater children with HFASD often may submit equality relatively similar to that of their contemporaries with TD as regards the recognition of emotions. These arguments support the results obtained in the experimentation performed.

In the case of MR group, the results determined that a predominant recognition of Anger (M=76.7, SD=26.3) in all patients, followed of Sadness (M=64.71, SD=29.02) and Joy (M=66.79, SD=40.71) emotions. Contrary to the latter trend, the Disgust (M=53.00, SD=41.77) was the least recognized emotion. These results agree with the founded studies performed on participants with MR regarding the recognition emotions, where it is suggested that mentally retarded subjects may have specific deficits in expressions recognizing (Hippolyte, Barisnikov, & Van der Linden, 2008). These deficits may be related to a decreased ability for decoding emotion expressions with declining levels of
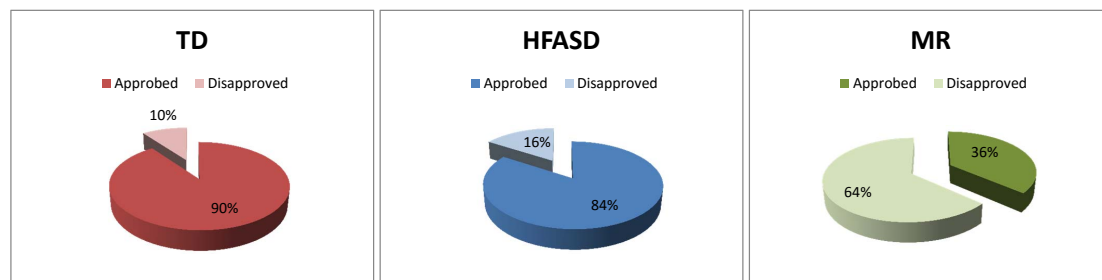
Figure 6.14: Screening results for the approved participants to continue with the *Test-2*.

cognitive functioning (Rojahn, Lederer, & Tassé, 1995). Similar researchs suggest that recognition accuracy of facial emotion increase with IQ (Moore, 2001). In fact, adults with mild mental retardation are more capable in the recognitions of the base emotions than those with moderate mental retardation (Rojahn et al., 1995).

It is worth mentioning that averages mistakes in emotion recognition for the all the participants groups are presented in Appendix D in the Table D.1. At a first glance, the MR group presents the higher rates in percentage of mistakes during the *Test-1* in comparison with the other two groups.

All the results, reported in this section, have confirmed the first hypothesis established due to the general success recognition performed by the HFASD participants during the *Test-1*. In fact, in a general point of view, average success of emotions recognition for the HFASD group has been higher than that reached for the MR participant group.

Screening of Rated Participants

In this section, an screening to evaluate the participants from each group that were able to perform the *Test-2* was done. The experimentation of the *Test-2* will be explaining in the next section. Regarding to this evaluation, it was established previously in the methodology. The criteria of selection refers that only those participants that reached a higher evaluation than 50 % in the average of successes emotion recognition in the *Test-1* were able to continue with the *Test-2*. The success percentage average was determined through the addition of all the correct answers, divided by the total number of projections, and multiplied by 100.

The results of this screening process for each participant are presented in a summarize manner in the Appendix C, in the Tables C.1, C.2 and C.3 for the TD, HFASD and MR groups, respectively. As final screening result, the 90% of TD participants group, the 84.2% of HFASD participants group and only the 36.4% of the MR participants group were able to continue with the *Test-2*. A graphical representation of the before mentioned is presented in the Figure 6.14.

Dynamic Facial Expressions Recognition Results

The results obtained in the *Test-2* are the strong point of the present study. The main interest was to identify in which intensity level of the DFE sequence generation, for individual emotions, an acceptable recognition for each participant group was performed. Thus, an individual analysis for each emotion, considering the percentage of hits according to each intensity level (005, 010, $\cdots$, 100), per individual participant group have been done. Summary of these results are presented in Table E.1 in the Appendix E.

Determination of Intensity Levels

To objectively determine at which intensity level, an acceptable recognition for each emotion within a certain DFE sequence has occurred, a mathematical data analysis technique was used. The latter was based in obtaining certain parameters of a power curve fitting on the experimental data presented in the Table E.1 (Appendix E). Such fitting expression is defined by:

$$y = a \cdot x^b, \tag{6.1}$$

were:

  y: is the dependent variable (Percentage of emotion recognition),
  x: is the independent variable that can be experimentally adjusted (Intensity level of emotional expression),
  a and *b*: are the parameters that would best fit the function to the experimental data.

It is worth mentioning that the power curve was selected to fitting the data because of its natural tendency to accept only positive values for the independent variable and the output dependent variable can only report positive values also depending on the fitting parameters *a* and *b*. In our case, these properties are important because the percentages of success recognition as well as the intensity level of DFE sequence generation are only positive values ranged between 0 and 100. Moreover, the fitting parameter *b* in the equation 6.1 determines the growing rate of the dependent variable (percentage of success recognition) as function of the independent variable (intensity level of emotional expression) scaled by the fitting parameter *a*.

Thus, the plot of the power fitting applied to the experimental data of this stage are presented in the Figures F.1-F.6 in the Appendix F for the Anger, Disgust, Fear, Joy, Sadness and Surprise, respectively. An example of these plotting results is replicated in the Figure 6.15 for the Anger emotion. A summarized information of the fitting parameters *a* and *b* for each emotion per participant groups TD, HFASD and MR are presented in the Tables 6.7-6.9, respectively. In these tables the values for each emotion according to the answers of the three analyzed groups is presented.

Furthermore, through a change of variable in equation 6.1, it is possible to determine the intensity level inside the DFE sequence per emotion at which the percentage of success recognition fills a predetermined criteria. The latter was established assuming
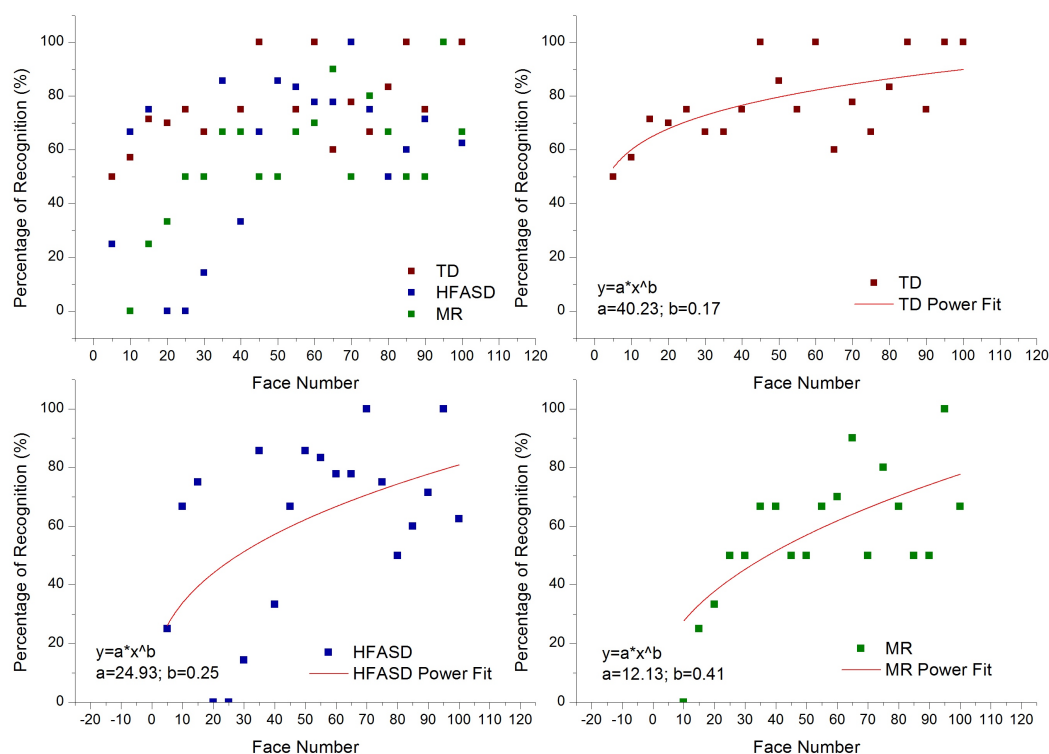
Figure 6.15: Individual recognition of intensity levels from the Anger emotion in *Test-2* with fitting representation.

that an acceptable success recognition of emotional expressions is guaranteed when at least the 50 % of hits is reached by each participant group. The resulting expression for the evaluation of this criteria is:

$$x = \left(\frac{y}{a}\right)^{\frac{1}{b}}. \tag{6.2}$$

Therefore, the evaluation results of the equation 6.2 were also included in the Tables 6.7-6.9 for the TD, HFASD and MR groups, respectively. These results determine the single values of the intensity level by the emotions, corresponding to the approximate value of the acceptable recognition begun.

In this way, similar results of an acceptable intensity level emotion recognition between the groups was founded, regarding to *Joy* and *Sadness* emotions. In fact, was determined that an acceptable emotion recognition starts from the earliest levels of intensity of each emotion. These results are detailed in the Tables 6.7, 6.8, and 6.9. Furthermore, the graphical representation of this statement is also shown in the above mentioned Figures F.1-F.6 in the Appendix F

Table 6.7: Parameters of the power fitting on the percentage of success recognition results from the DFE evaluation performed on the TD group.

