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AUGMENTED LEARNING: THE DEVELOPMENT OF A LEARNING ENVIRONMENT IN AUGMENTED REALITY

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Abstract

In this thesis we present our research project on an augmented environment developed using the technology available in the field of Augmented Reality, capable of delivering learning contents on Information and Communication Technologies and e-services to older adults without computer and digital literacy. The learning environment is meant to provide a contribution in solving a problem of social exclusion in older adults. In recent years, technology has helped older adults in many ways to slow down the effects of ageing. Yet, at the same time, technology has also created new problems for older adults. Indeed, technology has transformed society into a strongly technological-based e-society, in which citizens without competences on the use of computer and digital tools, such as older adults, are progressively pushed to the margins, and run the risk of being socially excluded. Learning is the key-concept for a possible solution to such a problem. Older adults can still learn, even in older age. Learning is beneficial to older adults in many ways. So, why not using learning for teaching older adults the basic of technology necessary to make them citizens of e-society? That is the purpose of our research: our learning environment is meant to teach older adults the basic of technology through a technological device. We designed our augmented environment specifically for older adults without computer and digital literacy: it takes into account older adults' needs and possible disabilities; it does not require any particular psycho-physical competence to be used; it does not require any technological knowledge. In this thesis we show how we designed a learning augmented environment with such features, how we developed it, and how we tested it on a group of older adults to ensure that what we have developed meets the requirements we set during the design process.

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List of Abbreviations

AE	Augmented Environment
AEs for HMD	Augmented Environments generated by applications running on HMD
AL	Augmented Learning
AR	Augmented Reality
HMD	Head-Mounted Display
HCI	Human Computer Interaction
ICTs	Information and Communication Technologies
LAE	Learning Augmented Environment
LE	Learning Environment
LM	Learning Module
UWP	Universal Windows Platform

CHAPTER 1

1. Introduction

1.1 Purpose of the Project Presented in this Thesis

Nowadays, older adults must deal with many problems due to ageing: their physical and mental conditions tend to deteriorate and they find it difficult to cope with many situations that in younger age they could easily control. Yet, studies on topics such as active ageing or health and wellbeing show that older adults, more than in the past, want to remain healthy and active as they age. Information and Communication Technologies (ICTs) can help older adults in many ways to slow down the effects of ageing and preserve their psycho-physical conditions for a longer time, so to guarantee them longer and healthier lives. However, ICTs also contribute to create new social problems in older adults, especially social exclusion and loneliness. In a world more and more shaped by technology and digital communication, social relationships, public and private activities and services, entertainment and, overall, any form of exchange of information, will increasingly be based on the use of technology. Therefore, older adults without computer and digital literacy[1] will find it progressively more difficult to maintain their social relations and activities, and feel that they are active citizens of the technological society.

Then, the goal of our research is to help older adults to cope with their illiteracy on computers and digital tools and to avoid this new form of social exclusion. In this thesis, we present our work on an innovative learning environment, specifically tailored for older adults, easily accessible without any previous knowledge of technology, and capable of delivering educational material on the use of computers and digital tools and, particularly, on e-services.

Such learning environment should be able to serve two different purposes: first of all, it should provide older adults with the computer and digital literacy they need to become active members of e-society; in addition, it should contribute to increase the overall wellbeing of older adults by helping them, through the process of learning, to maintain cognitive functionality.

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[1] With computer literacy we mean "the knowledge and ability to use computers and related technology efficiently, with skill levels ranging from elementary use to computer programming and advanced problem solving"[182]. In our case, given the target we chose for the learning environment we want to develop, when we talk about computer literacy we refer to a *basic* knowledge and ability to use computers. As for digital literacy, it is the knowledge and ability to find, evaluate, and create information through the different media on a variety of digital platforms [183]. In the past, computer literacy and digital literacy could be considered very similar forms of literacy. In recent times, this is no longer true. Nowadays, individuals with digital literacy possess the knowledge and skills to use a variety of digital tools, the Internet and Social Media, and also mobile devices.

To create this learning environment, we decided to use the technology available in the field of augmented reality. The learning environment we designed and developed is an immersive, 3-D and fully interactive environment that can be easily experienced with wearable devices called "head-mounted devices". Such learning environment can contain many learning modules, each of which provides the user with learning contents on selected topics. To facilitate the use of the learning environment, we created Elektra, a virtual assistant (a human-size hologram of a woman) capable of interacting with the user, so to help him out to understand how to navigate throughout the learning environment, or how to interact with the holograms, and how to use the learning modules.

The actual product we developed is an application that can run on one particular head-mounted device called *Microsoft HoloLens*, and is capable of generating, through the device, an immersive experience in a prototype (i.e., a reduced version) of the learning environment.

Before working on the final version of the learning augmented environment, we need to verify whether the learning environment satisfies the usability requirements we set during the design process. Moreover, we want to understand whether older adults are able to use our learning augmented environment, find it easy to use it, and are also willing to use it for learning. To these purposes, we designed a test, and developed – within the learning augmented environment – an immersive Testing Area to be used with a group of target users. By analyzing the results from the test, we will able to understand whether we can use augmented reality as an effective technology capable of providing older adults with the literacy on computers and digital tools they need to become active and integrated citizens of our technological society.

1.2 Research Questions

As we explained in the previous Section, with our project, we want to design and develop a learning environment using the technology of augmented reality. We also want this learning environment to be tailored for older adults without computer and digital literacy, so that older adults find it easy to use, and enjoy the learning experience it provides.

To reach these objectives we define the following main research questions:

RQ1: What are the design principles we need to adopt to design an augmented environment tailored for older adults?

RQ2: What is the relationship older adults have with new technologies and augmented reality?

RQ3: What are the rules defining older adults' interactions in augmented environments?

RQ4: Is it possible to use effectively our augmented environment with older adults to provide them with the necessary knowledge and skills to use computers and digital tools?

To answer to these research questions, we must explore several research areas.

If we want to understand how create an augmented environment (RQ1) we must focus mostly on augmented reality. Augmented environments, meant as the products of augmented reality, are new forms of communications. Augmented environments use 3D visual spaces and sound spaces; holograms existing in augmented environments are complex virtual objects with complex behaviors; users of augmented environments can freely move everywhere within the augmented environments, and can interact with the holograms almost as if they were real objects. This means that augmented environments are not only *new*, but also *very complex* forms of communication that barely resemble any other form of communication produced by other media. Consequently, we still do not have a solid knowledge on, and understanding of the rules and principles necessary to create augmented environments that fully display the potential of augmented reality. So, it is only through a close exam of the properties and features of augmented environments that we can understand how to design an augmented environment that satisfies our needs.

As for the second part of the RQ1 (augmented environment must be *tailored* for older adults) and the RQ2-3, in order to find answers, we need to move the focus of our research on a different direction. By answering the RQ1 we find the way to design a general augmented environment that, later, can be developed into a working prototype. But it is only by answering the RQ2-3 that we can understand how to adequately shape the augmented environment for its *target users*. In our case, these target users are *older adults*, with a certain background, certain needs, interests and capabilities, certain psycho-physical or behavioral traits which are typical in older age.

So, by exploring the relationship older adults have with new technologies and, particularly, with augmented reality (RQ2), and by investigating the forms of interaction our target users have with a first version of our augmented environment (RQ3), we can understand what changes we must introduce into our augmented environment so to make it (a) *tailored* for older adults, (b) *easy* to use, (c) and capable of providing older adults with an *enjoyable* learning experience.

Finally, by testing a working prototype of an augmented environment with the above features with a group of older adults, we will find out whether older adults are *able to use* augmented reality, are able to use it *effectively*, and are *willing* to use it. This, will provide us with an answer to the RQ4, and will also give us directions to follow for future research works on the Learning Augmented Environment.

1.3 Methodology

Our research is interdisciplinary[1], [2] and, through the different Chapters of this thesis, we explore different contexts and domains of knowledge. The problem we want to deal with – older adults' social exclusion due to their illiteracy on computers and digital tools– is a social problem and needs to be addressed within a social context. However, the solution we propose to the problem – a learning system specifically made for older adults – will be defined within the domain of learning and, particularly of e-learning, and will be implemented by using a new technology: augmented reality.

Due to the variety of domains of knowledge and topics we deal with in our work, throughout this thesis we will make use of different methodologies.

Semiotics of media: In Chapter 4, we use semiotics, and particularly semiotics of media, to systematize and deepen the knowledge related to Augmented Reality. In addition, we set the basis for a semiotic investigation on Augmented Reality and on the immersive augmented environments generated by applications running on head-mounted devices. Through such a semiotic approach, we can open up augmented environments and break them down into their components, each of which can be examined from many different perspectives. The semiotic approach can be particularly useful when it is used – as we did – during the process of design of an augmented environment.

Augmented Environment Design and Development: In Chapter 5 and Chapter 6, we mostly deal with the design and development of augmented environments. Augmented reality is a new medium. However, it is still in its infancy, and people working with augmented reality did not have enough time yet to fully explore definitions, theories, methodologies and practices on augmented reality, and develop a well-structured set of methodologies capable of explaining exactly how to design and organize the objects that augmented reality, as technology, is able to create. Unable to find at our disposal a well-established design methodology, in Chapter 5, we created our own design methodology by integrating our own considerations, based on many hours of observation and analysis of available augmented environments, with many useful suggestions and best practices coming from the game design world, and (some) from the augmented reality world. This set of ideas, suggestions, practices, considerations *is* the informal design methodology we used to design our Augmented Environment.

In designing and developing our Augmented Environment (Chapter 5 and Chapter 6), we treated the Augmented Environment as a sort of video-game with a narrative. This allowed us to take advantage of the many and well-established methodologies used in the gaming world. We defined the general architecture of our Augmented Environment according to the design requirements, and we used Unity, the game-engine used by many game developers to create video-games, to create the different modules/sections that, together, make up our Augmented Environment. The final product – a prototype of our Augmented Environment – is an app that, once running on the head-mounted device *Microsoft HoloLens*, generates the Augmented Environment that we have designed.

Test of the prototype: The test we describe in Chapter 7 is made up of three different "testing moments", or testing sections, each of which uses different tools or methodologies to acquire different data sets. The test is meant to provide information on the usability of the Augmented Environment, on the capabilities older adults have in dealing with augmented reality, and on the relationship they have with augmented reality. Such information will allow us to answer many of the Research Questions previously presented.

To evaluate the usability of our Augmented Environment we use one Usability Inspection Method, according to which the evaluation of user interfaces is based on the judgment of groups of *inspectors*. By following the Usability Inspection method, we created a questionnaire, to be filled out by the final users of our Augmented Environment, that allows the identification of usability problems and the evaluation of many usability features of the Augmented Environment.

By examining the data acquired by the HoloLens while older adults were performing some exercises within the Augmented Environment, we can understand whether older adults are able to use augmented reality. By comparing the above data with the data acquired by the HoloLens while a group of students (the control group) were performing the same exercises within the Augmented Environment, we can understand whether older adults are able to use augmented reality effectively.

Finally, to gain information on the relationship older adults have with augmented reality we set up a Focus Group, during which older adults can freely express their opinion on new technologies and augmented reality. Through the Focus Group, we will be able to understand whether older adults like augmented reality, enjoyed the experience with our Augmented Environment, and would be willing to use augmented reality for learning new things.

1.4 Contributions and results

We believe that through this thesis we provided several contributions to different research areas related to Augmented Reality.

1.4.1 General knowledge on Augmented Reality

The semiotic approach to augmented reality, that we summarized in the previous section, is a significant and innovative alternative to the more wide-spread technological approach. While the technological approach allows engineers and technicians to develop the technological components of augmented reality, it does not seem very effective for analyzing and designing the forms of communication (the augmented environments) produced with augmented reality. On the contrary, the semiotic approach here proposed favors the analysis of augmented environments and their components, and helps analysts, designers, humanists, and, in general, non-technical people, to get a good understanding of what augmented reality is.

1.4.2 Design of Augmented Environments

During the design of the Learning Augmented Environment, we followed the well-known software engineering practice of "separation of concerns" [3], and we thrived to keep as separate as possible the *design of the Augmented Environment* from the *design of its contents*. This has allowed us, during the design of the Augmented Environment, to freely explore all the features and possibilities offered by augmented reality, without any constriction or limitation imposed on the design by the learning contents, or by the features of real users of the Learning Augmented Environment.

As a consequence, we have been able to create a complex, very flexible and powerful virtual object – we called it the *Virtual Room* – displaying the most important features of augmented environments (see Chapter 5). The Whole Augmented Environment has been built around the Virtual Room, and we consider the Virtual Room as our major contribution not only to the design of our Augmented Environment, but also to the design of augmented environments in general. Indeed, we believe that with the creation of the Virtual Room we set a first step toward the definition of a Content Management System (CMS) for Augmented Reality similar to the CMSs, very popular nowadays, used for the creation of websites.

1.4.3 Evaluation of Usability in Augmented Environments

We said that Augmented Environments are very complex and new forms of communication produced by Augmented Reality. Since many of the features and properties of such augmented environments are unique, if we want to evaluate the usability of such augmented environments, we cannot easily apply the existing methodologies, which have been created for the evaluation of the usability of forms of communication produced with other media. Therefore, we modified one existing methodology (Usability inspection) so to be able to account for the existence of augmented environments and to evaluate their usability. Moreover, we designed a test (and developed a Testing Area) that uses such methodology to evaluate the usability of our Augmented Environment and to detect its possible usability problems. Considering that the evaluation of the usability of augmented environments is a research area largely unexplored, we believe that with the design of the test and the development of the Testing Area we provided an important contribution to the field.

1.4.4 E-LEARNING AND EDUCATION

It is already possible to find on the market applications for augmented reality that are considered “educational”. However, most of the times, they refer to a very narrow definition of education. Most of them are made to facilitate the acquisition of specific skills within a limited domain of knowledge (e. g., how to assemble, or repair, or use a particular device or machine), but do not deal with the process of facilitating learning in a more general meaning. We consider these apps as sophisticated "technological translations" of manuals or handbooks. With our Learning Augmented Environment, we propose something new and different, and in so doing we provide a significant contribution to the research on e-learning. Our Learning Augmented Environment is meant to be a *system for learning through augmented reality*. It is a flexible, virtual container of learning contents. Its contents can be easily modified to satisfy the needs of different target users. Its original contents can be easily replaced with completely new contents, while the general system for delivering those contents stays the same. So, we believe that we can consider the app we have designed and developed (and, of course, the Augmented Environment generated by the app) a real educational application.

1.5 Thesis Structure

The general outline of this Thesis is based on a paper [4] we started writing when our project was at an early stage, and that was published in March, 2019. In that paper we introduced the idea of an augmented environment that could be used to deliver learning contents on the use of computers and digital tools to older adults without computer and digital literacy, and we briefly described the work needed to design and develop such an augmented environment.

The contents presented in this Thesis, however, are almost entirely new and are, therefore, still unpublished. Only Chapter 4, dealing with a semiotic approach to augmented reality, is based on a paper [5] that has been recently published (November, 2019).

Chapter 2: *Augmented Reality*

Augmented Reality is the technology we chose to develop a learning platform for older adults, and this Chapter aims at introducing augmented reality. Through this technology, we can “augment” and enrich the everyday world with a variety of computer-based virtual worlds. In Chapter 2 we explore the technology of Augmented Reality and try to see why and how this technology has the potential for reshaping our world.

First, we look at one definition of augmented reality, trying to understand what augmented reality is and how it works. Then, we present a short history of augmented reality, so to have the chance to understand how different ideas, technologies and devices from the last Century contributed to create the actual technology that is called Augmented Reality. We also take a close look at the devices nowadays available on the market that, through their hardware, make possible the creation of different forms of “augmented experience”. Finally, we examine the applications for augmented reality, that is, the pieces of software running on the different devices, responsible for the generation of augmented environments.

Chapter 3: *A Learning Augmented Environment for Older Adults*

In this Chapter, we will examine the new form of social exclusion older adults might suffer in e-society, that is, a society in which social relationships, public and private activities, are based on the use of electronic services. We will also see how – through learning – we might be able to help older adults to enter the digital world defined by e-society. Particularly, in the concluding section of this Chapter, we introduce the learning augmented environment for older adults we will be working on in the following Chapters.

Chapter 4: *A Semiotic Framework for The Analysis of Augmented Environments*

In this chapter, we intend to use semiotics of media to systematize and deepen the knowledge related to Augmented Reality, especially with regard to the *objects* developed using Augmented Reality technology, that is, the immersive augmented environments generated by applications running on head-mounted devices for Augmented Reality.

This approach to Augmented Reality is meant to be an alternative to another approach, certainly more common and widespread, that deals with Augmented Reality from a technological point of view. Such technological approach often uses a technical language to describe Augmented Reality that is not easily comprehensible by those people who are interested in Augmented Reality, but don't have a technological background.

Then, the approach to augmented reality presented in this Chapter wants to provide a way of dealing with augmented reality that could help non-technologists (such as designers, analysts, humanists) to understand the potential of a technology that technologists have developed.

Chapter 5: *Designing the Learning Augmented Environment*
In Chapter 5, we discuss in detail about the design methodologies we use to design our Augmented Environment, and about the problems we have to cope with when we work with new and largely unexplored forms of communication. We also explain how we select and organize the contents of a possible course on the use of computers and digital tools, and how we modify and transform these contents, so that they become virtual and augmented contents existing within an augmented environment. In the second part of the Chapter, taking into account what was examined in the previous Chapters of this work, we discuss the details of the design of the immersive Augmented Environment that we want to use as a learning platform for older adults. Particularly, we describe the design of the *Virtual Room* – a complex virtual object which displays the most important features of augmented environments – which is the essential core of the whole Augmented Environment.

Chapter 6: *Development & Implementation of the Prototype*
In Chapter 6, we describe the main aspects of the process of development of a prototype of the Augmented Environment that we designed in the previous Chapter. We describe the general architecture of the prototype, define the system requirements for developing the prototype, and explain the different programs we use to develop the variety of components the prototype is made of. The prototype is in the form of a piece of software – an app – that can be deployed on the head-mounted device for augmented reality called *Microsoft HoloLens* and that, once running, is capable of generating the immersive, 3-D and interactive Augmented Environments.

Chapter 7: *Testing the Prototype with Microsoft HoloLens*
Chapter 7 is focused on the test we designed to see how the prototype works "outside-the-lab", with real people in real contexts. In the previous Chapter, we discussed about the development of a working prototype of the Augmented Environment. In this Chapter, we use that prototype with the test we designed. By administrating the test to a group of older adults, we want to acquire information on the usability of the Augmented Environment. Moreover, we want to understand whether augmented reality is the right technology to use to deliver learning contents to older adults. To this purpose, the test is designed in such a way to allow us to verify whether older adults are able *to use* augmented reality, are able to *efficiently* use it, and are *willing* to use it for learning.

1.6 List of Publications

1.6.1 Published

S. Cicconi and M. Marchese, “Augmented Learning: An E-Learning Environment in Augmented Reality for Older Adults,” in *INTED 2019 Proceedings*, 2019, pp. 3652–3662.

S. Cicconi and M. Marchese, “Analysis of an E-Learning Augmented Environment: A Semiotic Approach to Augmented Reality Applications,” ICERI2019 Proceedings, 2019, pp. 4921–4931.

1.6.2 To be submitted

We are working in collaboration with psychologist Marta Mondellini on the following papers:

S. Cicconi, M. Mondellini, M. Marchese, When Older Adults Wear the HoloLens: A Test in Immersive Augmented Reality to Teach Older Adults How to Interact with Holograms.

S. Cicconi, M. Mondellini, M. Marchese, Evaluating Usability in Immersive Augmented Reality.

1.7 Final Note (August, 2020)

1) The lockdown of most economic, social and cultural activities, imposed by the Italian Government as a way to fight the pandemic spread of Covid-19, blocked our work as well. From February 2020 on, we were forced to stop any kind of activity related to the administration of the test described in Chapter 7. As a result, we were not able to obtain any type of data to analyze, neither from the test with the HoloLens, nor from the Questionnaire for the Evaluation of Usability of Augmented Environments, or from the Focus Group.

As a consequence, at the time of this writing, we have not been able to conclude this work as planned, and as described in the previous Sections. Particularly, we have not been able to provide the answers to some of the Research Questions we asked at the beginning of this Introduction.

On the other hand, we believe that, through the work presented in Chapter 7, we have provided an articulated definition of the test, and we have also defined the overall conditions for the administration of the test. This will allow us to find the answers to the Research Questions as soon as we will be able to administer the test.

Even without the data from the test, in the final Chapter of this work (the Conclusions), we try nevertheless to examine the scenarios resulting from the different, possible outcomes of the test. By analyzing these scenarios, we can make hypothesis on the possible directions our work will take.

2) Once we realized that we could not work on the test, we decided to partially change our original working plan, and to focus our work on a further development of the Testing Area. In so doing, we tried to concretely experiment with some of the features of Augmented Reality that we present in Chapter 4.

At the time of this writing, the Testing Area has become something larger and more complex than the basic augmented area that we originally designed to host the test. It does still contain the 6 exercises we originally planned to use for the usability test. However, it also contains many new functionalities and features that increase the perceptive and emotional impact the Augmented Environment has on the user, making the user's immersive experience more involving and entertaining.

Chapter 5, dealing with the design of our Augmented Environment, has been considerably expanded to account for the changes and improvements we introduced to the Testing Area.

Part I: Context & state of the art

Previously, we said that the problem we want to deal with is a social problem that needs to be defined within a social context. On the other hand, a social context would be inadequate to frame the solution we propose – which is a technological solution – to that social problem. Therefore, the problem we want to deal with and the proposed solution need to be contextualized within the following backgrounds:

Augmented Reality. This is the technology we chose to develop a learning platform for older adults. Through this technology, we can "augment" and enrich the everyday world with a variety of computer-based virtual worlds. In Chapter 2, we will explore the technology of Augmented Reality and will see how this technology has the potential for reshaping our world.

Older adults in e-society. In recent years, society has been permeated by technology and technological tools and services. Traditional public and private services have been increasingly replaced by electronic services, so that social relationships, public and private activities, entertainment and, overall, any form of exchange of information, are more and more based on the use of electronic services. E-society requires its active members to have literacy on computers and digital tools. Older adults, who often do not possess such a literacy, run the risk of finding themselves pushed at the margins of e-society. In Chapter 3, we will explore the new form of exclusion older adults might suffer in e-society, and we will also see how – through learning – we might be able to help older adults to enter the digital world and e-society.

CHAPTER 2

2. Augmented Reality

2.1 Introduction

Augmented Reality is the technology we are going to use to create the Learning Augmented Environment for older adults, so it will be the key concept throughout this work. However, augmented reality is more than just a technology. By augmenting the real world with computer-based virtual worlds, augmented reality provides us with a new way of looking at the world, and we believe that it will soon become an important tool capable of helping us on many of our everyday activities.

This chapter aims at providing an introduction to augmented reality. First, we will look at one definition of augmented reality, trying to understand what augmented reality is and how it works. Then, we will present a short history of augmented reality, so to have the chance to understand how different ideas, technologies and devices from the last Century contributed to create the actual technology that we call *Augmented Reality*. We will also take a close look at the devices nowadays available on the market that, through their hardware, make possible the creation of different forms of "augmented experience". Finally, we will examine the applications for augmented reality, that is, the pieces of software running on the different devices, responsible for the generation of augmented environments.

2.2 What is Augmented Reality?

Augmented Reality (AR) is an emerging form of experience in which the real world is enhanced (or augmented) by computer-generated content. AR allows digital content to be seamlessly overlapped and combined into our perceptions of the real world in real time [6], [7], [8]. The most evolved forms of AR create a full-rounded immersive experience involving all senses, and add rich and meaningful extra-worlds to the real world [9], [8] [10].

The digital content can take the form of 2D or 3D visible objects; but it can also be in the form of sounds, music, images, videos, textual information, and, in some cases, even olfactory information. Some recent AR systems, actually leading the AR market (such as Microsoft HoloLens, Meta, or Magic Leap [11]) allow even the interaction between users and the virtual objects belonging to the augmented environments, by using, for example, eye-tracking systems identifying what the users are looking at, or systems capable of recognizing the users' voice or hand-gesture commands.

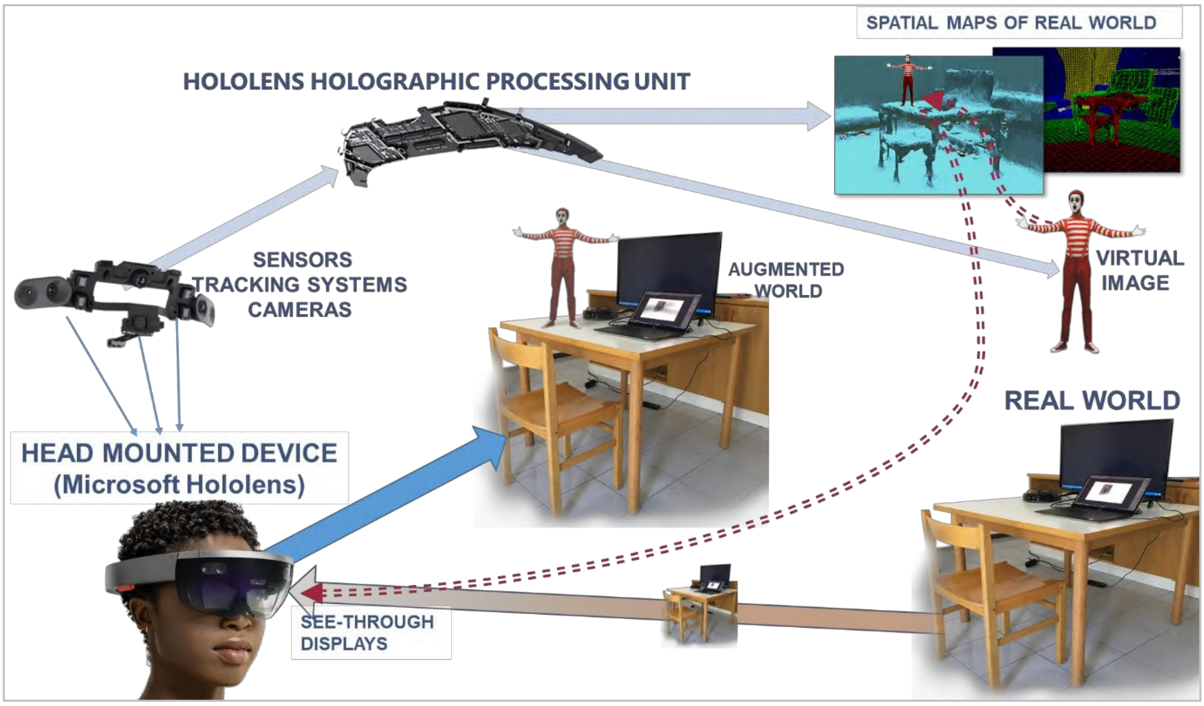


Figure 1: A conceptual diagram of an Immersive AR system

Figure 1 shows a conceptual diagram of an AR system with a head-mounted device (Microsoft HoloLens) and see-through displays (for more details on this, see 2.4, 2.5). The see-through displays allow the user to see the real world as if looking at it through a normal pair of glasses. Through several sensors and tracking systems and cameras embedded into the device (see 2.5) the device processor acquires information on the user's head, eyes and hands positions, and other information (e.g. shape and distance of objects, user's distance from walls and objects) on the real world surrounding the user. The processor uses the input data to create a 3D virtual environment exactly mapping the real world and its objects; virtual objects are then generated in real time and placed into such virtual environment and, finally, are sent to the see-through displays of the device, so that they are seamlessly integrated with the objects in the real world perceived by the user.

2.3 A Short History of Augmented Reality

When we read a text on augmented reality, we often find adjectives such as “young”, “new”, associated to it, or we might find out that augmented reality is “in its infancy”, or is “an emerging technology”. Of course, all of this is true: augmented reality *is* a new technology that just a few years ago did not exist. However, if the technology for the generation of augmented reality has become available only in recent years, the *idea* of a reality which is somehow augmented by means of some technological trick goes back to the beginning of the last century.

Here we want to show some among the most relevant moments in the history of technology that, little by little, transformed that initial idea into the concrete and well-developed technology that we now call *augmented reality*. To outline this brief history of AR, we refer to several sources: [6], [12], [13], [14], [15], [16], [17], [10], [18], [19].

The phrase “augmented reality” is generally considered to have been coined by Tom Caudell and David Mizell, back in 1990 [14]. However, the concept of Augmented Reality is much older.

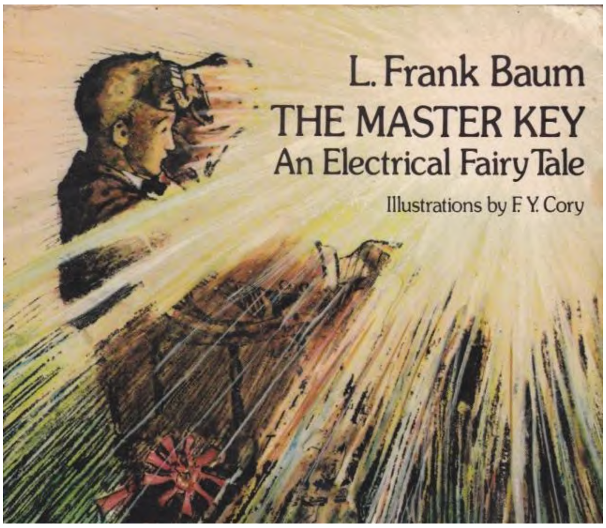


Figure 2: The Master Key, by Frank Baum

The Character Maker “consists of this pair of spectacles. While you wear them every one you meet will be marked upon the forehead with a letter indicating his or her character. The good will bear the letter 'G,' the evil the letter 'E.' ... Thus, you may determine by a single look the true natures of all those you encounter.”

In **1901,** L. Frank Baum, author of the well-known novel *The Wonderful Wizard of Oz*, in the novel he wrote, *The Master Key (see* Figure 2, and that he defined as an "electrical fairy tale”, used the term “Character Marker” to describe a set of special glasses. These glasses could project a key onto the foreheads of others. The wearer could tell from a single letter whether someone was good (G), evil (E), wise (W), foolish (F), kind (K), or cruel (C). [16] Of course, we cannot say that Baum was talking about Augmented Reality; however, the description of his Character Maker is somehow similar to the description we could provide for a device that was to be invented more than 50 years later.

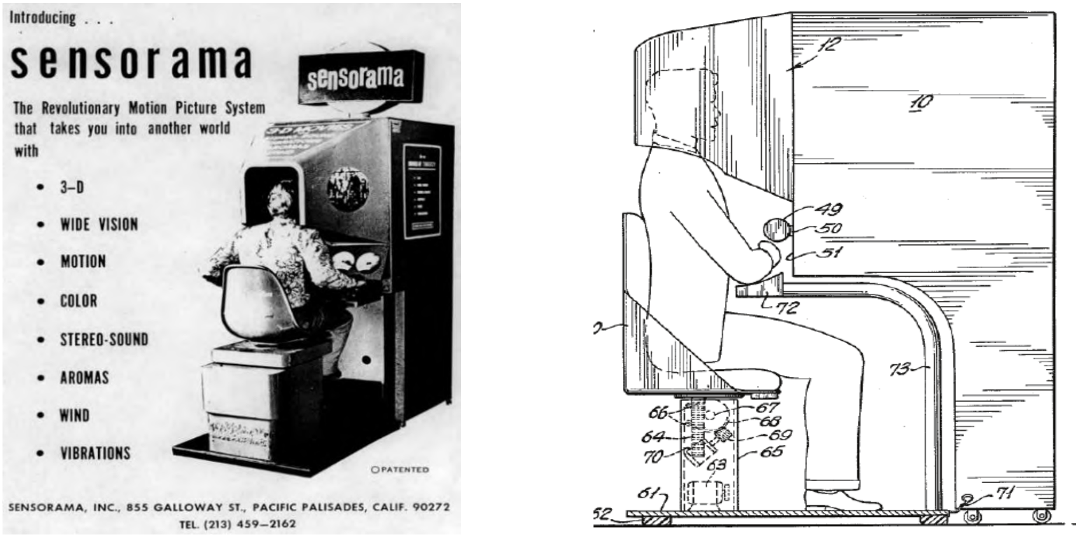


Figure 3: Morton Heilig' Sensorama Simulator

In **1955**, an idea somehow close to augmented reality appear again in a paper by Morton Heilig describing a "Sensorama Simulator" machine concept (see Figure 3). Heilig, convinced that the theater could and should be multi-sensory, in the paper proposed what he called "Experience Theater". His concept machine was not really a device for augmented reality; yet, it could provide something that not even the actual AR is able to provide: a 4D experience, inclusive of a stereoscopic experience with the addition of smells. The machine was not interactive, but it was comprehensive.

In **1962**, the machine concept became a prototype: the *Sensorama*, with sounds, user chair movement, 3D visuals, and smells (the machine was programmed to spray perfume at particular times during the projection of a film). The machine still exists and functions today, but it is still the prototype stage [16].

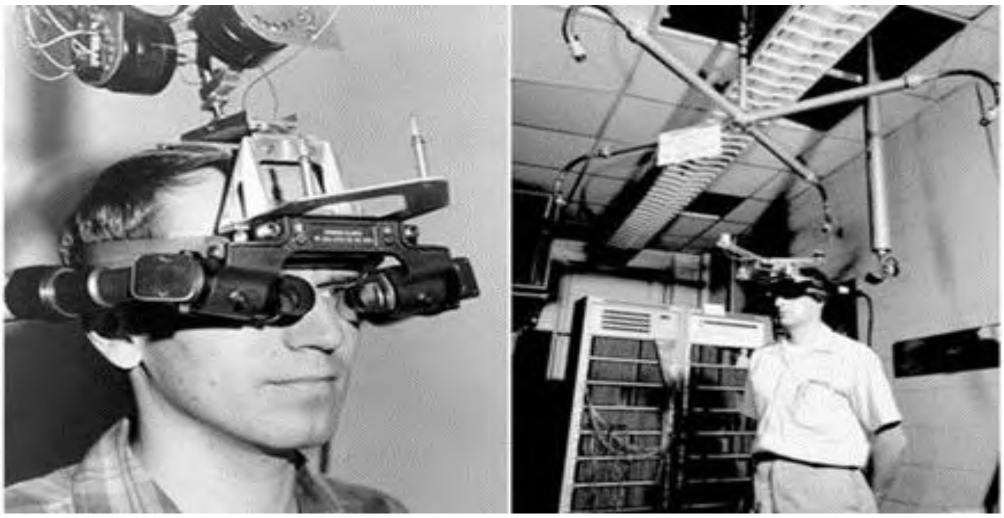


Figure 4: Sutherland Sword of Damocles - The First VR Head Mounted Display System

A few years later, in **1968**, Ivan Sutherland at the University of Utah, with the help of his student Bob Sproull, created what is considered to be the first Virtual Reality and Augmented Reality head-mounted display system [20]. The device used computer-generated graphics to show users grid-like rooms. Because of its heavy hardware, the head mounted display was suspended from the ceiling, and was also connected to the large computers of that time. The formidable appearance of the device inspired its name—the *Sword of Damocles* (see Figure 4). The system was primitive both in terms of user interface and realism, and the graphics comprising the virtual environment were simple wireframe rooms, and was not truly AR or VR. It was partially see-through, so users were immersed, but not entirely.

For this and several other inventions, many consider Sutherland the father of computer graphics [16], [18].

Figure 5: Kruger's Videoplace

In **1974**, Myron Kruger built an artificial reality laboratory called the Videoplace. Kruger's idea was to create an artificial reality by combining video cameras, that captured the users' movements and actions without forcing them to use goggles or gloves, with projectors that emitted all around the users silhouettes generated by the users' movements. The sense of presence was enough that users pulled away when their silhouettes intersected with those of other users [21] (see Figure 5).

The work done in the lab would form the basis of Kruger's well-known book Artificial Reality [22]. The Videoplace was the culmination of several iterations of artificial reality systems: GLOWFLOW, METAPLAY, and PSYCHIC SPACE; each offering improvements over the previous installation until Videoplace was a full blown artificial reality lab at the University of Connecticut and is now on permanent display at the State Museum of Natural History, also located at the University of Connecticut.

From the Seventies, up to the end of the Nineties, research on AR was mostly focused on the development of new technologies related to AR. Researchers knew that the technology developed so far was not good enough to produce real experiences of augmented reality, so the devices created in those years in most cases remained experimental devices with no concrete application in the real world. The only exception to this situation was, perhaps, the development of some very expensive and highly specialized devices for professional applications, such as maintenance and repair of complex equipment and medical visualization [12].

(a) *(b)*

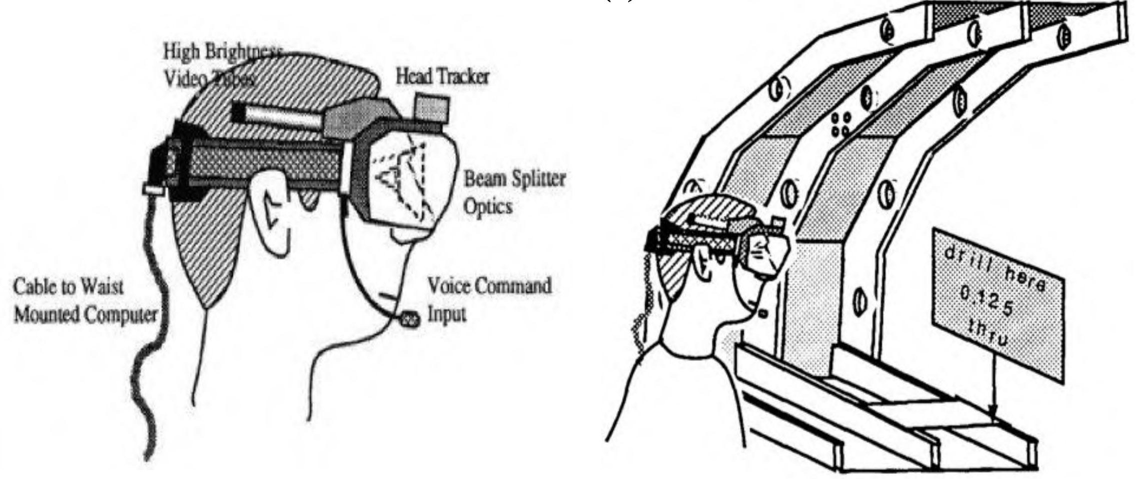


Figure 6 The HUDset created by Caudell & Mizell(a) - an application where the HUDset is used to dynamically mark the position of a drill/rivet hole inside an aircraft fuselage (b).

As we said earlier, it was **1990** when the term "augmented reality" was first coined at Boeing, by researcher Tom Caudell, and his colleague, David Mizell. They were asked to come up with an alternative to the expensive diagrams and marking devices then used to guide workers on the factory floor. Caudell and Mizell came up with a solution to replace the large plywood boards, which contained individually designed wiring instructions for each plane, with a head-mounted apparatus that would display a plane's specific schematics through high-tech eyewear and project them onto multipurpose, reusable boards. Instead of reconfiguring each plywood board manually in each step of the manufacturing process, the customized wiring instructions would essentially be worn by the worker and altered quickly and efficiently through a computer system [17].

In a paper they wrote in 1992, they describe the design and prototyping steps they have taken toward "the implementation of a heads-up, see-through, head-mounted display (*HUDset*). Combined with head position sensing and a real world registration system, this technology allows a computer-produced diagram to be superimposed and stabilized on a specific position on a real-world object." [14] (see Figure 6). *Augmented reality* came officially into existence!

Figure 7: The first AR system with virtual fixtures at US Air Force Armstrong Laboratory

In **1992** Louis Rosenburg from the USAF Armstrong's Research Lab created what was probably the first real operational augmented reality system, built for the Air Force: *Virtual Fixtures* [23]. A robotic system places information on top the workers work environment to help with efficiency. It was an incredibly complex robotic system which was designed to compensate for the lack of high-speed 3D graphics processing power in the early 90s. It enabled the overlay of sensory information on a workspace to improve human productivity. The full upper-body exoskeleton allowed the military to control virtually guided machinery to perform tasks from a remote operating space (see Figure 7). This system could be thought of as an early version of what most AR systems currently do today.