Emotions	a	b	x for y=50%
ANGER	40.23 (8.10)	0.17 (0.05)	3
DISGUST	5.09 (2.87)	0.6 (0.13)	40
FEAR	1.14 (0.99)	0.9 (0.20)	70
JOY	62.78 (12.80)	0.1 (0.05)	1
SADNESS	31.43 (7.53)	0.2 (0.06)	7
SURPRISE	3.75 (2.56)	0.7 (0.16)	41

Table 6.8: Parameters of the power fitting on the percentage of success recognition results from the DFE evaluation performed on the HFASD group.

Emotions	a	b	x for y=50%
ANGER	24.93 (12.21)	0.25 (0.12)	16
DISGUST	29.44 (14.65)	0.19 (0.13)	17
FEAR	1.17 (1.09)	0.89 (0.22)	70
JOY	41.06 (14.42)	0.15 (0.09)	4
SADNESS	38.60 (0.21)	12.07 (0.08)	1
SURPRISE	5.37 (3.49)	0.61 (0.15)	40

Table 6.9: Parameters of the power fitting on the percentage of success recognition results from the DFE evaluation performed on the MR group.

Emotions	a	b	x for y=50%
ANGER	12.13 (6.01)	0.41 (0.12)	31
DISGUST	21.93 (20.03)	0.24 (0.23)	32
FEAR	0.64 (0.59)	1.12 (0.21)	50
JOY	73.68 (42.22)	0.04 (0.14)	1
SADNESS	46.82 (20.74)	0.15 (0.11)	2
SURPRISE	10.10 (19.17)	0.36 (0.44)	89

Particularly, analyzing each group respect to the individual intensities level recognition, was obtained that in the TD group 6.7, the *Joy* is recognized from the firs intensity level *(face number 1)*. Followed by the *Anger* emotion which was identified from the *(face number 3)*. Similarly, the *Sadness* emotion that starts with an acceptable recognition from the intensity level 7 *(face number 7)*. However, an acceptable emotion recognition by the *Disgust* and *Surprise* emotions began from the level of intensity number 40 *(face number 40)*. And, finally, the *Fear* emotion was recognized only from the *(face number 70)*.

In the same vain, the HFASD group 6.8, the *Sadness* emotion was recognized by the participants of this group in an acceptable way since the first intensity level *(face number 1)*. Followed by the *Joy emotion* which was recognized from the intensity level number 4. A similar recognition was showed by the *Anger* and *Disgust* emotions, which started to be recognized since the intensity level number 16. The *Surprise* emotion was acceptably recognized from the intensity level number 40. And at the end, the *Fear* emotion was recognized only since the *face number 70*, in this last emotion the result was equal to the TD group.

In the MR group, the acceptable recognition was early *face number 1 and 2* only regarding to the *Joy* and *Sadness* emotions, like in the two previous groups. But for the other emotions the acceptable recognition started from the intensity level number 31. Even the *Surprise* emotion was recognized only since the intensity level number 89, this is almost reaching the level of maximum intensity of this emotion.

Determination of Response Time

In order to determine an accurate recognition, of the emotions in the *Test-1* between the individual participants inside of each group, also has been considered the single time employed to perform the recognition of each expression. For this purpose, has been take the *response time*, which is the difference between the time registered when the participant pressed the button and the time registered when the emotion was displayed. The single *response time* are summarized in the Table G.1, this is presented in the Appendix G

Thus, the scattering of the response times per participant group for each emotion, together with their corresponding mean values and SD, of the experimental data for this stage are presented in the Figures H.1-H.6 in the Appendix H for the Anger, Disgust, Fear, Joy, Sadness and Surprise, respectively. An example of these plotting results is replicated in the Figure 6.16 for the Anger emotion. A summarized information of the Mean Response Time of the hits recognition per participant groups and per emotion in *Test-1* are presented in the Table 6.10.

It is worth highlighting, based on the data from Table 6.10 that the participants of the HFASD group were those who more quickly recognized all the emotions during the evaluation of the Test-1. Also worth noting that the spread shown was less for the same group, which means that the recognition was similar among participants who formed such group.

The limitations in this study have been the small sample size of the groups analysed.
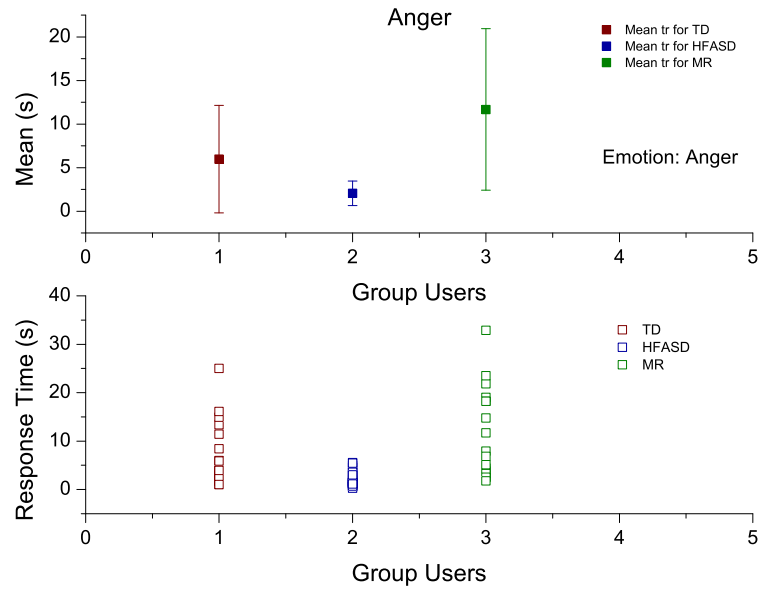
Figure 6.16: Response Time of the hits recognition per participant groups for Anger emotion in *Test-1*.

Table 6.10: Summary of Mean Response Time of the hits recognition per participant groups and per emotion in *Test-1*.

Group	ANGER		DISGUST		FEAR		JOY		SADNESS		SURPRISE	
	M [s]	SD	M [s]	SD	M [s]	SD	M [s]	SD	M [s]	SD	M [s]	SD
TD	5.972	6.175	6.097	5.130	8.661	7.248	5.094	7.124	5.924	5.789	4.958	4.291
HFASD	2.058	1.434	3.150	2.609	3.402	3.077	2.220	1.219	2.254	2.183	2.028	1.488
MR	11.674	9.255	8.748	4.806	11.056	13.917	12.712	11.618	9.190	6.230	8.733	4.992

This is due to the lack of assistance centres for people with ASD and other neurological disorders in nearby areas. Another limitation, especially in *Test-2*, was the reduced number of views and repeats of the emotions displayed to each participant, because of the long duration that generated the 20 levels of intensity per each emotion. An alternative for further studies may be to reduce the number of intensity levels for each emotion in the DFE sequences to increase the repetition occurrences per image, resulting in more representative data.

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Conclusions

The value of this proposal is not only the presentation of Virtual Advanced Learning Environments (VALE), but it has also reached to merge two completely different fields as Special Education and STEAM (Science, Technology, Engineering, Arts and Mathematics) Education. The work done during this project was aimed to be an innovative mean to improve the learning process in those fields, through the use of new technologies.

The preliminary study for the choice of tools and techniques that best fit the needs of the VALE proposal was important because of the wide available variety. It has also influenced the formation of a criterion of choice settled on a solid foundation and a real knowledge of the different avenues available for pursuing a good project. The greatest challenge has been the development and creation of the various scenarios, trying to minimize the use of resources and achieving the best possible flexibility and adaptability.

In this way, VALE was created with the two principal categories which are VALE-STEAM and VALE-Emotions. Regarding to VALE-STEAM, it includes three scenarios devoted to the Chaos Theory, Educational Robotics and Programming in Scratch. This last was evaluated in an educational context inside of the University of Calabria. The main participants were a group of 58 pre-service teachers which were enrolled in a physical educational science course. The objective was to share advanced current contents to the participant's target, which could be applied in their future occupational fields. As results, the attendees shown an efficient response during the development of group projects and shown affinity with the knowledges learned.

Continuing with VALE-STEAM, another important achievement of this project was the creation of functional applications that were tested singularly. These applications were focused on learning activities, but providing to the users the possibility to be enjoyed through high-end systems with the use of hardware dedicated to total immersion, VR systems and stereoscopic vision. In particular, it was possible to incorporate a 3D mouse prototype to interact inside of the Educational Robotics scenarios and virtual wanderings. This mouse uses available technologies in the Evolutionary System Group (ESG) and NexusLab (research laboratories inside the University of Calabria) and constituted an alternative Human Computer Interaction (HCI) device into the development of the VALE reported in this work.

Moreover, gratifying results have been obtained through the VALE-Emotions App. This application was developed with the aim of stimulating and facilitating activities teaching and/or evaluation of sequences with different intensity levels of six basic emotions recognition. The six basic emotions (Anger, Disgust, Fear, Joy, Sadness and Surprise) are sustainted by the works of Paul Ekman Paul Ekman (1999a), while the generation of the sequences of emotions with different intensity levels was done through a Dynamic Facial Expressions (DFE) proposed in this work.