Figure 8: "Dancing in Cyberspace", by Julie Martin

In **1994** Julie Martin creates the first augmented reality Theater production, “Dancing in Cyberspace" (see), featuring acrobats who danced within and around virtual objects on their physical stage.

Figure 9: “1st & Ten” system inserts a virtual yellow linemarking the “first down” on a real football field during a live broadcast

In **1998** augmented reality is used for the first time on a tv show. Thanks to *1st & Ten,* a computer system broadcast by *Sportvision*, tv viewers of a live ESPN Sunday Night Football broadcast, could see a graphical element (a yellow line displaying the so called “first down”) on the field of play as if the graphical element were physically there (see Figure 9).

By now, we are used to seeing this kind of visual effects on tv, and we take it somehow for granted, and we do not even think that the yellow line, a computer-generated line, a virtual line, was *seamlessly overlapped and combined into our perceptions of the real world in real time*. That yellow line, not only marked for the first time a real football field with a virtual element, but also opened up the world to non-immersive augmented reality. It took a few more years to have the same effects on mobile devices.

Figure 10: The Hybrid Synthetic Vision system used in the NASA X-38 spacecraft

In **1999**, Naval researchers begin working on *Battlefield Augmented Reality System* (BARS), the robust, original model of early wearable units for soldiers.

In the same year, The NASA X-38 spacecraft is flown using a *Hybrid Synthetic Vision system* (see Figure 10) that used augmented reality to overlay map data to provide enhanced visual navigation during flight tests.

Figure 11: Remote AR Conferencing using ARToolKit

It is the year **2000** when Hirokazu Kato, working at the Hiroshima City University, creates the *ARToolKit*, an open-source software library that uses video tracking to overlay computer graphics on a video camera [24]. The ARToolKit is still used widely to compliment many augmented reality experiences.

In the following years, augmented reality technology started becoming more and more world-wide spread. It becomes then more difficult to identify specific events related to AR and that significantly changed and improved the technology of AR. We can try to mention just a few.

In **2009,** augmented reality enters for the first time in the world of print media. *Esquire Magazine* prompts readers to scan the cover to make Robert Downey Jr. come alive on the page. Again, in **2009**, *ARToolkit* brings augmented reality to web browsers. In **2013** AR manufacturers begin to use augmented reality as the new age vehicle service manuals. The Volkswagen *MARTA* app (Mobile Augmented Reality Technical Assistance) provides virtual step-by-step repair assistance, allowing service technicians to foresee how a repair process will look on the vehicle in front of them. **2014** is the year of *Google Glass*. Google Glass displayed information in a smartphone-like, hands-free format. Wearers communicated with the Internet via natural language voice commands. With the announce of the shipment of Google Glass devices for consumers in 2014, Google started the trend of *wearable AR*. Strangely enough, Google Glass did not become as popular and trendy as Google expected. Moreover, the headset received many critics, especially on the fact that the use of the device could violate existing privacy laws. Maybe it was not yet the right time for mass augmented reality.

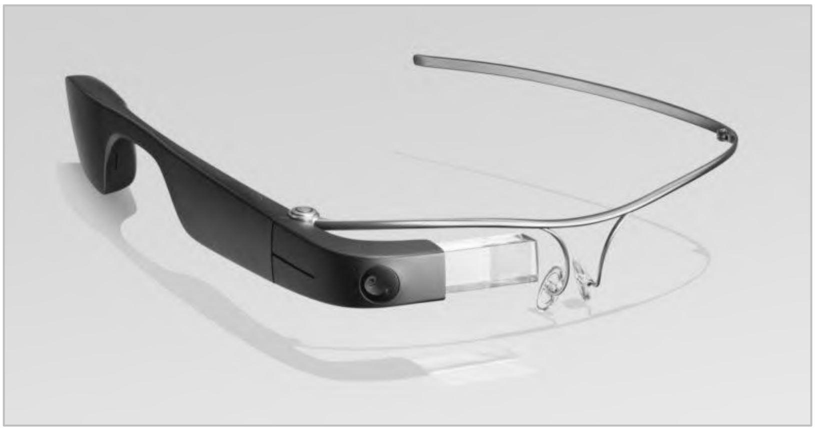


Figure 12: Google Glass

Ever since, many applications for mobile were created that somehow display the same functions Google Glass had. Moreover, the computational power of mobile phones allows now applications to create rich augmented worlds that Google Glass could only dream about. However, Google Glass had a feature that mobile phones cannot yet reproduce: *immersivity*. Of course, it was a simple, and even partial form of immersivity (with only one eye, so no 3D), mostly with texts and simple graphics that the user perceived as overlapped onto the real world; yet, it pointed the attention toward the most complete form of augmented reality: the immersive augmented reality.

Indeed, *immersivity* is the secret of the head-mounted device *Microsoft HoloLens*. In **2016** Microsoft HoloLens ships the HoloLens, and the HoloLens becomes the first commercial device for *Immersive Augmented Reality* available on the market (see section 2.5.2 for more details on the HoloLens).

Soon after, many new devices, both HMD and Smart Glasses (Google-Glass-like), were introduced in the market: Magic Leap One, Meta 2, Daqri Smart Helmet, Focals by North, Google Glass Edition 2, Epson Moverio BT-350, Data Sheet vuzix M400, just to name a few. The second version of the HoloLens, *HoloLens 2*, was introduced in the market in the beginning of 2019. Even Apple is working on its own Apple Glasses, and according to rumors, Apple is planning to release a mixed AR/VR headset in 2022. And many others to come. No matter what device we mention, we will forget for sure to mention the name of new, better devices that are just out in the market and we did not know about.

In 2008, Gartner, Inc., one leading IT research and advisory firm, in its annual report *Emerging Trends and Technologies Roadshow* [25], predicted that, for the 2008 to 2012 period, AR would be one of the top 10 disruptive technologies that is, a technology that will cause major change in 'the accepted way of doing things'. In 2011 and again in 2012, the New Media Consortium, an international community of experts in emerging technologies which promise to have a significant impact on various sectors around the globe, in their annual *Horizon Reports* [26] predicted that AR would have seen widespread use even on US college campuses within the next 2 to 3 years.

Today, maybe AR has not a widespread use on U.S. campuses yet, however it keeps growing tremendously at a rapid pace, and it is impossible to keep up with all the different technologies, devices and applications for AR. The recent advances in augmented reality and the growth in investments in the field give evidence that AR could soon be the next big commercial service. In 2014, Augmented reality and Virtual reality investments reached $700 Million; in 2016 the investments for Augmented Reality reached $1.1 billion. And they are continuously growing. And we are not only talking about non-immersive AR (that is, for mobile); the Head-Mounted Display (for AR and VR) market is expected to grow from $4.8 billion in 2017 to $25 billion in 2022. This is due to the increasing adoption of HMD (in this case, especially for VR) in consumer and entertaining applications and smart glasses (therefore, for AR) in enterprise and industry applications. Moreover, the market for HMD is expected to grow at a highest rate, up to the point that AR HMDs or smart glasses (and their applications) are expected to drive the market in the near future.[27].

Today, AR is no longer an "emerging" technology, and even though it cannot yet be considered a flawless technology (researcher need to work on a few problems such as precise tracking, higher-resolution displays, new interfaces, semantic understanding of real-world objects before AR can be considered a flawless technology) [12],[28], [29], it's not difficult to think that in a few years it will become a powerful and familiar tool in everyday life.

2.4 Devices for Augmented Reality

Nowadays, anything that overlays any kind of information related to what we are seeing over our view is considered augmented reality. However, depending on the device we use to deliver augmented reality experiences, we have different forms of augmented reality. The most common devices used to deliver AR content are *mobile devices* and *wearable devices* [15], [30], [31], [28].

(1) *mobile devices*: through AR applications, mobile devices provide augmented experience by showing on the main device display the virtual contents mixed with the portion of real

world captured by the device camera. In so doing, mobile devices produce a 2D, non-immersive, interactive form of Augmented Reality. It is important to notice that, besides the typical technology nowadays present in almost every mobile device, no additional technology is required to have such non-immersive AR experience. And this makes of mobile AR the easiest, cheapest and most popular form of augmented reality.

(2) *wearable devices*: Users mount this type of devices on their head, with the device see-through displays in front of their eyes [8], [32]. The virtual contents are projected on the displays, so to superimpose them onto some portions of the real world perceived by the user directly through the see-through displays. In this case, the wearable devices allow full 3D, interactive and immersive form of Augmented Reality (see Figure 1).

Many AR wearable devices (e.g. AR headsets, also called *Head-Mounted Displays* (HMDs), connected glasses, smart glasses, smart eyewears, contact lenses) are actually available on the market [33], [15], [30], [31] and many new ones are created almost monthly. Figure 13 shows some of these devices. AR HMDs ((a) and (b) in Figure 13), thanks to their shapes and dimensions, in some cases are standalone devices, such as Microsoft HoloLens, so that they can host a processor integrated in their hardware. Some other HMDs, like the Meta AR device, are wired (tethered) to an external computer. In both cases, their computational power is such to allow the creation of complex, 3D, immersive and interactive augmented environments. However, non-tethered devices such as the HoloLens, allow the user to move around freely, while the tethered device forces the user to stay close to the computer that processes the information displayed by the device.

Figure 13: Wearable devices: (a) Daqri Smart Helmet - (b) Microsoft HoloLens - (c) different types of smart glasses.

There are also some other cheaper, lighter and smaller, and usually less powerful devices, such as *smart glasses* ((c) in Figure 13), that make use of integrated micro-processors. Due to their limited computational power, smart glasses are primarily designed for micro-interactions, like reading text messages or getting textual information from the real-world objects surrounding the user, but are still far from being able to manage the well-rounded applications for augmented reality delivered by HMDs. Google Glass, that we mentioned in the previous section, are smart glasses.

When we started this project, Microsoft HoloLens (Figure 13-b) was the only wearable device for augmented reality available on the market. Therefore, the whole project was developed to produce an immersive augmented experience that could be delivered through the HoloLens.

2.5 The Technology for Augmented Reality - *HoloLens*

We will not go into the details of the technology that enables AR in Head-Mounted Displays. As we will see in later chapters, our work mostly focuses on the products of the AR technology, that is, on the Augmented Environments that are generated by apps running on HMDs and, particularly, on the *Microsoft HoloLens*.

In Chapter 6 we will see that *Unity* –the game engine we use to develop a particular Augmented Environment – through a collection of scripts and components specially created for the development of holographic applications, is capable of managing all the HoloLens components necessary to produce an augmented experience. Therefore, in our work we will never directly deal with these components, at least from a technical point of view.

Figure 14: The HoloLens components

So, here we limit ourselves to list only the main hardware components of the HoloLens that we will sometimes refer to in this work [34], [35], [36]:

- The **HoloLens processors:** they are capable of generating realistic, rapidly changing, three-dimensional holographic images in the see-trough displays. These processors require a lot of processing power; to handle the load, the HoloLens has three different processors: a central processing unit (CPU), a graphics processing unit (GPU), and a holographic processing unit (HPU). Processing tasks are divided up among the three, and the result is combined to give the user an integrated, high-fidelity experience.
- The **cameras**: The HoloLens includes *five visible-wavelength cameras*, one looking straight ahead, two on the left and two on the right. These cameras track the user's head movements with respect to her surroundings. The camera looking straight ahead can also take either videos or still images. In addition, there is an *infrared camera* facing straight ahead and an *infrared laser projector* facing the same way. The laser is used to scan objects, which reflect the infrared light back to the infrared camera. This provides a laser-ranging capability that enables the HoloLens to map the distance to everything in the room. A quick 360-degree pirouette will map out a room and everything in it. That map gets refined as the user moves around and interacts with the environment.
- The **Inertial Measurement Unit (IMU):** includes an accelerometer, a gyroscope, and a magnetometer. These sensors, along with head-tracking cameras, track where the user's head is and how it is moving. This information is integrated with what the HoloLens knows about the space the user is moving through to render the virtual objects in the see-through displays from the right perspective, with the right sizing, and at the right apparent distance from you.
- The **microphone**: The HoloLens includes a microphone, so that the user can provide input to the running app with voice commands. As an example, a user can navigate throughout an Augmented Environment by using voice commands.
- **Speakers:** through small, unobtrusive speakers next to the user's ears, the HoloLens makes is possible to *spatialize* sounds (noise, voices, music), so that the user can perceive the sounds as if they were coming from the different holograms that are in the augmented environment.
- The **lenses** (also called **see-through displays**): The lenses of the HoloLens are transparent so the user can see right through them. However, they also contain an array of very fine, invisible grooves that direct the virtual images generated by the app into the user's eyes, making it appear that virtual objects are at various positions and distances in the room. The virtual objects can appear solid or semi-transparent, with background (real) objects showing though from behind them.

2.6 Augmented Reality Applications

As we have seen in 2.3 and 2.4, the AR market is now in turmoil, and AR applications are innumerable. If we visit the Apple Store or the Google Play Store, we see that for (almost) any need we can think of, we can find an AR app that fulfils it. So, considering the purpose of our work, it seems a useless effort even to mention a few of these AR apps for mobile.

It suffices to say that, when we speak about AR applications, we must make a clear distinction between *applications for mobile devices* and *applications for wearable (or head-mounted) devices.*

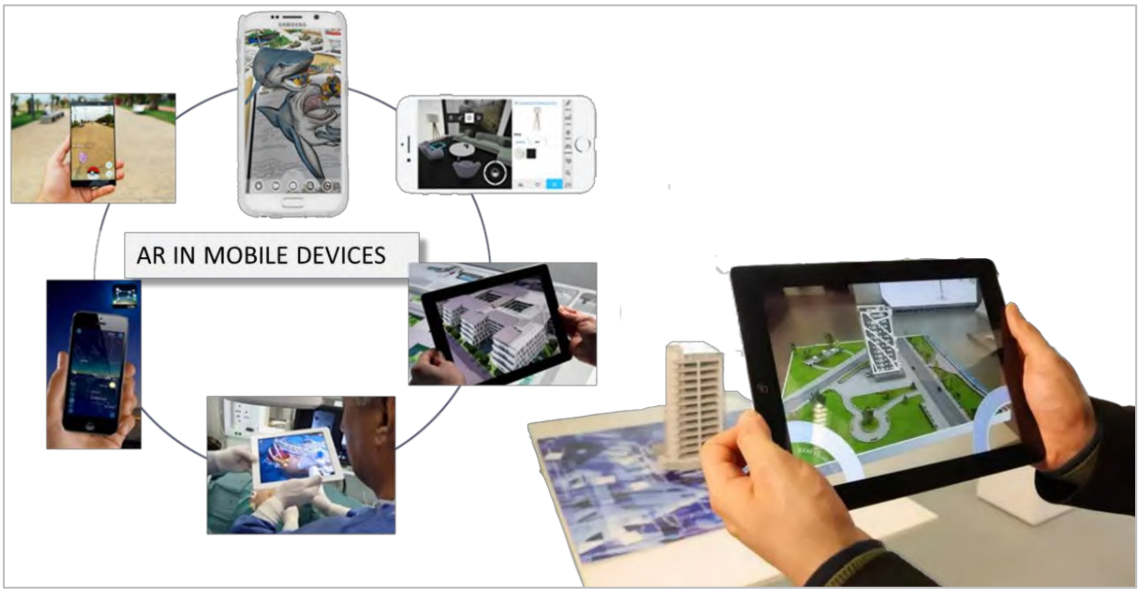


Figure 15: Augmented Reality in mobile devices

We saw in Section 2.5 that the substantial difference between the two types of devices is in their ability to generate 2D, non-immersive AR (mobile) or 3D, immersive AR (wearable). But there is also another important difference between the two forms of Augmented Reality produced by the two types of device, a difference that might be not so evident at a first look: it’s in the kind of augmented environments these devices can create. The augmented environments created by mobile AR applications (with the exception of a few of them) don’t really take into account the “real world” captured by the device camera and sent to the device display. They don't even need to know that the real world is there, around the user. For such augmented environments to work it is only necessary that the user places in the real world some *markers* (images, drawings, objects) that the app is able to recognize. Every time the app “sees” one marker through the device camera, it adds up a hologram on top of the marker, or next to it. And that is enough. The augmented environment created by the app is up and running (see Figure 16). The marker is the only thing the augmented environment really needs to know.

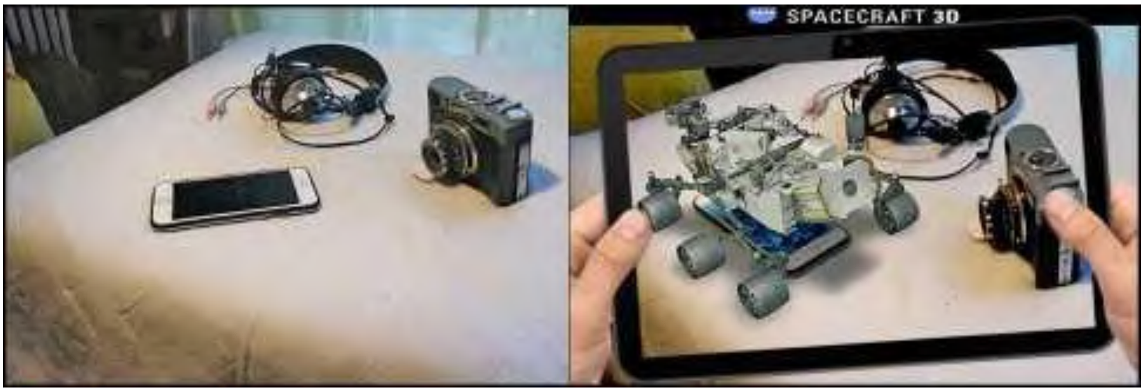


Figure 16:NASA AR Spacecraft-3D mobile app adds a virtual 3D model of Curiosity spacecraft to a real-world environment. In this case, the mobile phone we see in the left picture works as a marker. The app recognizes the marker and adds to the image of the real world, acquired by the device camera, a virtual model of the Spacecraft on top of the mobile phone.

When we deal with apps created for head-mounted displays, it is a completely different story. Even in this case, we can have an immersive augmented environment showing particular holograms when the device "sees" particular markers scattered around the real environment surrounding the user. However, the immersive augmented environments usually work in a very different and much more complex way.

In Figure 1 we saw that, before generating a whatsoever augmented environment, a head-mounted device uses its many sensors and cameras (see 2.6) to scan the real environment surrounding the user, and then creates some maps of the real world, and in so doing "recognizes" the real world and the real objects therein contained. After the scanning, the virtual objects (the holograms) belonging to the *augmented world*, in a way "know" where the real world is, and also "know" their place in the real world. And because of this knowledge they have about the world, they can always re-arrange their position, features and behaviors according to the changing position of the user.

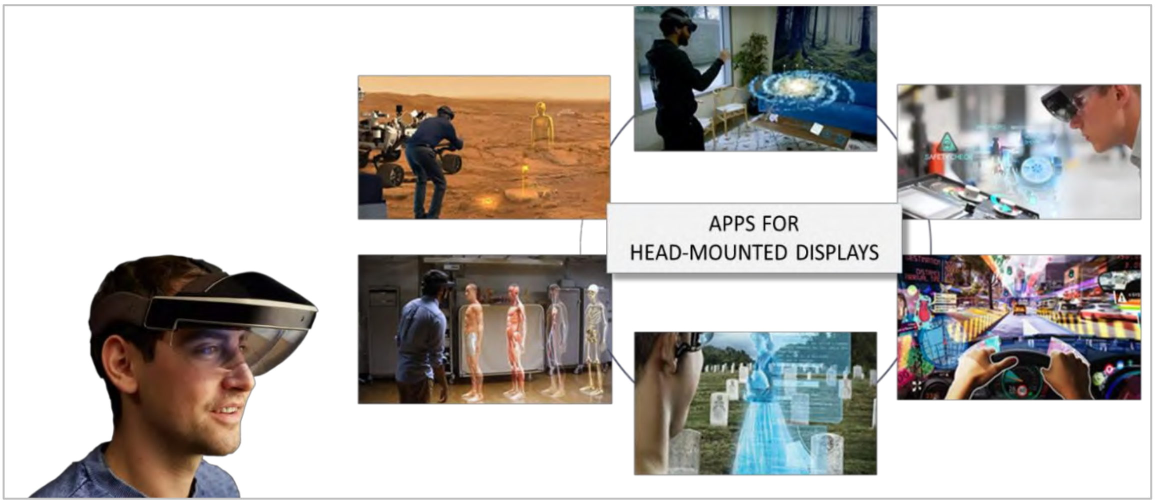


Figure 17: Augmented Reality in head-mounted devices

Since applications for head-mounted devices are more difficult to develop (and are much more expensive than AR apps for mobile), and since the head-mounted devices actually available on the market are quite expensive (just to give a couple of examples, the HoloLens 1 is about $3.000, and Magic Leap is around $2.300), the Immersive Augmented Reality is not yet a technology for consumers; at the moment, it is studied, adopted and used almost only by business companies or research centers. However, as more models of HMDs will soon become available, and their prices will decrease, also applications for HMDs will become more affordable and popular [27].

We already find many professional apps for AR HMDs [6], [12], [37], [32], especially in high-tech fields such as medicine [38], robotics [39], industry automotive [40], architecture [41], advertising and marketing, visual arts [42], [43], [44] [45], [46].

As for AR applications for HMDs in the field of Education – the field we are interested in – the research is just in its infancy, and it is difficult to find applications devoted to explore educational settings. It is true that several "educational" applications for immersive AR are already available. However, as far as we could understand, many of those apps deal with "the teaching of specific, tangible, skill sets" [10]: how to assemble and repair a specific machine or device, how to accomplish certain particular tasks, how to use a particular piece of equipment.

From our perspective, such applications are more AR "translations" of (often very technical) manuals or handbooks than educational apps. What we have in mind when we talk about AR educational applications are apps capable of generating learning systems in AR, AR *platforms* enabling the learning – in augmented environments – of different kinds of contents.

It is difficult to find such applications. We could not find any. Maybe, this is due to the fact that, for several years, e-learning seemed mostly focused on the Web and the online courses for distant education. We believe, however, that in the near future, augmented learning will be able to take education away from the Web and move it into a new reality which will be enriched by augmented reality[37], [47], [48], [49], [50] (see also 3.6.2).

2.7 Conclusions

In this chapter we introduced Augmented Reality as the core concept in our project. We will use what we learned in this chapter about Augmented Reality as a background knowledge to better understand the context within which we are going to design and develop our learning platform in Augmented Reality.

In this chapter we saw that if we think of Augmented Reality as a concept, we can find traces of its existence back in the beginning of the 20th century. However, if we think of Augmented Reality as a technology, then we can only go a few years back. Devices capable of producing primitive forms of Augmented Reality have been created since the Sixties, but it is only in the last few years that we find on the market working devices capable of delivering Augmented Reality. In a few years, the technology for AR has made great strides; it is not perfect yet, but it is good enough to provide us with believable forms of "augmentation of reality".

Soon, chances are that we will not be able to distinguish the real from the virtual, and real and virtual will really be “seamlessly overlapped and combined into our perceptions of the real world in real time”, as declared by the very definition of AR. At that point, reality will be augmented in many different ways to satisfy many different purposes and needs.

We believe that Augmented reality is really going to change the world, by changing the way people will see the world, or the way they will work, or buy products on-line, or look for new forms of art and entertainment. Or the way people will learn.

Indeed, it is exactly learning, and learning through augmented reality, the topic we want to introduce in the next chapter.

CHAPTER 3

3. A Learning Augmented Environment for Older Adults

3.1 Introduction

Older adults must deal with many problems due to ageing: their physical and mental conditions tend to deteriorate and they find it difficult to cope with many situations that in younger age they could easily control. Nowadays, Information and Communication Technologies (ICTs) can help older adults in many ways to slow down the effects of ageing and preserve their psycho-physical conditions for a longer time. However, ICTs also contribute to create new social problems in older adults, especially social exclusion and loneliness. In a world more and more shaped by technology and digital communication, social relationships, public and private activities and services, entertainment and, overall, any form of exchange of information, will increasingly be based on the use of technology. So, older adults without literacy on computers and digital tools will find it progressively more difficult to maintain their social relations and activities, and feel that they are active citizens of the technological society.

In order to avoid this new form of social exclusion, the research has to find ways to provide older adults with knowledge on the use of computer and, more in general, on digital tools. Through our research project, we present our work on the design and development of an innovative form of e-learning, specifically designed for older adults, that could provide a contribution in solving the outlined problem of social exclusion.

If in the previous Chapter we defined the technology we will use to develop the learning environment for older adults, in this Chapter we focus our attention on the social context framing the problem we want to solve through our learning environment.

3.2 Older Adults and Active Ageing

Researches and Governmental Institutions agree on the fact that, all over the world, there is a significant increase in lifespan, and the number of people who are 65 or older is constantly growing. This phenomenon is becoming so evident, and has so many economic and social consequences, that can no longer be neglect [51]. With age, many physical, and mental problems arise. According to the World Health Organization (WHO) [52], health problems in old age may be a consequence of factors such as poor nutrition, physical inactivity and bad habits, which may lead to several chronic diseases. However, these bad health conditions might also be caused by social problems [53], especially loneliness, social isolation, and social exclusion [54].

Social isolation is not uncommon among older adults, and is often caused by impaired physical functioning, which might limit the older adults' ability to move and prevent them from having social interactions. So, older adults must rely on their social networks (family, friends) [55]. Such networks provide assistance and, at the same time, prevent from social isolation. However, nowadays, older adults' social networks tend to shrink and lose their supportive role. Furthermore, social services - such as residential care - provide no practical support, if compared with the one that peers and relatives provide [56]. As a consequence, older adults easily feel lonely and socially isolated or excluded. And this feeling of loneliness is dangerous, as it might trigger many severe physiological and mental issues [57]. The existence of so many health problems in older population will have an important impact on the societies of the near future. The increasing longevity, without an adequate increment of older adults' health conditions, will lead to a greater demand in health services, and consequently to higher costs for public institutions. Therefore, researches and policy makers have urged the development of specific strategies for the wellbeing of older adults [55], [58], [59], [60], [61].

The idea behind this view is "Active Ageing", which has been defined the first time in 2002 by the WHO [62]. Active Ageing refers to "the process of optimizing opportunities for health, participation and security, in order to enhance quality of life and wellbeing as people age" [51]. The European Commission has presented an agenda that proposes specific norms for active ageing [51]. At the same time, researchers have tried to identify the needs of older adults, and to find the ways to best help them, so to make their lives healthier, more active, enjoyable and independent. Within the active ageing context, there is one topic-area relevant for our research: learning, and particularly, learning of Information and Communication Technologies.

3.3 E-services and E-society

According to a recent report commissioned by eBay [63], in 2014 more than 90% of U.S. small and medium-sized businesses used eBay platform to export goods internationally. In 2009, only 10% were exporting. This means that eBay, by using the Internet, has enabled businesses to become really global traders. And eBay is not the only provider offering such services. Large e-service providers such as Google, Amazon, Alibaba and others enable small and medium-sized businesses to use their platforms to promote their business. In so doing, these big providers not only become able to sell any sort of product or service to an increasing number of customers everywhere in the world, but also boost the shift of traditional business toward electronic business. So, business companies, even those that do not want to join large service providers, trying to remain competitive, are somehow forced to move their business on-line.

Of course, U.S. is not the only country to move business services on-line. In many developed countries, the trend is the same: business companies, no matter where their base-country is, use the Internet to operate globally. And their services are cheaper, faster, and more reliable than old, regular, off-line services [64]. And non-business and public services undergo the same change as well: public services progressively become e-services. E-services offer national governments the promise of increased convenience, lower transacting costs, increased consumer choices, enhanced efficiency and effectiveness of the services being delivered to all citizens, and greater accessibility by eliminating space and time constraints [64]. So, Governments from the various developed countries are gearing up to transform traditional services into on-line services: government services become e-government services, healthcare services become e-health services, and so on. The progressive conversion of services into e-services marks the transition of our society into e-society. In an e-society, social relationships, public and private activities, entertainment and, overall, any form of exchange of information, will increasingly be based on the use of electronic services.

3.4 Older Adults in E-society

The transformation of society into e-society has many evident economic and social benefits. However, the pervasiveness of e-services in e-society also raises a fundamental issue: e-services, in order to be used, need literacy on computers and digital tools. So, people lacking such forms of literacy will find it increasingly more difficult to use all the public and private e-services available to e-society members, and will be excluded from any form of e-social interaction. In short, they will be excluded from e-society.

Clearly, those most at risk of ending up excluded from e-society are, again, those older adults who did not have many opportunities to learn new technologies during their working life. Once they are retired, they find it even more difficult to acquire literacy on computers and digital tools, and so they find themselves unable to cope with e-society. It is true that the portion of older adults using ICTs is increasing; for example, the Italian Institute of Statistics (ISTAT) [65] states that in Italy, in recent years, the number of older adults using the computer and the Internet tripled. But it is still low if compared with the number of younger adults using the computer and the digital tools [66].

Earlier, we saw that social exclusion and loneliness were two major sources of mental and physical problems in older adults. Now, we see that the same society that urges to find technological solutions to the problem of social exclusion in older adults, also creates, because of technology, a new possible form of social exclusion. Without literacy on computers and digital tools, older adults will find it difficult, to use technologies to maintain their mental life active. Moreover, they will find progressively harder to "feel connected with the world" and to maintain their social relations in a world that is more and more permeated by technology. So, as we already said, it becomes important to address this problem within the active aging context; it becomes important to look for new strategies for making knowledge on the use of computers and digital tools more accessible to older adults, so to reconnect them with the world.

3.5 Older Adults and Learning

Despite the common opinion, older adults are still capable to learn [67]. Various studies [68], [69], [70], [71] show that older adults learning can deliver many social, mental and physical benefits: not only can learning decrease older adults sense of isolation and loneliness, and enhance their personal and community wellbeing, but it can also can reduce their dependency on government-funded social services. Certainly, the learning interests of older adults differ from those of younger adults. Older adults are mainly interested in learning solutions to practical problems of real-life contexts [72]. Of course, there are biological changes that lead to memory decreases as people age [73]. Nonetheless, in order to learn new information, older adults usually cope with their memory loss by relating new information to previous knowledge or to their personal experience [74].

Learning, in general, can provide older adults with many social, mental and physical benefits. If we now take into account what we just said on older adults and e-society, we can easily see that learning focused on ICTs can have on older adults even more beneficial effects. As some studies suggest [75], [76], knowledge on ICTs makes older adults feel connected again with the world, integrated again in society, and part of the “human race”.

3.6 E-learning and Augmented Learning

“E-learning is a combination of methods, structures and networked electronic tools orchestrated into systems that bring about, or are intended to bring about, learning” [47]. Overall, e-learning studies can be focused on three principal research areas [48]:

(a) users, interacting with e-learning systems;

(b) technologies, enabling the direct or indirect interaction of the different groups of users;

(c) learning theories and pedagogical practices.

In the literature, we find four learning theories considered the major and most influential pedagogical approaches on learning: Behaviorism and Cognitivism, both developed during the first half of the 20th century, and Constructivism and the On-line Collaborative Learning theory, developed in more recent years, and perhaps more capable of accounting for the emergence of technology in everyday life [47], [49], [77], [78]. Of course, the above theories on learning are not the only ones available. In recent years, as on-line learning and technology-based teaching have evolved, many new theories of learning are emerging [48], [50]. Given the range of learning and teaching styles, the potential ways technology can be implemented, and the ways in which educational technology itself is constantly changing, no single theory seems capable of accounting for all possible e-learning experiences. So, it is reasonable to think that different theories will continue to co-exist, and they will be used to satisfy the different needs of different people, using different technologies in different learning contexts.

3.6.1 Forms of E-learning

Here, we consider some varieties of e-learning [79]:

(a) *standalone courses:* self-paced courses taken by a solo learner;

(b) *learning games and simulations:* learning by performing simulated activities that require exploration and lead to discoveries;

(c) m*obile learning:* learning from the world while moving about in the world;

(d) *social learning:* learning through interaction with a community of experts and fellow learners;

(e) *virtual-classroom courses:* on-line classes structured much like a classroom course, with reading assignments, presentations, discussions via forums, synchronous on-line meetings, and other social media, and homework.

3.6.2 Augmented Learning

There is one more form of e-learning: A*ugmented Learning* (AL), a form of standalone learning within Augmented Environments which provides users with 3-D, interactive, and, in some cases, immersive learning experiences [80]. Researchers started years ago to investigate the potential of AR in educational settings [50],[81] [82]. Many argue that fully working AL environments deployed as AR applications could really contribute to change, enrich, and improve the learning experience in many ways: by facilitating the learning of visual contents; or by encouraging the process of "learning-by-doing"; or by increasing the user’s involvement in the process of learning; or by encouraging collaboration and social interaction; or by connecting the user's personal experience to the contents to be learned [83], [6], [84], [85], [86], [87], [88], [89], [90].The state of current research in AR for education can be still considered in its infancy [50] but, finally, AR is a mature technology, already available on the market. So, researcher can really start thinking about AR applications for education.

3.7 Conclusions: Augmented Learning for Older Adults

It is now the moment to sum up what we collected in the two chapters we examined so far:

(a) We realized that older adults in e-society must deal with a problem of social exclusion due to their computer and digital illiteracy;

(b) We also found out that older adults are willing to learn new things even at an advanced age, and that learning can provide older adults with many social, mental and physical benefits.

(c) Finally, we saw that there is a new technology called augmented reality, which makes it possible to create – among other things – also standalone e-learning courses on different topics, including the use of computers and digital tools.

So, it should now become clear why we think that our innovative form of e-learning, specifically designed for older adults, might provide a contribution in solving the problem of social exclusion they are forced to face. The Learning Environment we have developed is capable of delivering learning modules on a variety of topics. Each learning module is meant to provide the user with learning content on a selected topic; the content is delivered via many different media (e.g. audio, video, texts, images). Moreover, the Learning Environment hosts a virtual guide/assistant capable of interacting with the user, so to help her on orientation and navigation throughout the LE, or on how to use the interfaces and the learning modules. Overall, through our learning system in augmented reality, older adults can easily learn concepts, ideas, the use of technologies and devices that are necessary to become active members of e-society.

We are aware of a possible objection to what we just said: since there are already many on-line courses and e-learning platforms that can help older adults to acquire the literacy on computers and digital tools they need to enter e-society, why do we need to develop a new form of e-learning such as the one described above?

We can think of different answers to this objection. First of all, these existing courses and platforms are usually not tailored for older adults [67], [91], [92], and often lack of specific accessibility requirements necessary to support physical and/or mental impediments, thus resulting not really compatible with older adults' conditions. Moreover, we should also take into account the fact that the few courses available for older adults are more focused on the condition of being old, rather than on technological topics [92]. And there is one more problem with on-line courses: the access to whatever on-line content, including courses on the use of computers and digital tools, requires at least a basic knowledge of ICTs; so, older people with no literacy on computer and digital tools cannot even reach the courses they would need to acquire the literacy on computers and digital tools.

The learning environment we designed should overcome these obstacles. Indeed, contrarily to what happens with on-line courses, the user of our Learning Environment does not need to have any kind of technological knowledge in order to use the LE. Once the user has the HMD on place, he is guided by the virtual assistant in all the activities possible within the LE, including the use of the learning modules on ICTs and e-services. So, after a first training session, necessary to get familiar with the LE, the user should be able to focus on the learning contents, while enjoying a fully immersive learning experience (on this, see Chapter 7).

Part II: Contributions

We believe that through this thesis, and particularly in the following Chapters, we provided several contributions to different research areas related to Augmented Reality.

General knowledge on Augmented Reality

The semiotic approach to augmented reality, presented in Chapter 4, is a significant and innovative alternative to the more wide-spread technological approach. While the technological approach allows engineers and technicians to develop the technological components of augmented reality, does not seem very effective for analyzing and designing the forms of communication (the augmented environments) produced with augmented reality. On the contrary, the semiotic approach here proposed favors the analysis of Augmented Environments and their components, and helps analysts, designers, humanists, and, in general, non-technical people, to get a good understanding of what augmented reality is.

Design of Augmented Environments

Chapter 5 discusses the design of the Learning Augmented Environment, while Chapter 6 focuses on the development of a prototype of the Learning Augmented Environment based on the design defined in Chapter 5.

During the design of the Learning Augmented Environment, we followed the well-known software engineering practice of "separation of concerns" [3], and we thrived to keep as separate as possible the *design of the Augmented Environment* from the *design of the contents*. This has allowed us, during the design of the Augmented Environment, to freely explore all the features and possibilities offered by augmented reality, without any constriction or limitation imposed on the design by the learning contents, or by the features of real users of the Learning Augmented Environment.

As a consequence, we have been able to create a complex, very flexible and powerful virtual object – we called it the *Virtual Room* – displaying the most important features of augmented environments (see Chapter 5, and particularly Section 5.2.3). The Whole Augmented Environment has been built around the Virtual Room, and we consider the Virtual Room as our major contribution not only to the design of our Augmented Environment, but also to the design of augmented environments in general. Indeed, we believe that with the creation of the Virtual Room we set a first step toward the definition of a Content Management System (CMS) for Augmented Reality similar to the CMSs, very popular nowadays, used for the creation of websites.

Evaluation of Usability in Augmented Environments

We said that Augmented Environments are very complex and new forms of communication produced by Augmented Reality. Since many of the features and properties of such augmented environments are unique, if we want to evaluate the usability of such augmented environments, we cannot easily apply the existing methodologies for the evaluation of the usability of forms of communication produced with other media. Therefore, we modified one existing methodology (Usability inspection) that we believed most useful to our purpose, so to be able to account for the existence of augmented environments and to evaluate their usability. Moreover, we designed a test (and developed a Testing Area) that uses such methodology to evaluate the usability of our Augmented Environment and to detect its possible usability problems. Considering that the evaluation of the usability of augmented environments is a research area largely unexplored, we believe that with the design and development of the Testing Area we provided an important contribution to the field.

E-learning and Education

It is already possible to find on the market applications that are considered “educational”. However, they refer to a very narrow definition of education. Most of them facilitate the acquisition of specific skills within a limited domain of knowledge (how to assemble or repair or use a particular device or machine), but do not deal with the process of facilitating learning in a more general meaning. We consider these apps as sophisticated "technological translations" of manuals or handbooks. With our Learning Augmented Environment, we propose something new and different, and in so doing we provide a significant contribution to the research on e-learning. Our Learning Augmented Environment is meant to be a system for learning in augmented reality. It is a flexible container of learning contents. Its contents can be easily modified to satisfy the needs of different target users. Its contents can be completely changed, while the general system for delivering those contents stays the same. So, we believe that we can consider the app we have designed and developed (and, of course, the Augmented Environment generated by the app) a real educational application.

CHAPTER 4

4. A Semiotic Framework for The Analysis of Augmented Environments

4.1 Introduction

4.1.1 GOALS

In the previous chapters, and particularly in Chapter 2, we proposed a general introduction to Augmented Reality: what AR is, how it works, what its applications are, what it can be used for. In this chapter, we intend to use semiotics of media to systematize and deepen the knowledge related to Augmented Reality, especially with regard to the objects developed using AR technology, that is, the applications that, once deployed in Head-Mounted Devices, are capable of generating immersive Augmented Environments.

This approach to AR is meant to be an alternative to another approach, certainly more common and widespread, that deals with AR from a technological point of view. Such technological approach often uses a technical language to describe AR that is not easily comprehensible by those people who are interested in AR but don't have a technological background.

We believe that the discourse on AR cannot be limited to explaining how the technology makes it possible to technically create immersive AEs. And this is especially true when, like in our case, we want to *design* an augmented environment before developing it. Designing AEs and developing them by using a certain technology or certain pieces of software are two very different activities (see, for example, [93]), that require different skills and different ways of looking at AR, and, therefore, that also require different professionals working together in collaboration.

Unfortunately, we must say that the prevalence of the technical approach to AR does not favor those opportunities for collaboration. So, with this work we want to show that even a non-technical approach to AR is possible, hoping also to foster the dialogue between technologists and non-technologists.