The experimentation of the VALE-Emotions App was carried out in two assistance centres in the south of Italy. The first centre was the "Associazione Autismo KR" of Crotone, and the second one was the "Centro Socioeducativo servizio di Neuroriabilitazione" of Rende. The participants from these centres received diagnosis of High Functioning Autism Spectrum Disorder (HFASD) and Mental Retardation (MR), respectively. The results obtained in three different stages pertaining to the VALE-Emotions app allow for the validation of two hypothesis established for the experimentation. For the first hypothesis, the HFASD participants shown a greater recognition in all the emotions tested in comparison with the MR group. Instead, the second hypothesis was confirmed through the determination of the intensities of level at which an acceptable emotion recognition begun for each emotion. Furthermore, a final analysis of the response time of each participant for each group demonstrates that the HFASD participants were faster in the recognition of all the six basic emotions, when these are presented at the maximum intensity level, than their counterparts.

The possibility to carry out the experimental stage, using the VALE-Emotions App developed, has become an extremely enriching experience because the direct contact with participants allows obtaining important appreciations to the work performed and its significant contribution that provides the researcher groups in every area.

Appendices

Appendix A

Collection of Facial Animation Parameters (FAP) extracted from the MPEG-4 FAB

Table A.1: Facial Animation Parameters (FAP) from MPEG-4.

N	FAP name	FAP description	Min/Max I-Frame quantized values
1	viseme	Set of values determining the mixture of two visemes for this frame (e.g. pbm, fv, th).	viseme blend:+63
2	expression	A set of values determining the mixture of two facial expression.	expression intensity 1 and 2: +63
3	open_jaw	Vertical jaw displacement (does not affect mouth opening).	+1080
4	lower_t_midlip	Vertical top middle inner lip displacement.	±600
5	raise_b_midlip	Vertical bottom middle inner lip displacement.	±1860
6	stretch_l_cornerlip	Horizontal displacement of left inner lip corner.	±600
7	stretch_r_cornerlip	Horizontal displacement of right inner lip corner.	±600

Continued on next page

N	FAP name	FAP description	Min/Max I-Frame quantized values
8	lower_t_lip_lm	Vertical displacement of midpoint between left corner and middle of top inner lip.	±600
9	lower_t_lip_rm	Vertical displacement of midpoint between right corner and middle of top inner lip.	±600
10	raise_b_lip_lm	Vertical displacement of midpoint between left corner and middle of bottom inner lip.	±1860
11	raise_b_lip_rm	Vert. displacement of midpoint between right corner and middle of bottom inner lip.	±1860
12	raise_l_cornerlip	Vertical displacement of left inner lip corner.	±600
13	raise_r_cornerlip	Vertical displacement of right inner lip corner.	±600
14	thrust_jaw	Depth displacement of jaw.	+600
15	shift_jaw	Side to side displacement of jaw.	±1080
16	push_b_lip	Depth displacement of bottom middle lip.	±1080
17	push_t_lip	Depth displacement of top middle lip.	±1080
18	depress_chin	Upward and compressing movement of the chin (like in sadness).	±420
19	close_t_l_eyelid	Vertical displacement of top left eyelid.	±1080
20	close_t_r_eyelid	Vertical displacement of top right eyelid.	±1080
21	close_b_l_eyelid	Vertical displacement of bottom left eyelid.	±600
22	close_b_r_eyelid	Vertical displacement of bottom right eyelid.	±600
23	yaw_l_eyeball	Horizontal orientation of left eyeball.	±1200
24	yaw_r_eyeball	Horizontal orientation of right eyeball.	±1200
25	pitch_l_eyeball	Vertical orientation of left eyeball.	±900
26	pitch_r_eyeball	Vertical orientation of right eyeball.	±900
27	thrust_l_eyeball	Depth displacement of left eyeball.	±600
28	thrust_r_eyeball	Depth displacement of right eyeball.	±600
29	dilate_l_pupil	Dilation of left pupil.	±420

N	FAP name	FAP description	Min/Max I-Frame quantized values
30	dilate_r_pupil	Dilation of right pupil.	±420
31	raise_l_i_eyebrow	Vertical displacement of left inner eyebrow.	±900
32	raise_r_i_eyebrow	Vertical displacement of right inner eyebrow.	±900
33	raise_l_m_eyebrow	Vertical displacement of left middle eyebrow.	±900
34	raise_r_m_eyebrow	Vertical displacement of right middle eyebrow.	±900
35	raise_l_o_eyebrow	Vertical displacement of left outer eyebrow.	±900
36	raise_r_o_eyebrow	Vertical displacement of right outer eyebrow.	±900
37	squeeze_l_eyebrow	Horizontal displacement of left eyebrow.	±900
38	squeeze_r_eyebrow	Horizontal displacement of right eyebrow.	±900
39	puff_l_cheek	Horizontal displacement of left cheek.	±900
40	puff_r_cheek	Horizontal displacement of right cheek.	±900
41	lift_l_cheek	Vertical displacement of left cheek.	±600
42	lift_r_cheek	Vertical displacement of right cheek.	±600
43	shift_tongue_tip	Horizontal displacement of tongue tip.	±1080
44	raise_tongue_tip	Vertical displacement of tongue tip.	±1080
45	thrust_tongue_tip	Depth displacement of tongue tip.	±1080
46	raise_tongue	Vertical displacement of tongue.	±1080
47	tongue_roll	Rolling of the tongue into U shape.	+300
48	head_pitch	Head pitch angle from top of spine.	±1860
49	head_yaw	Head yaw angle from top of spine.	±1860
50	head_roll	Head roll angle from top of spine.	±1860
51	lower_t_midlip_o	Vertical top middle outer lip displacement.	±600
52	raise_b_midlip_o	Vertical bottom middle outer lip displacement.	±1860
53	stretch_l_cornerlip_o	Horizontal displacement of left outer lip corner.	±600
54	stretch_r_cornerlip_o	Horizontal displacement of right outer lip corner.	±600

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N	FAP name	FAP description	Min/Max I-Frame quantized values
55	lower_t_lip_lm_o	Vertical displacement of midpoint between left corner and middle of top outer lip.	±600
56	lower_t_lip_rm_o	Vertical displacement of midpoint between right corner and middle of top outer lip.	±600
57	raise_b_lip_lm_o	Vertical displacement of midpoint between left corner and middle of bottom outer lip.	±1860
58	raise_b_lip_rm_o	Vert. displacement of midpoint between right corner and middle of bottom outer lip.	±1860
59	raise_l_cornerlip_o	Vertical displacement of left outer lip corner.	±600
60	raise_r_cornerlip_o	Vertical displacement of right outer lip corner.	±600
61	stretch_l_nose	Horizontal displacement of left side of nose.	±540
62	stretch_r_nose	Horizontal displacement of right side of nose.	±540
63	raise_nose	Vertical displacement of nose tip.	±680
64	bend_nose	Horizontal displacement of nose tip.	±900
65	raise_l_ear	Vertical displacement of left ear.	±900
66	raise_r_ear	Vertical displacement of right ear.	±900
67	pull_l_ear	Horizontal displacement of left ear.	±900
68	pull_r_ear	Horizontal displacement of right ear.	±900