Already in 2001, MacIntyre et al. wrote: "AR techniques will not move beyond specialized application areas, such as equipment maintenance, into areas of interest, such as entertainment and education, until we develop [the theories to understand how to design AR experiences] and the corresponding tools, and that the best way to develop these theories and tools is through tight collaboration between technologists and New Media theorists" [94, p. 197].

Our recent experience in designing and developing an augmented e-learning environment (see Chapter 5 and Chapter 6) can only confirm the continuation of the situation described almost twenty years ago by MacIntyre et al.. Unfortunately, at least as far as AR is concerned, even today the collaboration between technologists and new media theorists (and designers, artists, humanists) seems rather fleeting [10], [9], [95].

On the one hand, we still find many professional figures with solid skills in the humanities, but with limited experience with technologies, and who do not have the time or interest to acquire new knowledge coming from the technological world. These should be the professionals who decide *how to design* Augmented Environments, and what contents to use. However, since they do not know the full potential of AR, nor do they know what new forms of experience can be created with AR, they are not really able to define the characteristics of the AEs to be designed.

On the other hand, we have developers with a thorough understanding of the technology behind AR. They should focus on the development of the technology and the applications to be produced with the technology, without being concerned too much with the design of the AEs generated by those applications. Unfortunately, as we have just seen, it is rare for developers to have at their disposal a design for an app created by professionals with appropriate skills. Therefore, developers often develop apps that they themselves have designed. The results, in these cases, are not always satisfying. The apps are perfectly working, yet they often lack of an appealing look, or exhibit poorly designed or unclear interfaces, or deal with the contents with excessive simplification.

Then, our work, and this chapter in particular, wants to be – among other things – a tool to stimulate and foster that collaboration advocated by MacIntyre et al., between two worlds that still do not talk to each other very often. With this work, we want to provide a way of dealing with AR that could help non-technologists to understand the potential of a technology – augmented reality – that technologists have developed.

4.1.2 Methodology

We intend to provide some methodological suggestions to organize the semiotic analysis of augmented reality and augmented environments. We will draw on concepts from different, but somehow contiguous, research areas: theory of new media [94], [96], [97], [98], [99], semiotics of media [100], [101], [102], [103] semiotic engineering [104], [105], semiotic textology [106], [107], [108], textual semiotics [109], [110], [111].

Generally speaking, semiotics studies all cultural processes as processes of communication, and therefore deals with the underlying systems of significations permitting those processes [110, p. 8]. Semiotic analysis proposes to systematically break down the objects to be examined into smaller and, at the same time, more general elements, so that they can be found both in the decomposed objects and in other objects of the same type. The semiotic investigation begins by taking into account what we can call a "surface analysis", which describes the object in its materiality and exteriority, and then continues with ever deeper levels of analysis, each of which shows an ever-greater degree of abstraction and generalization. Each level of analysis is meant to disclose new features of the object under examination, and show new ways of looking at it and understanding it. In fact, the identification of different hierarchical levels of meaning, is one of the fundamental characteristics that distinguish the semiotic methodology from other methodologies typical of the human sciences [100].

We would also like to point out that there is not a unified and all-embracing semiotic methodology capable of capturing all aspects of any possible object investigated. This means that, depending on the nature of the object under investigation, on the type of analysis desired, on the depth of the analysis, and on the objectives set by the analysis, each individual analysis will identify and use the theories and methodological approaches that the analyst believes to be most appropriate and effective.

In this chapter, we want to introduce what we consider essential to set up a semiotic investigation on AR and on the immersive Augmented Environments for HMD generated by applications running on HMD (in short, from now on: AEs for HMD). We begin by presenting a general semiotic approach, which we consider to be the analytical ground for any semiotic investigation dealing with media, and we will then continue by showing a few specific analyses focusing on some relevant features of AEs.

4.2 Media, And Multimedia Texts

In the perspective of a semiotics of new media, before proceeding with the analysis, we examine a few fundamental concepts that we will use in this chapter.

4.2.1 Media

In ordinary language, we tend to use the word media in an ambiguous way to identify any channel of communication, from the printed text to the digital data, including radio, television, and any other form of communication. Using this uncertain notion of media, there is often confusion in identifying what we define as media. Sometimes, we might be talking about the devices that are used to transmit certain pieces of information, for example, when we use the word "newspaper" to refer to a particular set of printed sheets. Other times, however, we use the word "newspaper" to talk about a group of news that has been published by a publisher. Finally, other times, with "newspaper" we mean to refer to a group of people (the editorial office) involved in writing and assembling the news to be published.

In the context of a semiotics that deals with media, we must get rid of the ambiguity coming from a generic use of the term "media".

We therefore propose a definition of media, or rather of medium, in its singular version, referring to a distinction that is quite common in the literature on the media between *medium as a technology* and medium as a *form of communication* (e.g. see, [94], [100], [101]).

In the definition we propose, we make a distinction between:

- the medium as a *technology*, that is, as a variety of material components (sensors, micro-processors, monitors, cables, storage devices, etc.) that, once assembled into some device, allow the transmission, reception, and possibly the storage of information;
- the medium as a *system of significations*, that is:
    i. a set of features (e.g. possible genres and formats of the objects that can be produced with the medium, possible types of communication allowed by the medium, etc.);
    ii. a set of rules for the formation, organization and manipulation of the features;
    iii. a set of conventions (culturally, socially and historically determined, and that people follow when they communicate using technologies) that can be used in certain communication contexts to produce particular and tangible forms of communication.

In the rest of this chapter, we will deal only with media meant as systems of significations. In this regard, however, we should be aware that in many cases it is not possible to make a clear-cut separation between the two ways of understanding media. In fact, certain material aspects of the media as technologies impose constraints and limits on the characteristics of the media intended as systems of significations (e.g. the act of writing on the touchscreen of a mobile phone establishes a particular relationship between the hands of the user and the (small) interface (the touchscreen) the user writes on: the small size of the interface modifies certain features of the text produced, such as brevity, synthesis, essential style, etc. [100]).

What we examined so far is enough to allow us to frame AR within the context of a semiotics of new media. Following our definition of medium, we can now treat AR as a particular system of significations - hence a particular medium - that can be investigated through the methods of semiotics. Moreover, we can also use semiotic analysis with the forms of communication produced with AR, that is, the AEs for HMD.

Here, it seems important to underline that the particular system of significations that we want to examine takes into account some specific features belonging to AR:

- the capability to work with (manipulate) virtual contents (holograms)
- the capability to mix virtual and real contents in a single blend
- the use of 3D spaces in which the user is able to immerge
- the use of specific forms (gestures) for the interaction between the user and the holograms
- the capability to provide the user with the full control of his own point of view

These features belong (almost) exclusively to AR and, therefore, are the features that more than anything else contribute to make of AR a unique medium. So, it is exactly by exploring the many possibilities these features offer for the creation of new and original AEs for HMD that we can better understand the great potential AR has in reshaping our experience.

4.2.2 Multimedia Texts

We are now able to define more clearly what we called, in the previous section, the "forms of communication" created by media, that is, the multimedia objects produced in some communicative context using a medium or several media meant as systems of significations. We will identify each of those forms of communication with a term that is the key concept in this work: a *text*.

First of all, we need to get rid of the quite common idea that a text is only what is written in a book, or in a paper. We need a definition of text capable of accounting for the text as a complex multimedia object. It is impossible here to report here, even briefly, the many definitions of text in the vast domain of textual semiotics (see on this the extensive bibliography in Nöth [112], Pozzato [109]). We have therefore chosen to refer to a definition of text (in Cosenza [100, p. 7]) which seems particularly useful for our purposes.

According to this definition, a text is any portion of reality:

a) that has meaning for someone;
b) whose limits can be clearly defined, so that it is possible to distinguish the text from what is outside it;
c) that can be broken down into discrete units, according to several hierarchical levels of analysis, from the most concrete (which is at the most superficial level) to the most abstract (which lies at the deepest level);
d) that can be decomposed according to objective criteria, that is, criteria based on motivations and arguments that can be found in the text itself.

Still following Cosenza's suggestions, we add to the above definition of text some further features to account for the fact that texts are usually *multimedia*, that is, use more than one medium.

e) The text described above can be said to be *multimedia* when it brings together several media, each of which is meant as a system of significations;
f) such media are assembled together through a unitary communication strategy,
g) that we enjoy through more than one sensory channel.

According to this definition of text, we can think of all books or articles using verbal language as the primary medium of communication as texts. Yet, we can also regard as texts many other 'objects' produced by different media: a comic strip, a film, a theatrical performance, a website, a commercial, or a piece of software and an augmented environment.

We can now finally reformulate the purpose of our investigation: we want to examine, from the perspective of semiotics of media, the multimedia 'objects' that are produced by using AR as a system of significations, that is, the AEs generated by applications running on HMD. During the analysis, these AEs for HMD will be treated as multimedia texts.

4.3 Disassembling Augmented Environments

We will now propose several ways to "disassemble" an AE for HMD, so to be able to examine its components from different perspectives. It should be noted that the analyses we propose presuppose a form of direct observation of the AE for HMD to be analyzed. And there is only one way for the analyst to have a direct observation of an AE for HMD: immerge herself into the AE he wants to observe.

4.3.1 Types of Apps for Augmented Reality

According to some statistics published online [113], Google and Apple classify mobile apps available in their Stores according to 33 and 24 categories, with the top ten categories (games, business, education, lifestyle, entertainment, utilities, travel, book, health and fitness, food and drink) containing more or less 70% of the apps downloaded in 2019. At the moment, AR shows an enormous potential on the market [114], but the number of apps for AR is not yet big enough to allow AR to have its own category, and even less to have a subdivision into sub-categories within the category, especially if we talk, as in our case, about apps running on HMD and generating immersive AEs. Nevertheless, since the task we set in this work is to disassemble as much as possible the AEs for HMD we are dealing with, we begin our analysis by proposing a subdivision of our apps for AR into sub-categories (the categories listed above).

On first approximation, we use the purpose of one app (usually stated by the producer/designer of the app) to insert the app into one of the above categories. So, for example, if we look at the sentence describing the app we have developed ("it creates a learning environment in AR for older adults") we can include our app in the "education" category. We are aware that using the purpose of the app as a way to identify the app category is not particularly reliable. That is why, later on, while examining the AE components, we will try to find better ways to confirm the initial categorical attribution (e.g. in 3.4.1).

4.3.2 TEXT SEGMENTATION

4.3.2.1 Paratext And Text

We consider an AE for HMD as a text. Let us now proceed to break down this text so as to acquire new information on its characteristics and properties. Particularly, we want to segment the text into blocks, each of which maintains a certain autonomy of forms and content.

In 1987, while working on the definition of some criteria for the analysis of literary works, Genette introduced a term to identify a set of heterogeneous elements present in a text: the *paratext*. The paratext is everything that, although is not really part of a text, accompanies the text and, in different ways and styles, helps it to make itself visible to its readers [115]. The texts Genette referred to were, of course, literary texts, books. So, the paratext was the set of elements typically present in a book: the book title, the author's name, the book cover, a particular graphic layout, the book index, and so on.

We intend to use the idea of paratext –modified to account for the type of multimedia texts we work with– to segment the text we are dealing with into two distinct spaces: the *space of paratext* and the *space of content* (containing the primary contents of the text, i.e., all that the text wants the user to perceive, understand, learn, and use). We propose to think of the paratext of a multimedia text as the set of those media components with a communicative function, that are somehow placed at the "periphery" of the text itself, and that help the user of the text to have the best possible experience while enjoying the text [13]. In an AE for HMD, there clearly exist some media components that help the user of the text to get the primary content of the text and yet, cannot be considered as part of the primary content: the *interfaces*.

By segmenting the text into two different sub-spaces we can keep the interfaces as separate as possible from the primary contents. In such way, not only can we analyze the two spaces separately, but we can also decide, for each space, the most adequate methodological approach to use for the analysis.

4.3.2.2 The Space of Paratext: The Interfaces

It is beyond the scope of this work to propose more detailed analyses of the space of paratext. The study of interfaces is well-established within the domain of Human-Computer Interaction, and the literature on interfaces is huge. So, we let those studies deal with in-depth analyses of interfaces and of the complex relationships between users and interfaces.

For the purpose we set for this work, we are interested in identifying only a few features of the interfaces defined in the space of paratext. Particularly, we want to distinguish the interfaces according to the following simple typology:

(a) *help* interface (providing the user with information enabling the user to deal with the Augmented Environment – see Figure 19);

(b) *navigation* interface (allowing the user to move throughout of the AE) (see Figure 18 and Figure 19);

(c) *configuration* interfaces (allowing the user to personalize some features of the AE).

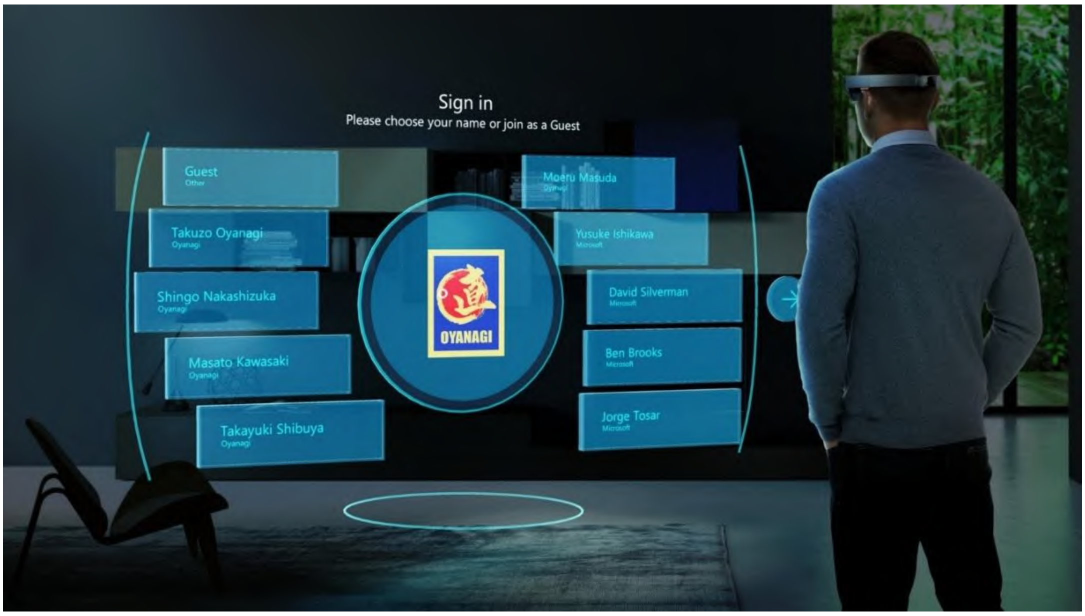


Figure 18: An example of Navigation Interface in an app for the HoloLens

In Figure 19 we can see another example of this subdivision of the interfaces in the space of paratext of the learning AE for HMD that we developed (for more details on the AE, see Chapters 5 and 6). Here, only two types of interface are visible:

(a) the *help interface* (which, in turn, is made up of two interfaces: a “help panel” showing general and local information on the AE and its features; a “virtual assistant” who interacts with the user and guides her throughout the AE);

(b) the *navigation interface* (made up of a “panel” showing the most common vocal commands (for voice navigation) and a more traditional “navigation” bar with links to the different scenes in the AE).

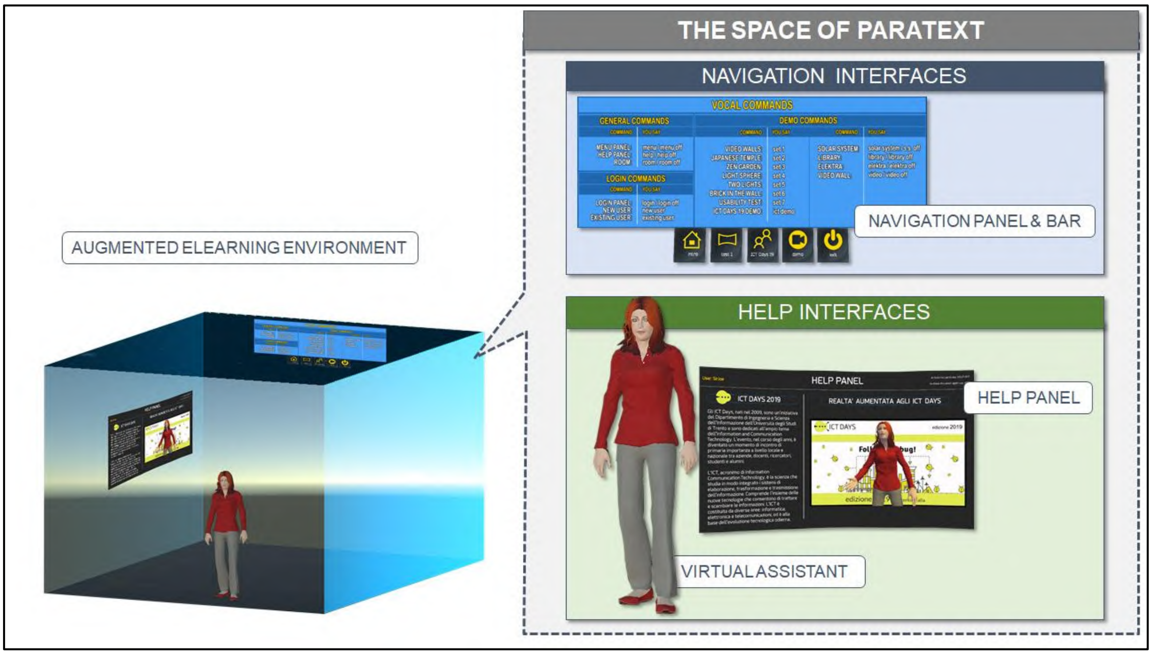


Figure 19: The Space of Paratext of an AE: Navigation and Help Interfaces

The reason why we want to clearly identify the navigation interface is that by examining the navigation interface we find a way to work out a further segmentation of the space of content.

4.3.2.3 the Space of Content: Content Macro-Units as Scenes

It seems reasonable to assume that, during the process of designing AEs for HMD, designers establish some criteria for segmenting the AEs primary contents. In fact, all the AEs we examined (e.g. *Fragments, Holo Tour, Holo Anatomy, Land of Dinosaurs, RoboRaid, Inside Heart*, just to name a few AEs for the HoloLens) show some sort of content segmentation. So, we need to find a way to identify and separate those textual segments – we call them *content macro-units* – that we see in the AEs for HMD.

We have a tool that can help us with this: the navigation interface, with its set of links (see Figure 20). When we activate one of the links in the navigation interface, we force the change of a substantial portion of the content: the portion of content we were dealing with is removed from the AE and a new portion of content takes its place. These *portions of content* are the content macro-units we are looking for. We assigned a name to the content macro-units that together define the whole space of content of a multimedia text: *scenes*. The choice, of course, is not accidental, since we took the term from Unity, the game engine we used to develop our Learning Augmented Environment. Unity organizes all the contents of a whatever project, often a game, into a hierarchy of scenes, each of which contains all the objects (graphics, environments, obstacles, scripts, characters, etc.) necessary to create a level or a section of the game (see 6.1.1).