Scripts programmed in Scratch for the Darwin's Jouney Edutaiment

Figure B.1: The scripts attached to the stages.
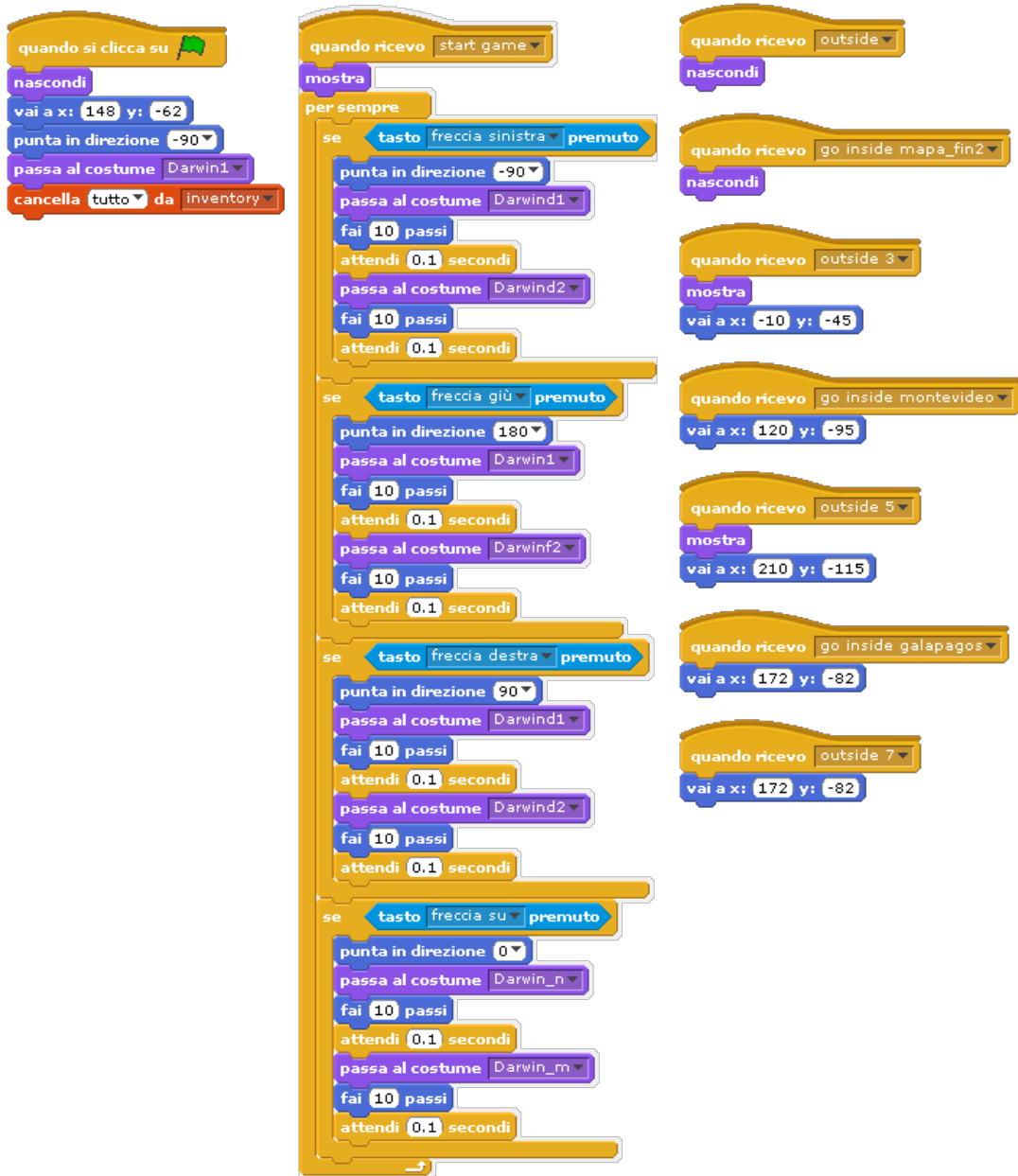
Figure B.2: Script for the Drawin's character behaviour.
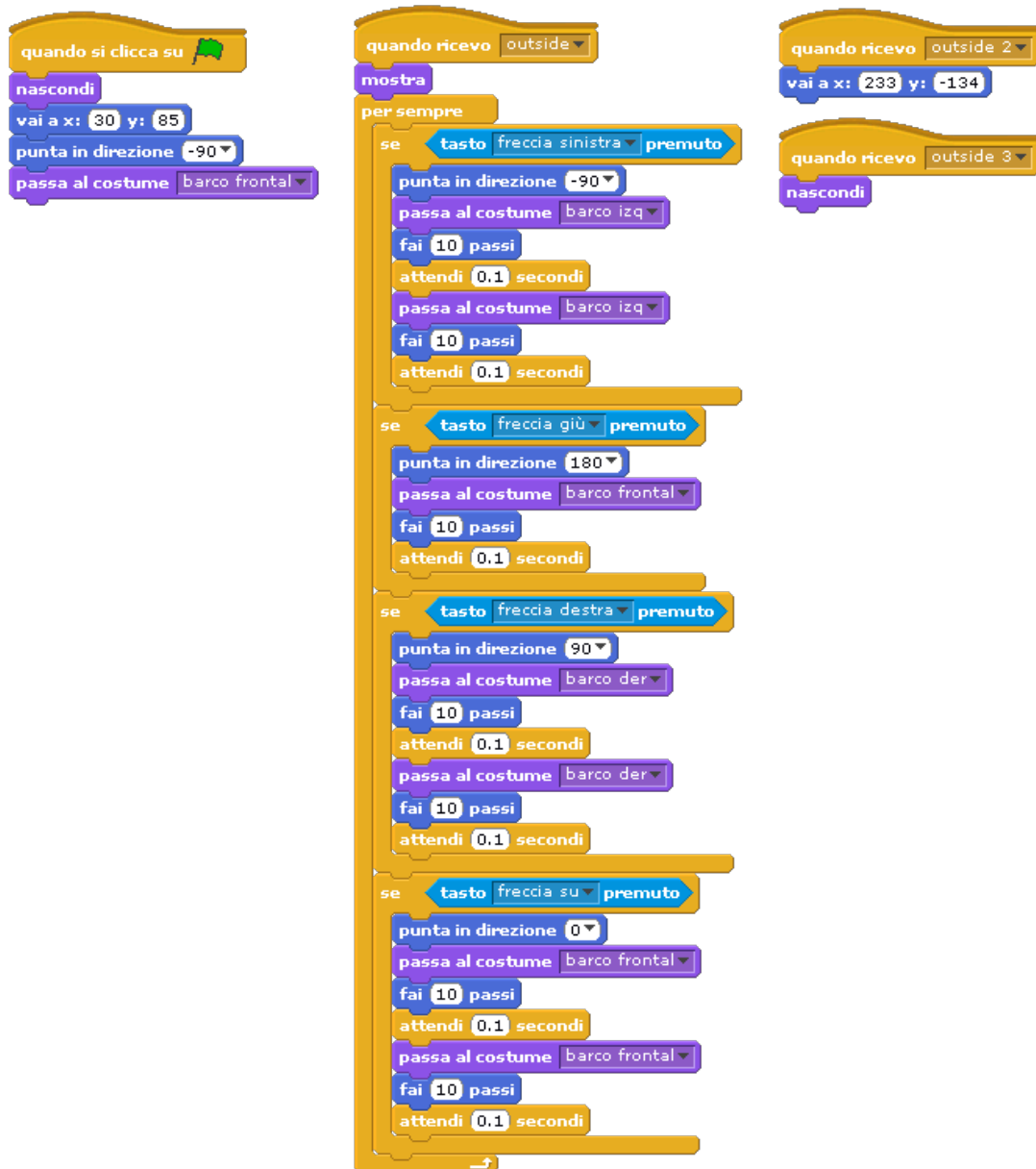
Figure B.3: Script for the Beagle's navigation through the map.
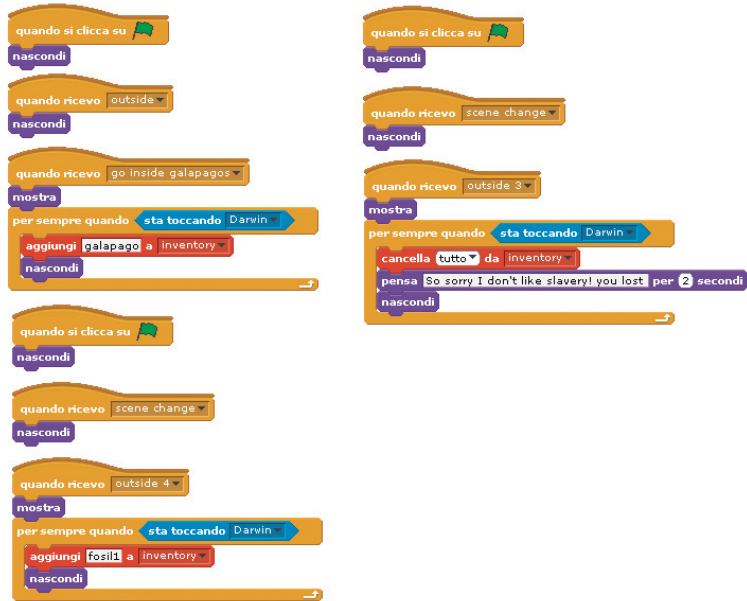
Figure B.4: Script for the collection of objects in some stages.
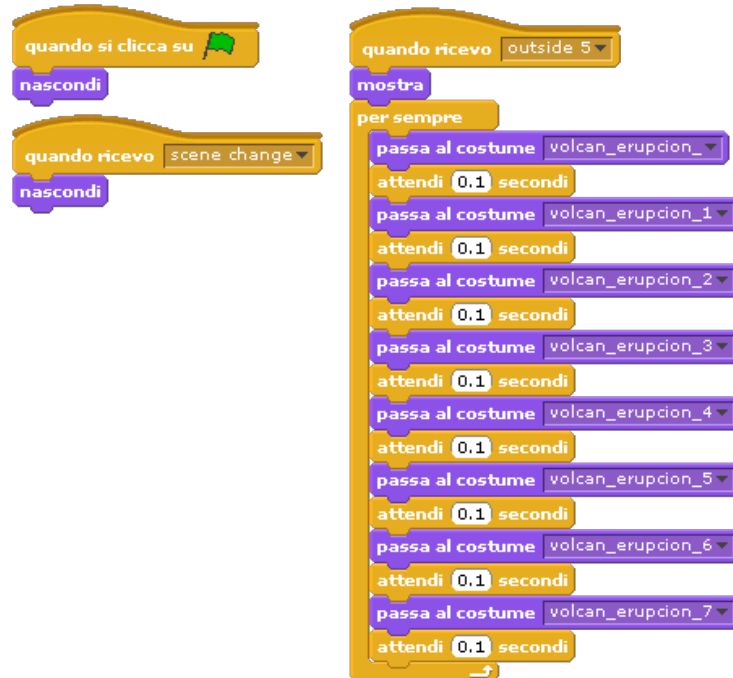
Figure B.5: Script for the volcan eruption animation.

Appendix C

Summary of Individual Performance of Participants in VALE-Emotions App Experimentation

In the following summary tables are presented the total duration time employed for each stage of the VALE-Emotions app experimentation per groups and per singular participants. Also, the individual percentage of success recognition is reported only for the *Test-0* and *Test-1* stages.

Table C.1: Summary of general performing (success and time) for each participant from the TD group.

| CODE | Training-0 | | Test-0 | | | Training-1 | | Test-1 | | | Test -2 | |
	done	time min	done	time min	% success	done	time min	done	time min	% success	done	time min
1	x	2.69	x	2.35	100	x	8.1	x	1.26	100	x	10.44
2	x	6.62	x	5.28	55	x	4.45	x	3.45	50	x	11.35
3	x	3.54	x	3.13	100	x	4.34	x	2.42	53.85	x	4.69
4	x	0.84	x	2.01	92.31	x	4.57	x	2.11	80	x	7.9
5	x	3.85	x	2.08	77.78	x	4.3	x	3.1	50	x	9.72
6	x	2.8	x	0.94	100	x	3.6	x	1.99	55.56	x	6.19
7	x	4.02	x	2.32	81.82	x	1.36	x	2.14	50	x	8.83
8	x	3.24	x	0.97	80	x	5.24	x	2.13	66.67	x	8.1
9	x	4.56	x	2.36	100	x	2.27	x	2.01	100	x	0.57
10	x	4.88	x	2.63	50	x	2.01	x	3.45	12.5		
11	x	0.13	x	2.02	66.67	x	3.34	x	2.18	53.33	x	11.92
12	x	4.16	x	1.95	100	x	3.8	x	2.1	66.67	x	9.27
13	x	3.36	x	1.94	100	x	3.73	x	0.38	66.67	x	10.83
14	x	5.59	x	1.84	100	x	3.02	x	2.01	83.33	x	11.32
15	x	1.89	x	2.27	40	x	0.042	x	2.52	26.67		
16	x	1.94	x	2.36	66.67	x	2.11	x	2.01	56.25	x	14.78
17	x	1.53	x	2.14	83.33	x	4.03	x	2.02	100	x	10.06
18	x	4.7	x	2.07	93.75	x	5	x	2.03	100	x	9.4
19	x	5.16	x	2.17	86.67	x	4.09	x	2.01	50	x	16.18
20	x	1.51	x	3.05	100	x	0.82	x	0.9	57.14	x	16.54
Average		3.35		2.29	83.70		3.51		2.11	63.93		9.89

Table C.2: Summary of general performing (success and time) for each participant from the HFASD group.

CODE	Training 0		Test 0			Training 1		Test 1			Test 2	
	done	time min	done	time min	% success	done	time min	done	time min	% success	done	time min
1	x	0.88	x	3.02	60.04	x	1.48	x	2.54	55.29	x	2.96
2	x	2.25	x	1.41	87.5	x	1.48	x	1.26	76.92	x	3.81
3	x	0.92	x	0.96	92.85	x	1.52	x	0.93	100	x	7.02
4	x	1.45	x	1.42	100	x	1.38	x	1.21	91.67	x	4.63
5	x	1.7	x	0.72	100	x	0.47	x	0.77	100	x	3.73
6	x	1.75	x	1.01	100	x	3.17	x	1.52	94.12	x	7.01
7	x	2.45	x	1.19	84.21	x	1.28	x	1.02	93.33	x	4.73
8	x	2.8	x	0.93	92.3	x	1.92	x	1.37	83.33	x	3.1
9	x	4.93	x	2.12	68.75	x	1.32	x	5.56	38.46		
10	x	2.92	x	1.15	81.25	x	1.22	x	1.31	73.33	x	2.99
11	x	1.01	x	1.08	100	x	0.53	x	1.41	95.83	x	3.05
12	x	1.38	x	1.27	100	x	0.83	x	1.5	100	x	9.12
13	x	3.63	x	1.01	100	x	1.92	x	1.37	83.33	x	3.82
14	x	2.08	x	1.13	87.5	x	0.91	x	1.4	61.11	x	2.53
15	x	4.33	x	2.1	38.09	x	1.32	x	2.3	64.28	x	3.33
16	x	3.23	x	0.98	100	x	1.38	x	0.85	100	x	3.73
17	x	1.92	x	1.24	50	x	2.35	x	3.28	31.5		
18	x	1.67	x	2.9	38.1	x	2.2	x	6.09	26.83		
19	x	1.9	x	0.89	78.57	x	1.23	x	2.09	62.5	x	4.96
Average		2.27		1.40	82.06		1.47		1.99	75.36		4.41

Table C.3: Summary of general performing (success and time) for each participant from the MR group.

CODE	Training 0		Test 0			Training 1		Test 1			Test 2	
	done	time min	done	time min	% success	done	time min	done	time min	% success	done	time min
10	x	4.84	x	2.69	92.31	x	6.13	x	7.83	68.75	x	39.19
11	x	1.89	x	3.72	41.18	x	2.74	x	3.54	46.15		
12	x	13.09	x	2.12	71.43	x	2.23	x	5.73	44.44		
13	x	0.57	x	11.19	41.18	x	2.07	x	3.99	30.77		
14	x	6.06	x	6.21	58.33	x	7.14	x	10.12	38.24		
15	x	2.9	x	3.97	25	x	5.10	x	26.48	25		
16	x	2.72	x	1.83	100	x	1.00	x	1.31	100	x	4.58
17	x	3.65	x	2.62	81.82	x	2.71	x	6.03	57.89	x	18.22
18	x	1.39	x	6.71	12.5	x	2.13	x	1.85	17.39		
19	x	1.25	x	1.41	100	x	1.18	x	1.47	100	x	13.44
20	x	1.84	x	3.95	47.06	x	10.67	x	8.99	36.36		
Average		3.65		4.22	60.98		3.92		7.03	51.36		18.86

Appendix D

Summary of Mistakes in *Test-1* from VALE-Emotions App Experimentation

Table D.1: Mistakes results obtained in the *Test-1* of VALE-Emotions

Emotion	Control		HFASD		MR	
	Media	SD	Media	SD	Media	SD
ANGER	25.08	32.36	12.19	28.12	23.33	26.29
DISGUST	33.13	33.48	15.09	21.47	47.00	41.77
FEAR	38.53	34.68	24.61	31.79	43.64	30.09
JOY	6.14	14.92	7.89	19.54	33.21	40.71
SADNESS	6.48	19.08	18.51	24.46	32.29	29.02
SURPRISE	15.63	30.10	14.91	26.45	46.44	26.44

Appendix E

Summary of Percentage Success for Individual Participant Group and Emotions in *Test-2* from VALE-Emotions App Experimentation

Table E.1: Summary of Percentage Success in DFE for Individual Participant Group and Emotions in *Test-2* from VALE-Emotions App Experimentation

Face Number	Anger			Disgust			Fear			Joy			Sadness			Surprise		
	TD	HFASD	MR	TD	HFASD	MR	TD	HFASD	MR	TD	HFASD	MR	TD	HFASD	MR	TD	HFASD	MR
005	50.0	25.0	–	0.0	66.7	0.0	0.0	0.0	0.0	71.4	33.3	–	20.0	20.0	20.0	0.0	0.0	0.0
010	57.1	66.7	0.0	0.0	0.0	33.3	20.0	0.0	0.0	62.5	100.0	–	50.0	25.0	35.0	50.0	20.0	0.0
015	71.4	75.0	25.0	12.5	20.0	–	16.7	0.0	25.0	83.3	62.5	–	85.7	100.0	100.0	28.6	0.0	0.0
020	70.0	0.0	33.3	25.0	33.3	50.0	14.3	0.0	0.0	100.0	50.0	100.0	71.4	100.0	100.0	50.0	50.0	0.0
025	75.0	0.0	50.0	50.0	100.0	33.3	20.0	25.0	33.3	85.7	40.0	66.7	50.0	100.0	–	0.0	60.0	100.0
030	66.7	14.3	50.0	33.3	57.1	100.0	20.0	22.2	33.3	71.4	100.0	100.0	70.0	75.0	100.0	40.0	50.0	0.0
035	66.7	85.7	66.7	60.0	71.4	100.0	14.3	33.3	33.3	62.5	50.0	–	63.6	85.7	100.0	50.0	28.6	0.0
040	75.0	33.3	66.7	55.6	71.4	100.0	33.3	25.0	50.0	66.7	50.0	33.3	100.0	80.0	100.0	16.7	50.0	100.0
045	100.0	66.7	50.0	71.4	80.0	33.3	11.1	25.0	25.0	90.9	100.0	100.0	87.5	80.0	100.0	42.9	70.0	100.0
050	85.7	85.7	50.0	77.8	50.0	50.0	50.0	62.5	25.0	100.0	75.0	100.0	100.0	100.0	100.0	50.0	85.7	–
055	75.0	83.3	66.7	57.1	66.7	25.0	50.0	16.7	100.0	77.8	75.0	–	75.0	100.0	50.0	75.0	44.4	100.0
060	100.0	77.8	70.0	100.0	57.1	25.0	28.6	75.0	50.0	71.4	66.7	100.0	87.5	100.0	66.7	100.0	50.0	50.0
065	60.0	77.8	90.0	50.0	75.0	33.3	60.0	50.0	50.0	100.0	66.7	100.0	88.9	87.5	100.0	80.0	57.1	–
070	77.8	100.0	50.0	50.0	66.7	100.0	80.0	60.0	100.0	100.0	75.0	100.0	88.9	100.0	–	66.7	100.0	–
075	66.7	75.0	80.0	72.7	50.0	33.3	44.4	75.0	50.0	100.0	75.0	100.0	87.5	100.0	–	88.9	60.0	0.0
080	83.3	50.0	66.7	88.9	100.0	25.0	75.0	60.0	100.0	100.0	75.0	50.0	90.0	100.0	50.0	63.6	80.0	50.0
085	100.0	60.0	50.0	87.5	60.0	100.0	71.4	75.0	100.0	75.0	60.0	100.0	85.7	80.0	50.0	87.5	50.0	50.0
090	75.0	71.4	50.0	66.7	66.7	50.0	62.5	50.0	100.0	87.5	100.0	100.0	83.3	100.0	100.0	71.4	66.7	0.0
095	100.0	100.0	100.0	80.0	50.0	50.0	40.0	60.0	100.0	60.0	100.0	66.7	85.7	66.7	100.0	90.0	100.0	0.0
100	100.0	62.5	66.7	80.0	57.1	100.0	72.7	50.0	100.0	100.0	75.0	100.0	87.5	100.0	100.0	100.0	100.0	100.0