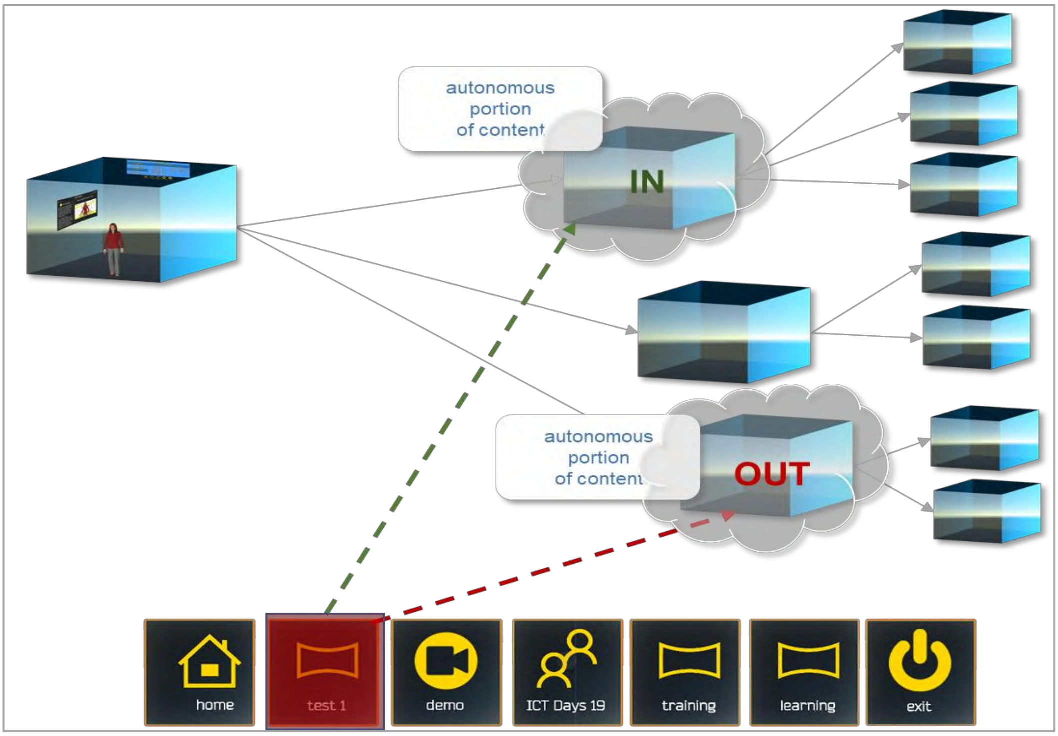


Figure 20: The AE contents segmented through the navigation bar

As an example, we examine again the learning AE we have developed. By means of the links we find in the navigation bar, we can identify the scenes that are in the space of content of our AE. Figure 21 shows the segmentation of the space of content into scenes, and the scenes internal organization.

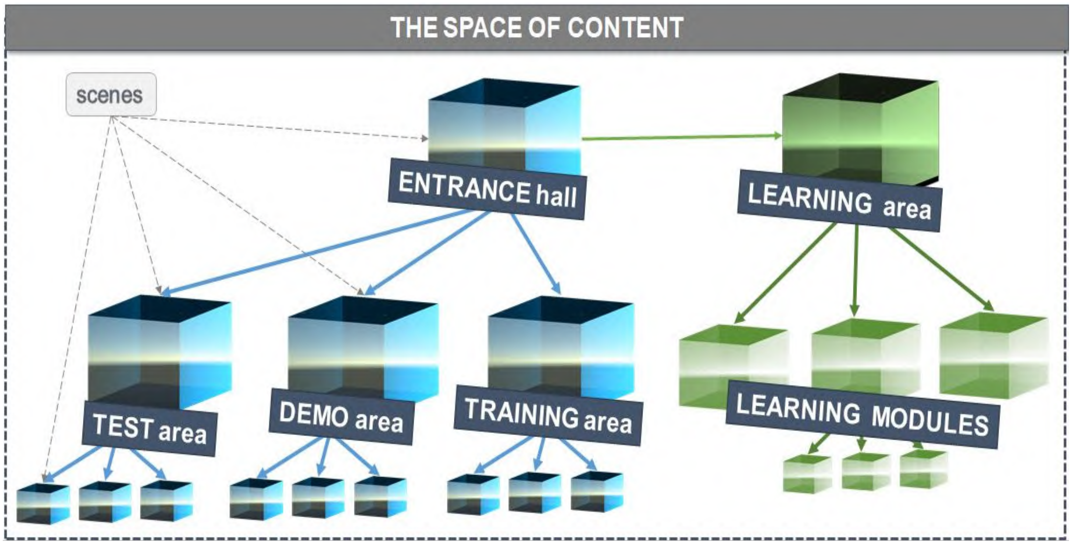


Figure 21: The Space of Content: Scenes segmentation and organization in our LAE

4.3.3 Text Layering

So far, we found a way to separate the space of paratext from the space of content of a multimedia text, and also a way to decompose the space of content into scenes. Yet, we still do not know how to really distinguish one text from another. The simple segmentation of the space of content of a whatever multimedia text into scenes does not yet allow us to say much about the primary content of the text: what is the text about? what is the content the text wants the user to perceive, understand, know and use? How is this content organized?

It is then necessary to proceed with a further process of decomposition of the text. This time, however, rather than segmenting the text into smaller units, we focus on each of the units we found so far, that is, the scenes. We will continue by creating a layering of analyses [116, p. 33] focused on the components of each scene and on the relationships these components have with one another. Particularly, we will:

- identify, for each scene, its various internal components (e.g. the visual space, the sound space, the virtual objects present in the scene, etc.) – we call them *content micro-units*;
- analyze, one by one, the above content micro-units, each time using the theoretical and methodological tools that we believe to be the most appropriate for the task (e.g. we can analyze the sound space of a scene by separating the verbal component within the sound space from the non-verbal and from the musical components; or we can examine the distribution of the different sound components in the sound space, and so on);

- analyze the ways in which the different content micro-units interact with one another within the same scene (e.g. we can identify the relationships between the music and the setting, or between the arrangement of lights and the arrangement of virtual objects in the visual space, and so on).

4.3.3.1 Scenes as Augmented Stages

There are various ways to analyze the content micro-units of each scene. To begin with, we find it useful to treat the scenes as parts of a *theatrical performance* [10]. In fact, AEs for HMD share many features with theatrical performances. And this means that many of the characteristics and elements of the scenes of an AE can be analyzed by resorting to the existing studies of semiotics of theater [117], [118].

By using semiotics of theater, we will be able to identify the various systems of significations used in theatrical performances. For example, depending on the goals set by our analysis, we can study the systems defining and organizing the visual and sound spaces of theatrical performances; or we can focus on the systems dealing with time, or with the ways actors use verbal and non-verbal communication; we can study the organization of the virtual objects used to create the scenography, or the forms of interaction between virtual actors (people or objects) and the user, and so on.

Of course, when examining AEs as forms of theatrical performances, it becomes necessary to consider the differences and distances between the worlds represented in the various AEs and those proposed by more traditional theatrical performances. For example, it seems important to point out that the *user's point of view* in an AE is very different from that of a spectator of a theatrical work. In a theater, except for rare cases, the spectator is placed in front of the stage and, in any case, outside the space that defines and delimits the space of the performance. In AEs, the user can change her point of view by simply changing her position; moreover, the user always remains somewhere on the stage, and within the space of the performance. This greatly affects the role of the user in relation with the contents presented. In an AE, the user is at the same time a spectator and a protagonist of the performance that has been created only for her. As main actor in the performance, the user is actively (and emotionally) involved in the construction and manipulation of the elements and events proposed by the AE. And we must remember that the ability to emotionally involve the user in the experience created by an AE for HMD is one of the peculiar characteristics of AR, which distinguishes it from almost all other media.

We must also consider that the space of a theatrical performance is less complex than the space defined in an AE. The space of the theatrical representation, with rare exceptions, is determined by the physical space available for the stage; in this space, actors and scenic objects are mainly distributed on a horizontal plane over the stage. The space of an augmented representation has no such limitations. By adapting itself to the size and shape of the real space in which the user is located, the space of an augmented representation coincides with the whole AE. Virtual people and objects can be literally *anywhere* within this space, with results that are impossible to achieve with the traditional theater.

Despite these and other differences, here not examined, between theatrical and augmented representations, we believe that the semiotics of theater can be a powerful analytical tool to capture many aspects of the internal components of the scenes of a text, particularly when the text is built around one or more narratives (as in the case of games, or cultural or artistic AEs).

4.3.3.2 AR Native and Imported Contents

There are further or alternative ways to analyze the content micro-units of a scene. We begin by making a distinction between two general types of content micro-units:

- *AR 'native' content micro-units:* the content micro-units that are created directly in AEs and that can only exist in AEs (e.g. in the learning AE we developed, we created an exercise that requires the user to manipulate (e.g. move, rotate, resize) a group of holograms until a certain spatial arrangement of the holograms is reached);
- *imported content micro-units:* the content micro-units that have been created with other media and are imported into AEs (e.g. a video of a lesson created for an e-learning website and imported unchanged into one AE, so that it is visible on a virtual player (a hologram) hanging on a real wall).

If we want to examine the *native content micro-units* (case a), then we need to refer to sets of features, rules and conventions defined in the AR medium meant as a system of significations (see 2.1).

It seems important to remind that some of these features (the capability to work with virtual contents (holograms), the capability to mix virtual and real contents in a single blend, the use of 3D spaces in which the user is able to immerge, the use of forms of interaction between user and holograms, the capability to provide the user with the full control of her own point of view) belong (almost) exclusively to the AR system of significations, and contribute to make AR a unique medium.

As for the rules, they take into account the above features, and:

- allow the definition (creation) of the possible holograms in AEs;
- allow various forms of hologram manipulation in AEs (e.g. moving, scaling, rotating, etc.);
- allow various forms of organization of holograms in AEs (e.g. the above exercise).

It should be noted that if we want to examine the forms of organization of holograms, we might find it helpful to refer to the forms of organization other media have already established to organize their own 'objects'. These objects are different from holograms; however, the ways these objects are organized might be quite similar even in different media. For example, if we think about the exercise we previously described (the manipulation of holograms in one AE, looking for a certain arrangement of the holograms) we realize that even though only AR makes it possible to manipulate holograms within an AE, the idea of moving some objects in a space according to some logic and goal can be formulated and used in other media and independently from AR. So, while designing exercises for our learning AE, we took that idea and used it to define one particular exercise, and to organize the behavior of some holograms in our AE.

We can take advantage of this to somehow simplify our analyses. To analyze the forms of organization of holograms, defined in the AR system of significations, we can use the extensive literature relating to the specific semiotics that study different (and more known) systems of significations, such as semiotics of film, of video and video clips, semiotics of visual communication, semiotics of visual arts, semiotics of photography, semiotics of music, semiotics of marketing, textual semiotics, semiotics of news, and so on (for bibliographical suggestions on these and other semiotic themes see [112]). After all, that is exactly what we did in the previously section on theatrical performances.

Of course, we must not forget that when we "import" into AEs certain forms of organization of objects defined in other media, we must inevitably adapt (that is, change, extend) those forms of organization in order to make them compatible with the AR system of significations. Therefore, we should account for all the possible transformations of whatever goes through the importing process (as we did in the previous section dealing with the difference between augmented and theatrical representations). (For more details on the importing process, see 5.3.4).

If we want to examine the *imported content micro-units* (case b), then we must consider that such units are originally created with other media and are then (re)constructed by the medium AR (meant as system of significations). Dealing with such texts might require two different type of analysis:

- on one hand, we can look at the content micro-units simply as objects going through a process of conversion due to their being imported into an AE. For example, let us consider again the video-lesson we previously talked about. The video is taken out of a web page and imported into one AE. By means of the process of importing, the video becomes a hologram (i.e., a virtual player showing the video, which maintains the exact content it had in the web page). Now, if we look at the video only as a hologram existing in the AE, then we can deal with it by using the rules for the manipulation and organization of holograms defined in the AR system of significations (e.g. move, rotate, resize, aggregate to other holograms, etc.), as we would do with native content micro-units.

It should be noted that, in this case, we don't even need to consider the content micro-units as texts. We are more interested in identifying the rules handling the importing process, and according to which the content micro-units are ‘re-written’ to fit and work in the new AR system of significations. These rules are mostly technical, since, in a general sense, they are used to convert texts given in certain format into texts in a different format. As such, they do not really require a semiotic analysis.

- on the other hand, we can analyze the content micro-units as autonomous texts, that is, regardless from the fact that those texts, due to the importing process, have become constitutive elements of one AE. In this case, we can again resort to specific semiotics (see point (a) in this section) and carry out particular analyses by examining each text from different perspectives and with different levels of penetration and abstraction. For example, if we consider, again, the video lesson we previously talked about, for our analysis we can use semiotics dealing with videos, films, or documentaries; or we can use others semiotics dealing with communication, or education, to explore the communication techniques used in the video to convey educational content in online courses; or we can examine the video editing techniques used to assemble the different sequences that make up the whole video; or we can identify the characteristics of the different media involved in the making of the video.

4.4 Text and Context

So far, we have focused our analyses on the AEs for HMD, considering them as texts. However, a text, any text, does not live in complete isolation. A text always exists within a context, that is, a culture that is historically, socially, economically determined, and has produced that text and/or uses it. So, to better understand the multiplicity of meanings that can emerge by analyzing a text from multiple perspectives, we place the text within a communicative situation capable of accounting for the complexity of the context.

Here, we cannot explore in detail the concept of communicative situation (for a more in-depth analysis on this, the reader can refer to Petöfi [106]–[108]). But we must at least mention the idea that in order to have a communicative situation we need at least two *communicators* that somehow interact by means of/with a text: one of the communicators is a *producer* who creates (by using one or more media meant as systems of significations) the form of communication that we call text; the other communicator is a *receiver* that receives the text created and uses it in some ways.

It is important to note that the production and reception of the text are possible because both the communicators possess a body of knowledge about the world that share, more or less extensively, with their social environment. In semiotics, this body of knowledge about the world is often called the *personal encyclopedia* of an individual. It is a whole, not always easy to systematize, made of knowledge, skills, experiences, beliefs and expectations. The personal encyclopedia is the necessary background knowledge each individual needs in any communication process [110], [119]. In fact, it is precisely by using what is present in their individual encyclopedias that communicators know, during a communicative act, all that is necessary to know to create a certain text and/or to use it.

4.4.1 Producers and Model Receivers of Augmented Environments

Since we propose a semiotic approach to AEs for HMD, we think it useful to talk about something that is within the personal encyclopedia of the producer of an AE: it is what, from a semiotic point of view, is defined as the *model receiver*. The model receiver is a more or less abstract and accurate profile, which is (more or less consciously) defined by the producer in his encyclopedia and which he will use during the process of design of the text. Therefore, when we talk about the model receiver, we are not talking about the empirical receiver, but rather about a set of predictions the producer makes on mental states, competences, interpretative steps, and concrete actions of the empirical receiver [100] [111].

The model receiver plays a fundamental role in the production of any text. In fact, we must remember that every text is produced not only for a purpose, but also for a specific target. So, the producer of an AE for HMD (as text) should always have that target/model receiver in mind (in her personal encyclopedia) during the design of the AE. Every aspect of the AE – from the organization of the scenes to the definition of the interfaces, from the graphics, to the music, up to the choice of the primary contents and of the different systems of significations to be used, etc. – should be carefully designed to allow the empirical users of that AE to have the best possible experience.

Given the importance the model receiver has in the process of designing AEs for HMD, once we undertake the analysis of an AE, we should be able to find, within the AE, the traces of the model receiver that the producer has somehow "embedded" in the AE. Then, we can use those traces to try to reconstruct the profile of the model receiver of that AE.

In an AE for HMD, there are various elements/features that help us to figure out the AE model receiver:

- the purpose of the AE (and, therefore, the type of app, identified in 3.1) and the information acquired from the analysis of the content micro-units of the different scenes (as seen in 3.3) can already provide us with an idea of what the model receiver of the AE is. We can then improve this first definition of the profile of the model receiver by examining the general features of already existing profiles (e.g. social, professional, cultural, or recreational operators; or, if we need a finer definition, we can even refer to more detailed profiles: doctors, students, engineers, humanists, gamers, visitors of museums or cultural events, users defined by age, or with specific impairments, etc.);

- the in-depth analysis of the interfaces and of the content micro-units of the different scenes allows us to identify also the types of possible actions the user is allowed/not allowed to perform in the AE, and that can be considered as typical actions for a certain type of user.

For example, let's examine the learning AE for HMD we have developed. Its purpose is to create a learning environment in AR for older adults, so we can say that the right category for the app is "education". From the analysis of the content micro-units of the scenes we have the confirmation that the AE deals with educational contents on a certain domain of knowledge (digital culture). So, as a first approximation, we can say that the right user of our educational AE is a student. Moreover, again from the purpose of the AE, and from other information we find in the interfaces (particularly the help interfaces) and in other content micro-units in the scenes, we have hints on the fact that the AE is designed for elderly users. So, we refine our previous definition: the right user of our AE is an adult student (who is 65 or older). By looking further into the interfaces and content micro-units of the scenes, we find other clues that confirm the type of user we identified. For example, the large font size used in all written words visible in the AE facilitates the reading even for users with impaired eyesight (a typical problem in older adults); the AE generates holograms only in the space in front of the user, so that even users with limited motor skills (a possible problem in older adults) can easily perform the gestures necessary to manipulate those holograms. We are therefore able to confirm again that the AE has been designed for elderly students, and that the "elderly student" is the model receiver we are looking for. Now, if we need, we can refine the profile of model receiver of our AE by conduction further research from different sources (e.g. ISTAT, demographic, sociological or medical studies, etc.).

How can the semiotic analysis of an AE for HMD use the profile of a model receiver extracted from within the AE to produce new insights or new analyses? Before taking into account the model receiver, the semiotic analysis allowed us to answer to questions such as: what kind of AE are we dealing with? how does this AE work? how can I segment it? what are its interfaces, and how do they work? how can we access the contents of this AE?

Once we introduce the concept of the model receiver of an AE, we can ask different types of questions: have the AE interfaces been properly designed for the target/model receiver (defined by the designer in her encyclopedia) of this AE? Are the various content micro-units of the scenes easily accessible (i.e., understandable, manageable, usable) by the model receiver? Or, more in general: is the AE generated by the app able to satisfy the needs, taste, emotions, capabilities, and competences of the user for whom the AE has been designed?

These questions open the way to new analyses focused on the entire design of the AE. Analyses that are, again, within the Human Computer Interaction domain, and that try to investigate all aspects of the interaction between the users of an app for AR and the AE generated by the app.

4.5 Conclusions

We have adopted the perspective of a semiotics of media to propose many analyses on what we called the AEs for HMD. Through such analyses, we have been able to separate the interfaces of an AE from its primary contents; we have been able to disassemble the scenes that make up the primary contents of an AE; we have been able to identify the different semiotic systems involved in the analysis of the micro-units of content of each scene, whether they are AR native or imported into the AE from other media; finally we have been able to examine the consequences of placing an AE within a communicative context.

We chose to deal with the semiotic analysis of AEs for HMD because we are quite confident that the opportunity to look at AEs for HMD from a multiplicity of perspectives, and the possibility to disassemble them to examine in detail their constitutive elements, can foster the understanding ─ from a non-technical point of view ─ of what AR is. Moreover, we believe that the semiotic approach here proposed might encourage reflection on how to concretely use the findings of the analyses to develop truly new forms of communication, which cannot be created with other media.

But there is a second, and perhaps more important reason that led us to write this chapter. Surely, analyses such as the ones we proposed here can be quite useful when we want to examine the AEs for HMD of already developed apps for AR in an attempt to establish, *a posteriori*, whether the AEs generated by those apps satisfy certain requirements, or show certain features. However, we really think that the analyses presented in this work can be used more profitably if carried out not *a posteriori*, on AEs generated by apps already developed, but rather *during* the design process of the AEs. Normally, semiotics has a descriptive attitude, that is, it limits itself to describe “only what it sees” during the disassembling of a text. On the other hand, nothing prevents us from using semiotics even in a normative way. Then, the findings of a particular semiotic analysis conducted on an

AE for HMD which is still at an early stage of development can be transformed into "guidelines" useful to define, change and improve the design of the AE.

And this is exactly what we did with the learning AE we designed, as we will see in detail the next Chapters of this work. While still in the process of looking for the features of the learning Augmented Environment we had I mind, we used the semiotic approach described above to examine the different signifying systems (e.g. theater, teaching, e-learning design, narratology, and so on) we thought we could profitably include in our Augmented Environment. Then, we used the findings of our analyses to give shape to our Learning Augmented Environment.

CHAPTER 5

5. Designing the Learning Augmented Environment

5.1 Introduction

In the previous Chapter, we presented our personal approach to augmented reality and, through a semiotic perspective, we explored the more theoretical aspects of immersive augmented environments generated by apps running on head-mounted devices.

In this Chapter, we will deal with the design of one of these augmented environments. Particularly, taking also into account what was examined in the first three chapters of this work, we will deal with the design of an immersive augmented environment especially tailored for older adults, and capable of offering older adults a learning experience on the use of computers and digital tools.

5.1.1 DESIGN OF AUGMENTED ENVIRONMENTS VS INSTRUCTIONAL DESIGN

During the design of the Learning Environment, we followed the well-known software engineering practice of "separation of concerns" [3], and we thrived to keep as separate as possible the *design of the Augmented Environment* from the *design of the Learning Area*, that is, the Learning Modules and their contents. This has allowed us, during the design of the general Augmented Environment, to freely explore all the features and possibilities offered by augmented reality without any constriction or limitation imposed on the design by the learning contents to be used in the Learning Modules, or by the features of real users of the Learning Augmented Environment.

There is also another reason for keeping the design of the Augmented Environment separated from the design of the Learning Area. The design of the Augmented Environment uses methodologies, principles and practices that have little or nothing to do with the methodologies, principles and practices used by what is normally called *Instructional Design*, and that are necessary to organize whatever learning content into a well-structured course. So, there is no need to mix together the methodologies, principles and practices used by the two different designs.

Finally, there is one more practical reason for desiring the above-mentioned separation. As we said, we decided to design and develop a learning augmented environment that can easily be used also by older adults. However, at the beginning of this project, we had to make a couple of assumptions to justify at least the first steps we took to start working on the creation of the Augmented Environment. Our assumptions were: (1) older adults *are* *capable* of using augmented reality, and (2) older adults *are willing* to use augmented reality.

Of course, these assumptions needed to be proved in order to fully justify the soundness of our project. And the only way to find relevant information that could confirm (or disprove) the correctness of our assumptions was to build a mockup of an augmented environment that older adults could immerge into, so to be able to have a first-hand experience of augmented reality. However, it became soon clear that no mockup of an augmented environment could really help us. Indeed, the only possible mockup of a 3D, immersive, and interactive environment capable of providing a good feel on what augmented reality is, was a fully working, 3D, immersive and interactive environment. That is, the actual Augmented Environment we wanted to create.

So, if we wanted to prove our assumptions to be correct, we had first to design and develop a fully working augmented environment. Or, at least, we had to design and develop a prototype of an augmented environment with some demo content in it, working enough to be tested on real users.

Which is exactly what we did. At the time of this writing, we have developed a fully working prototype of the Augmented Environment, displaying all the features of augmented environments we previously described. The actual prototype (see Chapter 6) is in the form of an application running on the Microsoft *HoloLens* and capable of generating an immersive, 3-D, and interactive augmented environment. However, we do not have yet a confirmation to our assumptions, since we still have to carry out the test with the prototype on a group of older adults (as described in Chapter 7).

Given the time and the resources necessary to design and develop the Learning Modules and their contents, only a positive answer to our assumptions – that is, only when the test will be concluded and the data will be analyzed – can provide us with good enough reasons to continue with the design and development of the Learning Area of our Augmented Environment.

5.1.2 DESIGN METHODOLOGY

When dealing with the design of a new medium such as AR, it is not easy to find theories or methodological approaches that work with other media and that could be adapted so to work also with the new medium.

So far, when talking about augmented reality, we mostly focused on the “augmenting” features of augmented reality, while taking somehow for granted an equivalence between the *environment* and *reality*. With the word *environment* we meant “whatever is around”, or “whatever is perceived by the user (and by the head-mounted device the user is wearing) in normal, everyday conditions”, and that is going to be *augmented* by technology. This is somehow correct, but it is also vague enough to be of little use. If we want to design an environment that has the property of being augmented, we need to have a clearer and more usable definition of environment.

Definitions of environment abound. In computer science, in natural sciences, in engineering, in social sciences, in architecture, we found many definitions of environment, and we soon realized that every discipline has its own definition, and every definition is different from the others. As a consequence, also the methodologies used to design those environments are different one from the other, and none, among the ones we found, seemed to be much of a use for us.

The definition of environment that seems to be closest to what we look for is the one used by game designers and virtual world designers. After all, augmented environments can be considered somehow similar to the fully-virtual environments we find in games. So, the methodologies for designing virtual environments might be used to design augmented environments.

However, after a closer look at the work of game designers, we realized that the augmented environment we deal with, and the virtual environments game designers usually deal with are different (see, for example, Taylor, especially chapter 14: *Creating Holographic Objects* - [36]). The virtual environments created by game designers for a game are often large, natural or artificial landscapes, packed with very detailed objects, and can be visited far and wide by the characters of the game. On the contrary, the environments AR designers deal with are much smaller spaces: usually, they are not larger than a room or, at the most, a set of connected rooms (such as the rooms in an apartment or in a museum). And even when AR designers include outdoor environments (such as an area around a monument, or a building) in their projects, they are anyway forced to consider the ‘environment’ as the area just surrounding the monument or the building they want to work on.

In addition, we must not forget that while the virtual environments designed by game designers are totally-virtual (i.e., they fill up the whole 3D space), the virtual component of augmented environments similar to the one we want to design (a) is only a portion of the whole 3D space, and (b) must overlap in real time onto the real environment around the user during his immersive experience.

Finally, some studies show that many game designers and virtual worlds designers do not even have a unified design methodology [95]. Quite often, they learn and use multiple design methodologies and many different programs, and document their designs with a variety of tools, sketches and drawings. Quite often, the quality of the design they produce depends almost entirely on the experience of senior designers [95, p. 458], or on the methodologies adopted, and the programs purchased, by the companies designers work for [120].

So, how do we approach the design of augmented environments?

Certainly, we can refer to the world of game design. In some cases, and to a certain extent, it seems reasonable to adopt and make use of game designers' definition of environment, and also to take advantage of the methodologies game designers have developed to create the environments they use for their games. On the other hand, we should also keep in mind that, most of the times, game designers, while designing the environments for a game, look for features and objectives that we, as AR designers, do not need (e.g. very large environments), or do not care about (e.g. a large number of very well-defined objects), or that we are not able to use (e.g. a high-resolution environment, which requires an amount of computation power much greater than the one available on head-mounted devices).

We already said that, when dealing with a new medium, *we need to invent the medium*, as Murray would put it [98]. A new medium requires new sets of definitions, theories, methodologies and practices allowing new forms of analysis, design and development. And also requires a new way of looking at the products that the new medium is capable of creating.

Augmented reality is a new medium. However, it is still in its infancy, and people working with AR did not have enough time yet to fully explore definitions, theories, methodologies and practices on AR, and develop a well-structured methodology capable of explaining exactly how to design and organize the objects that AR, as technology, is able to create.

So, unable to find at our disposal such well-structured methodology, we realized that we needed to create our own design methodology by integrating our own considerations, based on many hours of observation and scrutiny of the available augmented environments, with many useful suggestions and best practices coming from the game design world, and (some) from the augmented reality world. This set of ideas, suggestions, practices, and considerations *is* our *informal design methodology*.

Particularly, we referred to studies such as Bartie's book *Designing Virtual Worlds* [93], outdated by now (it was published in 2003, and augmented reality is not even mentioned), but still capable of providing good ideas and insights on the process of *virtual world making*, as well as the even older but interesting report by Boyd Davis, *The DESIGN of Virtual Environments with particular reference to VRML* [121]. Also, we found many interesting resources on how to design and develop apps for the HoloLens in the *Windows Dev Center* Website [122], and many useful tutorials in the *Holographic Academy* Website [123], and at the *Learn.unity.com* Website [124]. Other up-to-date sources we used are: Aukstakalnis [9], Dunleavy [125], [126], Gregory, Lee et al. [127], Lukosek [128], Odom [34], Ong [35], Schmalstieg and Hollerer [10], Taylor [36], [95], [120], Geroimenko [43], [129], [130].

5.2 The Process of Development of Augmented Reality Environments

Before working out the details of the design of our Learning Augmented Environment, we want to spend a few words on the general process of developing applications for immersive augmented environments.

In the previous section, we said that there are differences between the world of game design and the world of AR design. However, even though we keep those differences in mind, we believe that we can follow, to a certain extent, the same process of development of a game used by game designers.

In what follows, first we will examine the professional roles required in a team working on the development of a game. Then, we will analyze the five different stages the process of development of a game is dived into. Finally, we will see how we can use to our advantage the five-stage process of development of a game to develop our Learning Augmented Environment.

5.2.1 The Development Team

Usually, the process of design and development of a game is carried out by a team of professionals with different roles, skills and responsibilities, and coming from different departments [120], as shown in Figure 22.

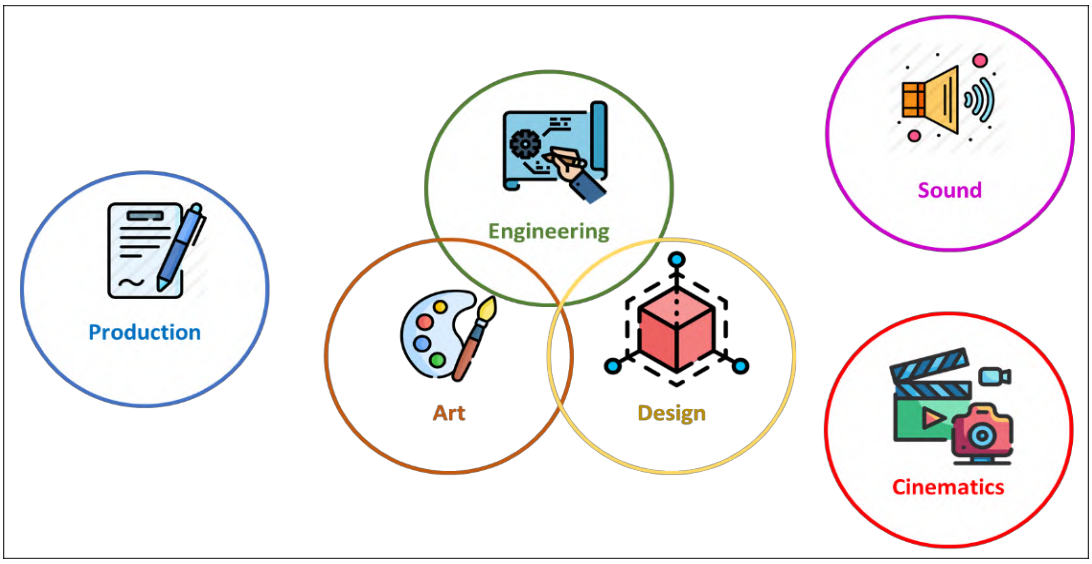


Figure 22: The major departments involved in the development of a game

It goes beyond the scope of this work to describe in detail the professionals who make up a video game development team. So, we only list here the key game development roles. A team devoted to the development of a game should include: *game artists* (concept artists, animators, 3D modelers, FX (special effects) artists), *game designers* and *level designers, programmers* and *game developers*. We should also include into the list some additional professional figures that are usually required to manage other important aspects of game development: a *project manager*, *sound designers* and *audio engineers*, *cinematic visual special effects artists*.

We can reasonably assume that a team involved in the development of immersive augmented reality applications is made up of professionals with skills and competences very similar to those required for the development of games.

As for our project, we did not have at our disposal a team of professionals with the right skills and competences required to complete the development of our Learning Augmented Environment. Therefore, for the duration of the development process, we were compelled to embody, from time to time, the different roles described above and acquire, when necessary and possible, the essential skills needed to perform the many required development activities.

5.2.2 The Development Process

As for the development of our Learning Augmented Environment, we found it convenient to follow the *game development pipeline* largely used by the world of game developers.

The game development pipeline is the process of building a game from concept to completion. The pipeline helps organize the flow of work, so that all members of the team know what they need to deliver, and when. It also helps to manage the game development timeline and budget, reducing inefficiencies and bottlenecks [131].

Even though the design methodologies and development tools might vary between projects, studios and game designers [95], as we saw in 5.1.2, the overall development process is fairly similar for the majority of game designers, games and platforms. Some authors describe it as a five-stage process [120], some others see it as a three-stage process [132], [131], or even as a seven-stage process [133]. However, no matter the number of stages the process is divided in, or the different names sometimes used to identify the stages, all authors describe more or less the same sequence of activities that we summarized in Figure 23.

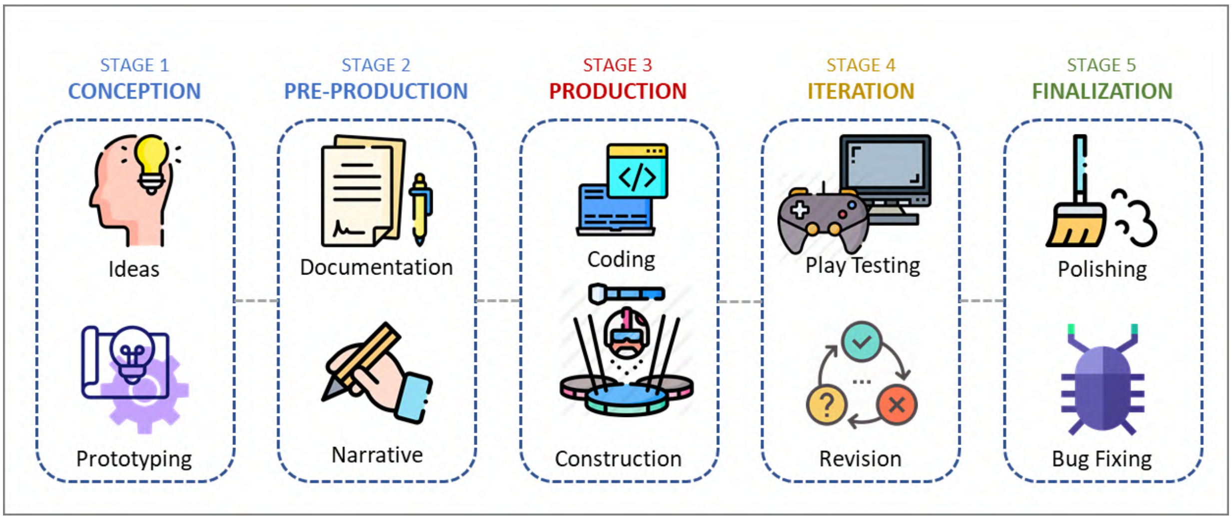


Figure 23: The process of development of games

In what follows we take a short look at these five stages, just to have a better idea on how a game is developed. Then we will see how we applied the five-stage process to our project.

Conception

The first stage in the development of a game is the *conception*, also called *planning*. The conception mostly deals with ideas. It involves creativity, freedom of expression, a lot of team work and many brainstorming meetings [132]. During this phase, all members of the team involved in the development of a game try to answer questions such as: what type of game are we producing?, what are some of the key features it must have?, who are its characters?, when and where does it take place?, who is our target audience?, which platform are we building this on? [133]. During this phase, designers and concept artists devise raw concepts, define possible scenarios and narratives, or sketch out the features of the main characters.

At the end of the conception step, usually the team comes up with a proof of concept, or a sort of prototype of the game, mostly on paper, which summarizes the main ideas and features conceived by the team about the game. Such a game prototype is a sort of raw test that checks functionality, user experience, gameplay, mechanics, and art direction [131].

Pre-Production

During this stage, the team tries to expand and polish the ideas and concepts laid out in the previous stage. Artists, writers, designers, engineers and developers collaborate, trying to put together all possible aspects and elements of the game. For example, concept artists prepare detailed sketches, define colors, moods, textures and environments for the different levels of the game. Writers work out the details about the narratives of the game: what is the main story of the game? what about the sub-plots? how many characters are in the game?

who are the main characters, and what are their backstories? How does each character relate to one another? Engineers examine what has been produced by writers to establish the technological feasibility of their requests. Developers discuss with engineers about the technological and technical aspects of the game: mechanics, physics, how objects will render on a player's screen, and so on.

At the end of this stage, many documents are produced on all possible aspects of the game, and from as many possible perspectives [131]. This allows the team members that will be working on the actual development of the game to have clear and solid instructions on what to develop, and how.

Production

Production is usually the longest and most complex stage of the game development pipeline. Production is where concepts and ideas start to take shape. During this stage, level of difficulty at each given moment of the game, rules of play, the point-scoring system, and many other aspects of the game are coded into software. Worlds are built: characters, environmental elements, and all assets (objects) in the game are designed and rendered according to the instructions and requirements set in stage 2. The ways objects and characters look and move, their colors, the sounds they produce, and their general behaviors are created through thousands-of-lines-of-source code written by developers, and/or by using all the programs that, from time to time, can best solve any specific need and request [133].

Since the beginning of the Production stage, the development team works hard so to have, as soon as possible, a working prototype of the game (also called the *first playable*) [133]. This first playable will go through many changes and improvements (see next paragraph on the Iteration and Revision stage), so to become, little by little, a fully working, "feature complete" version of the game.

Iteration and Revision

The *Iteration and Revision* stage does not start where the production stage ends. If here we keep the two stages apart, it is only to emphasize the difference between the activities of pure development of the prototype, and the activities related to testing and revising the prototype.

In reality, testing and revising begin as soon as the *first playable* is available to work on, and continue for the entire duration of the production stage.

Initial ideas don't always translate so well into reality. So, as production progresses, and new and more complex prototypes are gradually created, the game is continually tested and refined: elements of the game that have already been developed are modified, or even discarded; entire sections of the game are re-designed; codes are modified and added to improve performance; new ideas are added to the initial version of the game, and are then transformed into new elements or sections of the game.

Finalization

Finalization is the last stage in the game development process. After many revisions, the prototype has become a fully working, “feature complete” version of the game (called the *alpha version*), so that the game is fully playable from start to finish. It is now time to work on the final cleaning and polishing of the alpha version. The overall functionality of the alpha version should already be working without problems. However, some minor elements or parts of the game might still need some changing and fixing. Also, it is during finalization that all bugs should be properly identified and corrected.

When the cleaned and fixed version of the game (the *beta version*) is ready, there is only one last step to go through: optimization. Finally, when also the work on optimization is completed, the game development process is concluded, and the final version of the game, the *gold master*, is ready to be released to the public [131].

5.2.3 The Five-Stage Development Process Applied To Our Learning Augmented Environment

When we started working on this research project, we realized that the game development pipeline described above could be profitably used for our purposes. On one hand, the game development pipeline seemed to provide us with clear guidelines on how to organize the many activities necessary to complete the development of the Learning Augmented Environment; on the other hand, it seemed flexible enough to allow for inevitable revisions and course changes. So, we decided to segment the whole process of development of the Learning Augmented Environment according to the *game development pipeline*, as described in Figure 23. Of course, given the fact that we did not work with a team, we found it quite easy to freely move back and forward among the different stages of development (a working situation which is rather *unusual* in video game development). So, overall, we can say that we *loosely* followed the game development process normally used by game developers.

Table 1 summarizes the process of developing the whole Learning Augmented Environment segmented according to the five-stage process described in Figure 23.

Table 1: Stages necessary for completing the development of the Learning AE

Stage 1-2	**Conception & Design of the Augmented Environment (see Sections 5.2.3, 5.3)**	**Conception & Design of Learning Modules – Instructional Design (see Section 5.3.2)**
	- definition of the general features of augmented environments - definition of the features of the interfaces of the Augmented Environment - definition of the general features of the Learning Modules of the Augmented Environment - definition of the Testing Area - definition of the Usability Test + exercises - documentation & narratives - DESIGN of the general Augmented Environment - DESIGN of the Testing Area + Usability Test + exercises	- identification of the most common features of some courses offered by different websites for distant learning - selection of the contents related to computers and digital tools that will be used in the learning modules - definition of the main features of the course on the use of computers and digital tools for older adults, divided into learning segments (each of which will become a Learning Module) - definition of the particular features of each Learning Module of the LAE - documentation & narratives - DESIGN of the Learning Modules
Stage 3	**Development of the designed Augmented Environment**	**Development of the Learning Modules**
	- Prototype of the designed Augmented Environment (see Chapter 6) - Development of the Testing Area which is part of the general Augmented Environment	- Prototype of the Learning Area containing the Learning Modules - Integration of the Learning Modules into the prototype of the Augmented Environment
Stage 4	**Testing and revising the prototype of the Augmented Environment**	**Testing & revising the prototype of the full Learning Augmented Environment**
	- Usability and user experience test with the Prototype (see Chapter 7) - re-design of the AE considering the features of the ideal users of the AE and the results from the usability and UX test with the prototype - Revision & Bug Fixing	- Revision & Bug Fixing - Further testing with the Learning Area
Stage 5	**Finalizing the Augmented Environment**	**Finalizing the Learning Augmented Environment**
	- Alpha version of the Augmented Environment - Alpha version of the Testing Area - Final Revision, Cleaning & Bug Fixing - Beta version of the Testing Area	- Alpha version of the Learning Augmented Environment - Final Revision, Cleaning & Bug Fixing - Beta version of the Learning Augmented Environment - Optimization - Gold Master of the entire Learning Augmented Environment

In the following sections, we will show, stage by stage, the activities we carried out, and the documents we produced, during the development of our Learning Augmented Environment.