Power Fitting of the Hits Recognition in the DFE sequences per Individual Participant Groups and per Emotion in *Test-2* from VALE-Emotions App Experimentation

Figure F.1: Individual recognition of intensity levels from the Anger emotion in *Test-2* with fitting representation.

Figure F.2: Individual recognition of intensity levels from the Disgust emotion in *Test-2* with fitting representation.

Figure F.3: Individual recognition of intensity levels from the Fear emotion in *Test-2* with fitting representation.

Figure F.4: Individual recognition of intensity levels from the Joy emotion in *Test-2* with fitting representation.

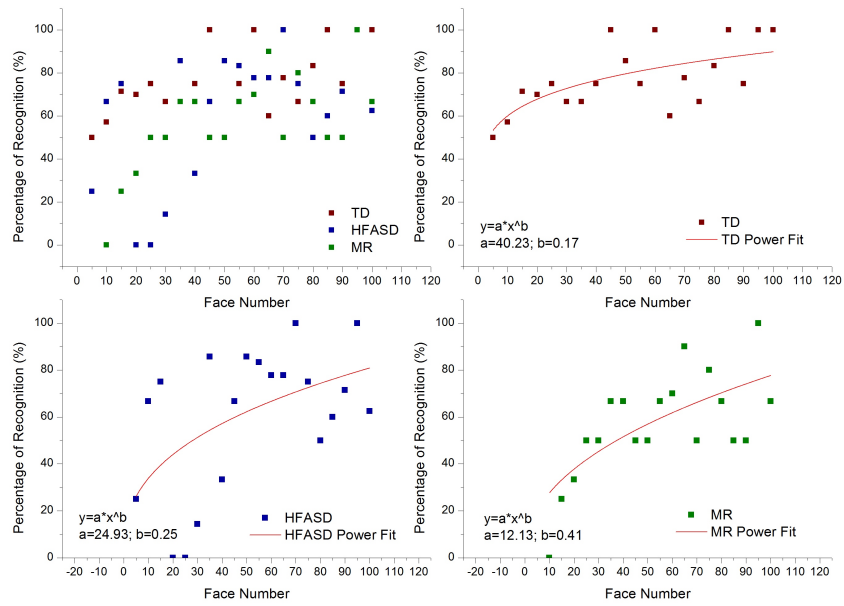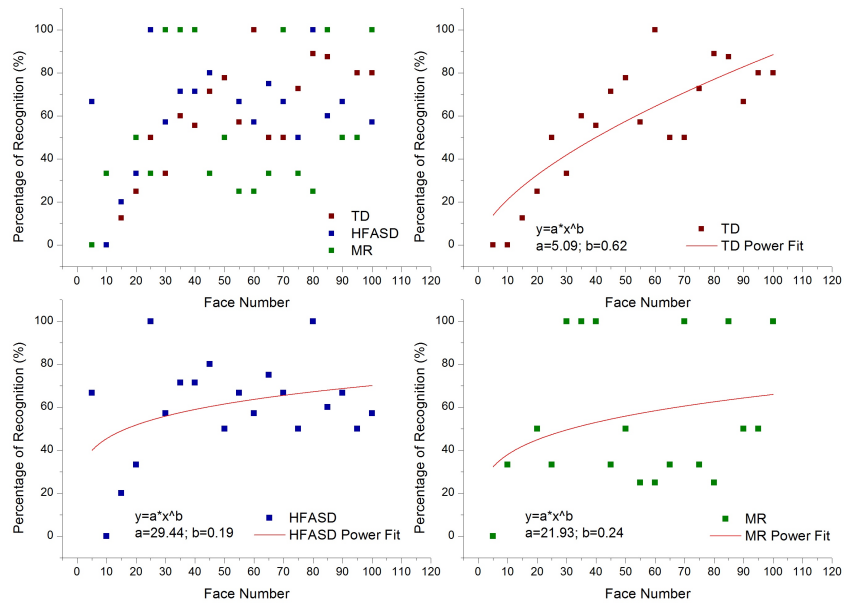**Figure F.5:** Individual recognition of intensity levels from the Sadness emotion in *Test-2* with fitting representation.

Figure F.6: Individual recognition of intensity levels from the Surprise emotion in *Test-2* with fitting representation.
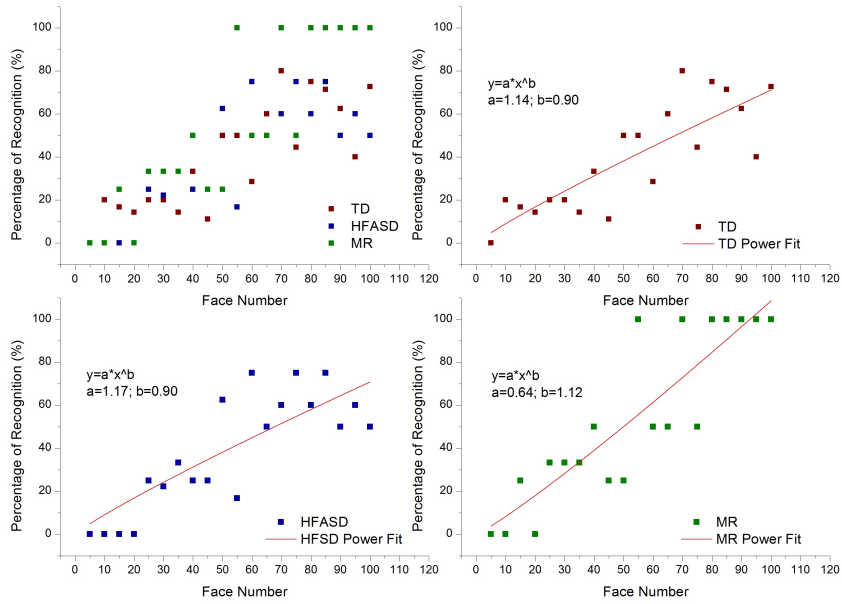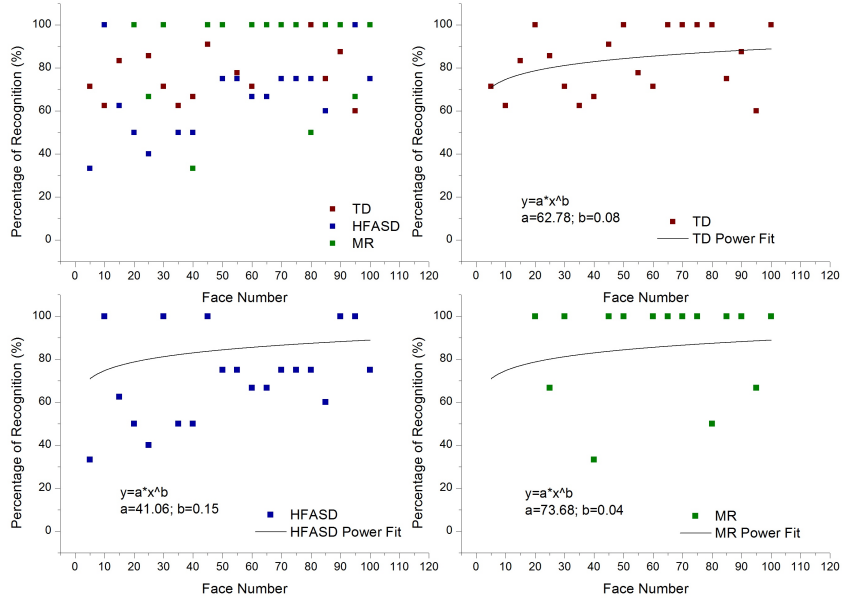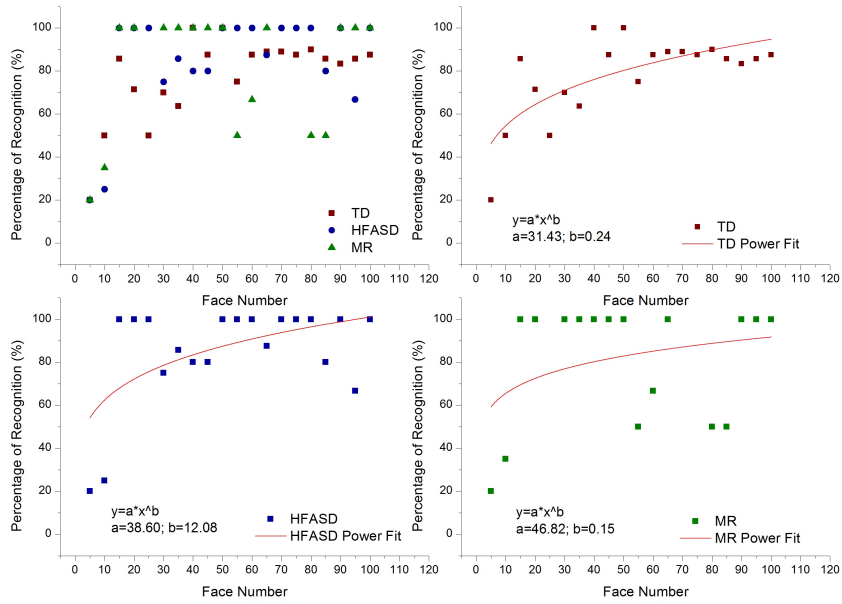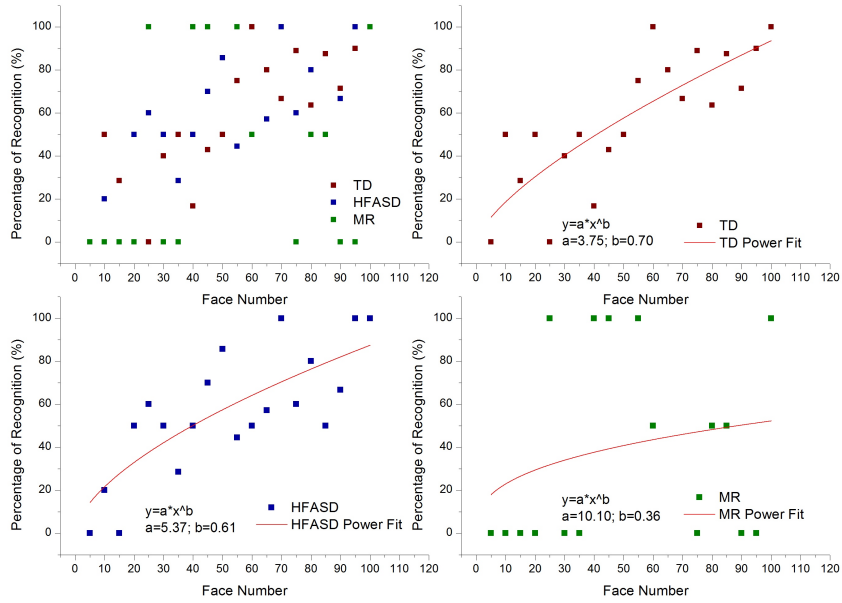
Appendix G

Summary of Response Time for Individual Participants per Group and per Emotion in *Test-1* from VALE-Emotions App Experimentation

Table G.1: Summary of Response Time for Individual Participants per Group and per Emotion in *Test-1* from VALE-Emotions App Experimentation

Reg	ANGER			DISGUST			FEAR			JOY			SADNESS			SURPRISE		
	TD	HFASD	MR	TD	HFASD	MR	TD	HFASD	MR	TD	HFASD	MR	TD	HFASD	MR	TD	HFASD	MR
	[s]	[s]	[s]	[s]	[s]	[s]	[s]	[s]	[s]	[s]	[s]	[s]	[s]	[s]	[s]	[s]	[s]	[s]
1	2.854	0.305	7.913	5.858	0.742	16.848	9.411	0.79	10.162	4.669	1.686	7.487	3.211	0.586	4.707	14.676	1.848	10.185
2	13.364	4.572	19.02	4.018	0.1	11.913	0.154	0.026	11.301	5.769	5.263	8.253	8.663	3.859	16.267	6.574	2.416	6.097
3	14.916	5.539	4.437	15.347	1.869	7.887	19.829	6.985	9.95	0.374	1.096	3.591	8.328	2.288	7.533	4.706	2.017	9.661
4	2.116	1.491	21.839	6.957	4.348	6.92	7.317	1.618	59.699	2.112	2.828	6.496	12.067	1.344	5.673	1.961	1.456	4.871
5	2.081	1.667	6.851	3.64	1.664	5.673	3.429	6.678	9.568	4.058	1.361	6.888	3.792	1.33	19.356	10.656	1.294	5.991
6	11.418	2.79	32.879	3.951	1.424	3.193	2.257	1.222	2.988	2.183	1.178	39.527	23.853	1.452	6.716	2.317	2.852	20.631
7	25.021	1.318	2.522	0.734	5.703	8.161	24.971	2.444	3.452	1.654	3.179	14.192	4.824	4.673	6.039	3.821	2.27	4.747
8	1.679	1.011	18.208	15.339	2.371	5.727	6.293	1.979	6.861	28.581	4.576	10.594	2.866	2.259	5.445	1.901	1.451	12.164
9	1.995	2.996	3.849	6.917	0.937	19.267	8.142	0.792	29.755	30.056	0.902	12.094	2.569	0.988	5.719	1.803	1.392	8.309
10	16.114	2.031	23.506	4.648	1.453	5.727	3.733	1.105	6.865	3.978	0.993	10.594	17.526	0.904	5.673	2.157	1.886	10.8
11	2.6	1.99	11.7	9.195	0.966	3.603	22.009	5.706	3.457	1.264	1.622	3.701	6.768	3.408	19.356	5.473	1.496	6.056
12	3.056	0.643	3.282	19.479	2.596	12.142	2.098	6.375	29.755	9.49	1.823	23.315	1.326	2.623	0.948	2.681	0.802	8.309
13	6	0.737	2.522	15.347	2.88	10.028	7.992	2.287	5.083	15.969	1.513	39.527	3.295	4.006	6.839	12.418	1.12	3.537
14	8.442	1.536	18.208	3.419	2.86	5.381	21.878	3.143	2.988	5.769	2.855	2.715	2.673	0.653	18.392	2.569	2.457	4.661
15	3.923	3.56	1.812	2.735	1.717		8.313	0.475	1.507	3.31	2.436	10.213	1.903	2.909		2.197	4.137	5.991
16	1.036	4.993	5.158	7.418	6.532		16.589	3.327	0.033	2.06	2.424	4.201	2.703	1.473		2.411	8.389	20.631
17	1.738	1.236	14.757	3.78	9.698		5.868	10.813	6.346	2.7	1.459		2.251	2.758		1.556	3.182	5.024
18	1.977	5.434		3.146	7.377		6.69	4.793	7.068	1.871	4.985		1.262	0.445		1.916	4.652	5.362
19	3.878	1.136		9.496	3.368		8.419	0.275	9.603	1.812	3.282		11.749	14.024		12.418	1.431	12.903
20	2.293	1.251		0.049	0.87		3.784	1.437	4.683	5.043	1.748		2.569	3.019			0.769	
21	5.901	1.111		11.303	0.94		3.224	1.445		1.682	1.365		2.703	4.818			1.17	
22	3.923	1.338		5.956	1.196		5.868	2.026		0.696	1.52		3.425	0.625			0.913	
23	1.036	1.544		3.838	1.021		0.944	1.05		3.642	0.924			0.94			1.379	
24		1.17		1.744	5.033			1.646		1.695	1.03			1.195			1.214	
25		3.56		1.961	1.961			8.669		1.36	1.49			0.958			1.757	
26		3.054		1.79	6.532			2.702		3.161	1.709			2.18			2.457	
27		0.643		0.049	0.332			3.327		2.448	2.402			1.463			4.137	
28		0.737		2.612	1.857			10.813		1.981	2.424			2.758			2.984	
29		1.536			2.86			0.363		0.696	1.459			0.445			2.296	
30		1.922			1.717			0.126		3.642	1.673			1.946			0.802	
31		1.369			4.427			3.143		4.179	6.074			1.68			1.12	
32		1.544			2.23			0.475			2.855			0.653			0.036	
33		1.17			5.033			2.982			2.436			2.909			1.214	
34		3.045			1.961			3.53			2.574			1.473			1.757	
35					8.855			8.669			1.844			1.68			1.263	
36					9.371			2.702			1.709			1.543			1.19	
37					1.758			9.419			2.402			2.18				
38								3.931			2.675			1.463				
39											1.006			3.66				
40											3.128			0.992				
41											1.12			2.624				
42														1.48				

Plotting of Response Time for Individual Participant Groups per Emotion in *Test-1* from VALE-Emotions App Experimentation

Figure H.1: Response Time of the hits recognition per participant groups for Anger emotion in *Test-1*.

Figure H.2: Response Time of the hits recognition per participant groups for Disgust emotion in *Test-1*.
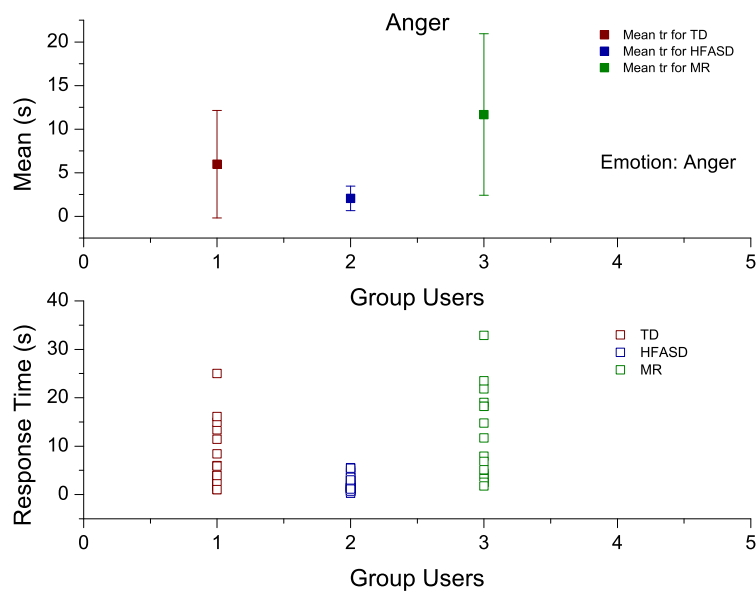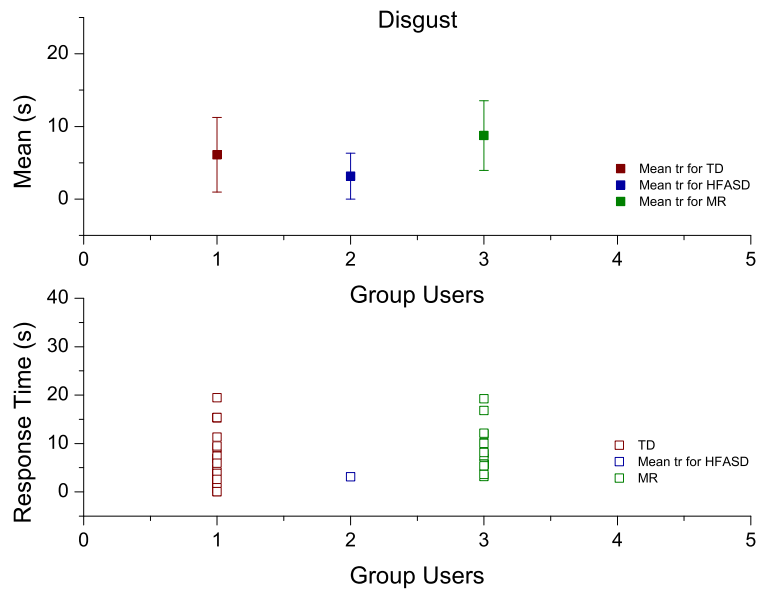

Figure H.3: Response Time of the hits recognition per participant groups for Fear emotion in *Test-1*.
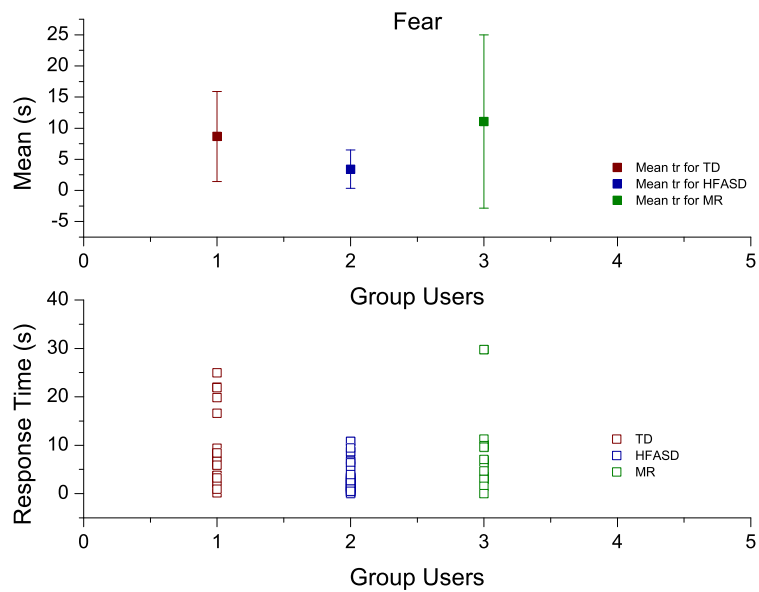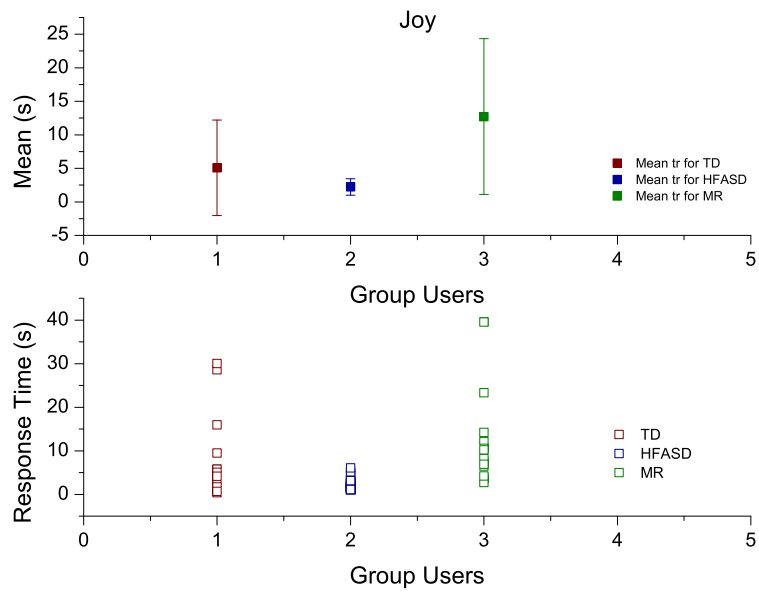
Figure H.4: Response Time of the hits recognition per participant groups for Joy emotion in *Test-1*.
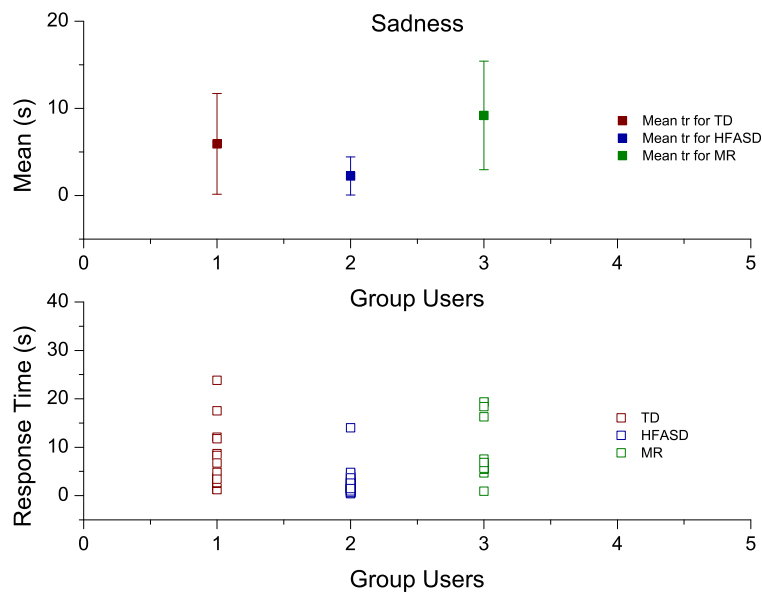

Figure H.5: Response Time of the hits recognition per participant groups for Sadness emotion in *Test-1*.
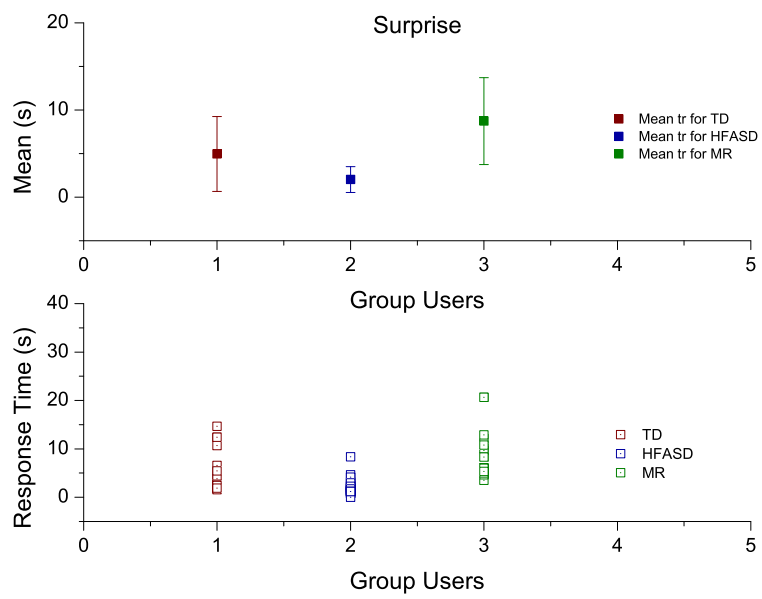
Figure H.6: Response Time of the hits recognition per participant groups for Surprise emotion in *Test-1*.

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