5.2.3.1 Stage 1: Conception

During the early stages of development of our Learning Augmented Environment (mostly, stage 1 and stage 2), we have identified, designed, and organized several elements/features/components that we believe are necessary to create our Learning Augmented Environment.

Table 2 shows the main components we took into account while working on the development of the Learning Augmented Environment.

Table 2: Main components involved in the design of the Learning AE

DESIGN OF THE LEARNING AUGMENTED ENVIRONMENT		
	General AE	Learning Modules/Testing Area
Setup/Configuration	All aspects of system configuration allowing the existence of the AE (see Chapter 6) -includes user management	
Virtual space/ environment	Features of general space (the features of AEs - See 5.3.1.1)	Features of Learning Modules (same as features of AEs - See 5.3.1.1)
	- Features of Visual Space	Features of Visual Space (same as GAE)
	- Features of Sound Space	Features of sound Space (same as GAE)
Interfaces	General features of Interfaces: - Help - Configuration - Navigation See 5.3.1.3	Localization (integration of local contents) of interfaces: - Help - Configuration - Navigation See 5.3.2
Main actors/players	General features of: - User (see 7.2) - Virtual Assistant (see 5.3.1.3.1) - Virtual objects (in GE)	Localization (integration of local contents) of: - User (see 7.2) - Virtual Assistant (see 5.3.1.3.1) - Virtual objects (defined in instructional design)
Types of activities	All different activities that are possible in the general spaces of the Augmented Environment	All different activities that are possible in the Learning Modules/Testing Area (those defined for the General AE and/or others defined in the instructional design – see example usability test in Ch. 7)
Types of possible virtual objects	Static - in the background (scene sets) - within the general space Dynamic	Static - in the background (scene sets) - within the space of the Modules Dynamic

Table 2: Main components involved in the design of the Learning AE [continued from previous page]

DESIGN OF THE LEARNING AUGMENTED ENVIRONMENT		
	General AE	Learning Modules/Testing Area
Forms of interaction	All different forms of interaction that are possible in the general space of the AE between: - User - virtual assistant/ interfaces/ virtual space/ static virtual objects/ dynamic virtual objects	All different forms of interaction that are possible in the Learning Modules (those defined for the General AE and/or others defined in the instructional design for educational purposes) between: - User - virtual assistant/ interfaces/ virtual space/ static virtual objects/ dynamic virtual objects (see example with the usability test in Chapter 7)
Ways of performing the forms of interaction	Through the set of gestures recognized by the HoloLens	Through the set of gestures recognized by the HoloLens
Narratives	General, managing: - temporal organization (visibility and behavior of objects through time) - spatial (location and size of virtual objects in the visual space of AE) - acoustic (location of sound-objects in the sound space of AE)	Local, defined in the instructional design for educational purposes. Managing local temporal, spatial and acoustic organizations

In what follows, we show just a few drawings or sketches among the many we created during the first stage of development, while trying to identify, define, represent, and give shape to the elements/features/components shown in *Table 2*.

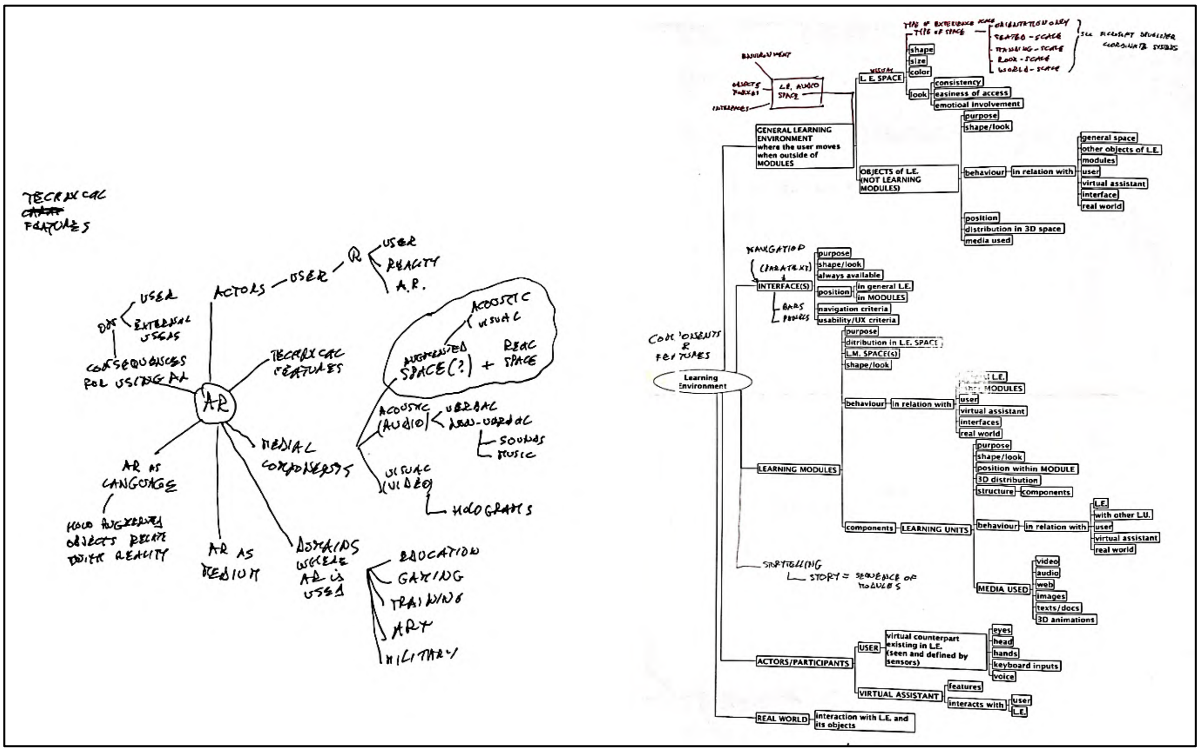


Figure 24: Brainstorming session, looking for the technical features of Augmented Reality

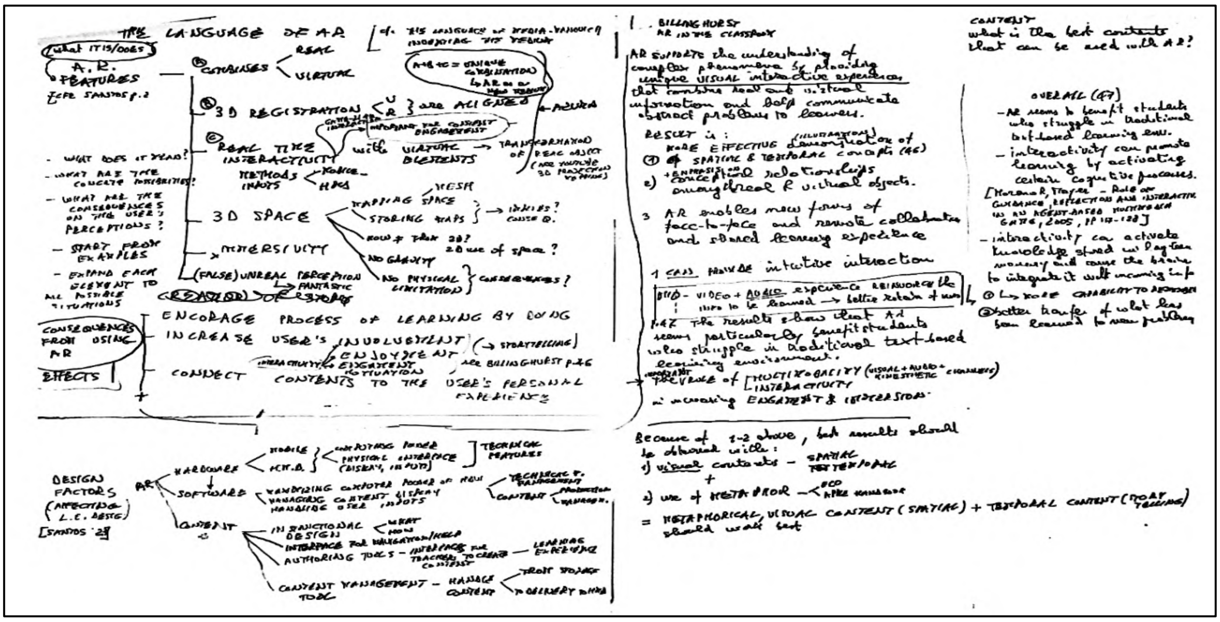


Figure 25: Free writing session, looking for the features of the "Language of AR"

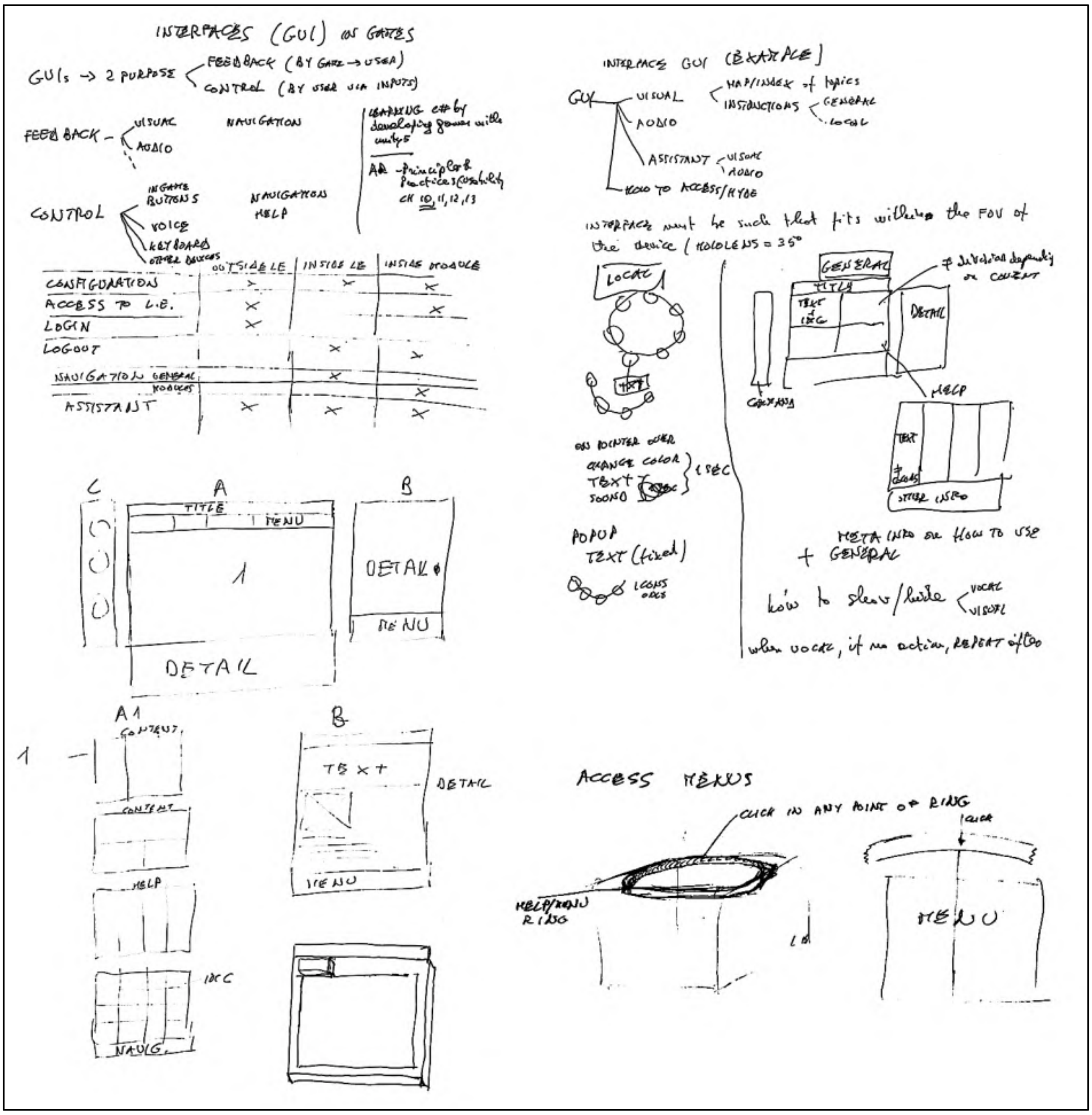


Figure 26: Study on the interfaces of the Augmented Environment - possible features and functionalities

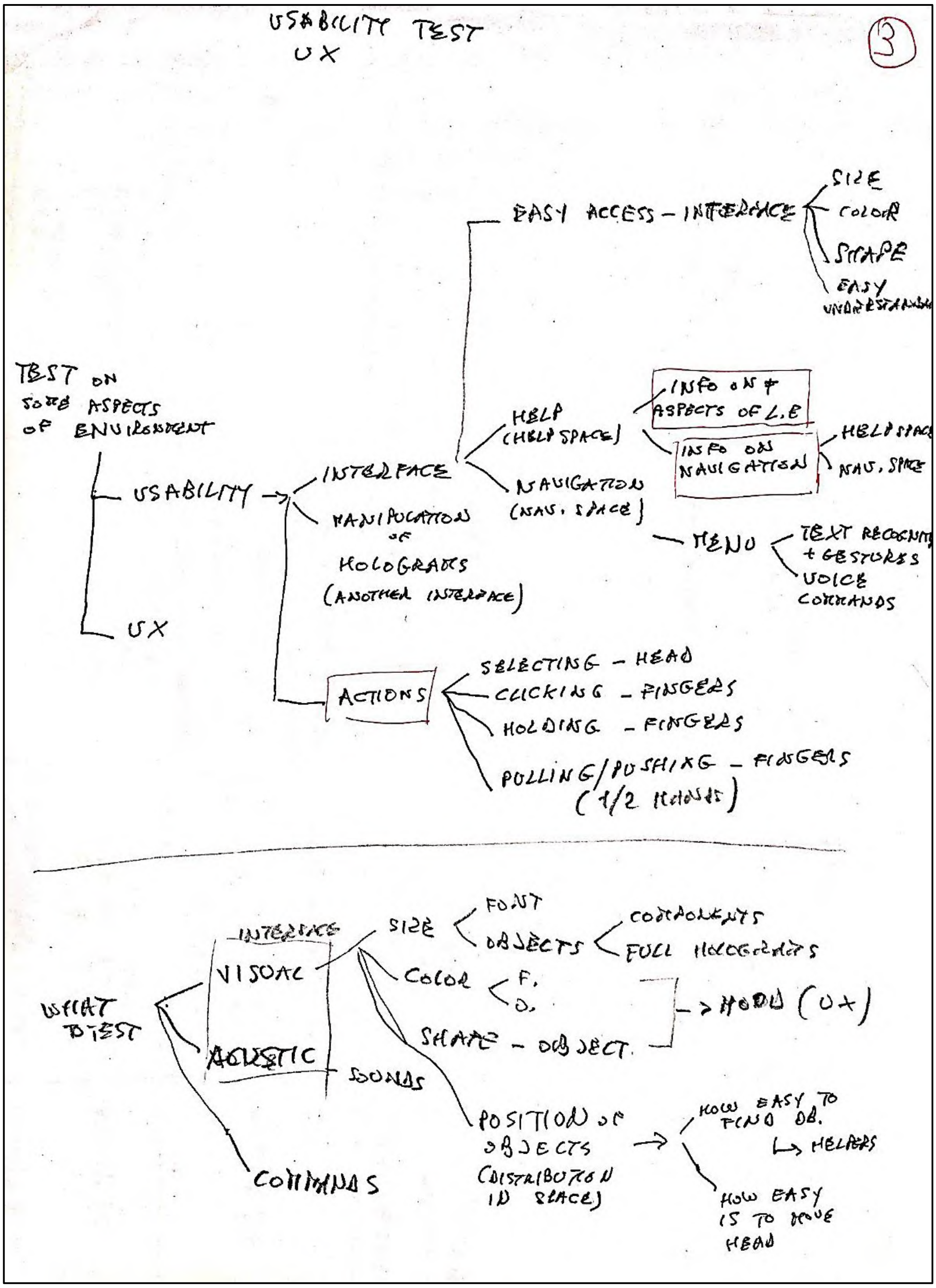


Figure 27: Brainstorming session – looking for the features of the usability test

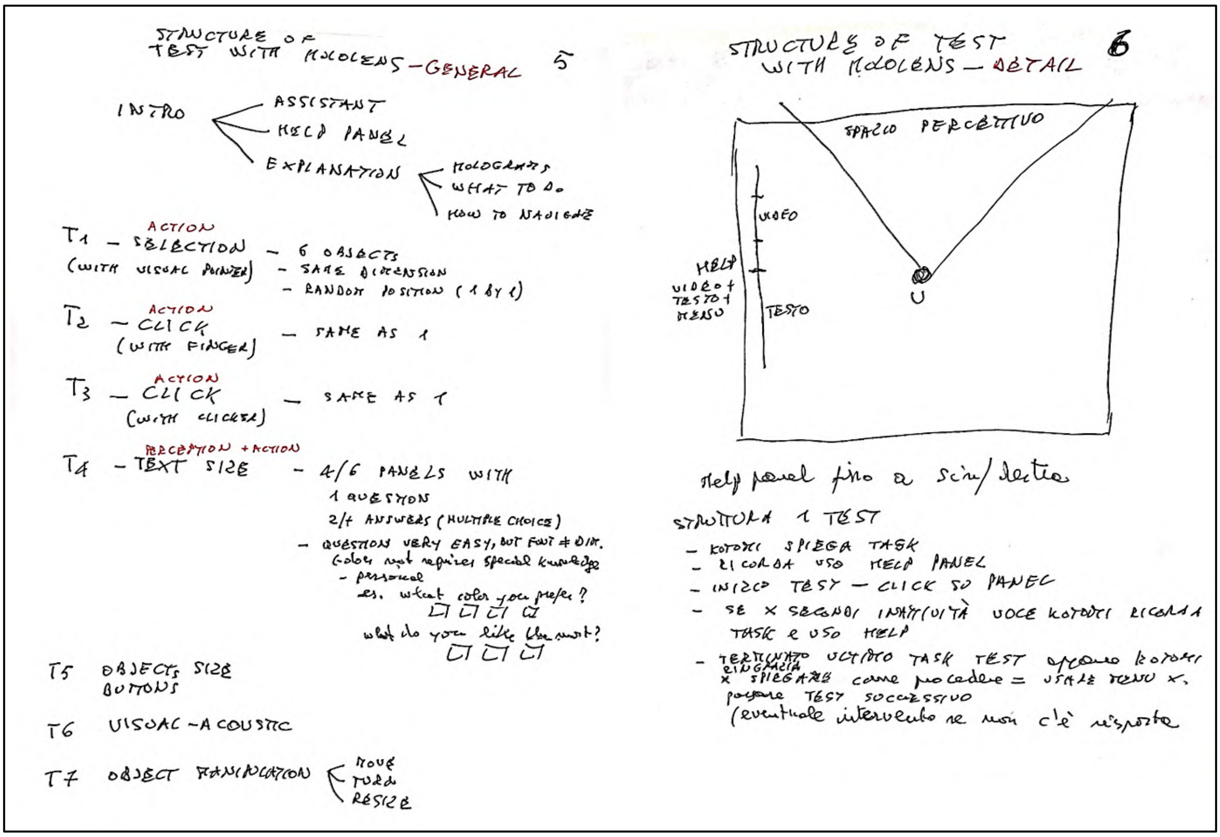


Figure 28: Study on the general structure of the Testing Area and on the organization of the virtual space within which the exercises are defined.

5.2.3.2 Stage 2: Pre-Production

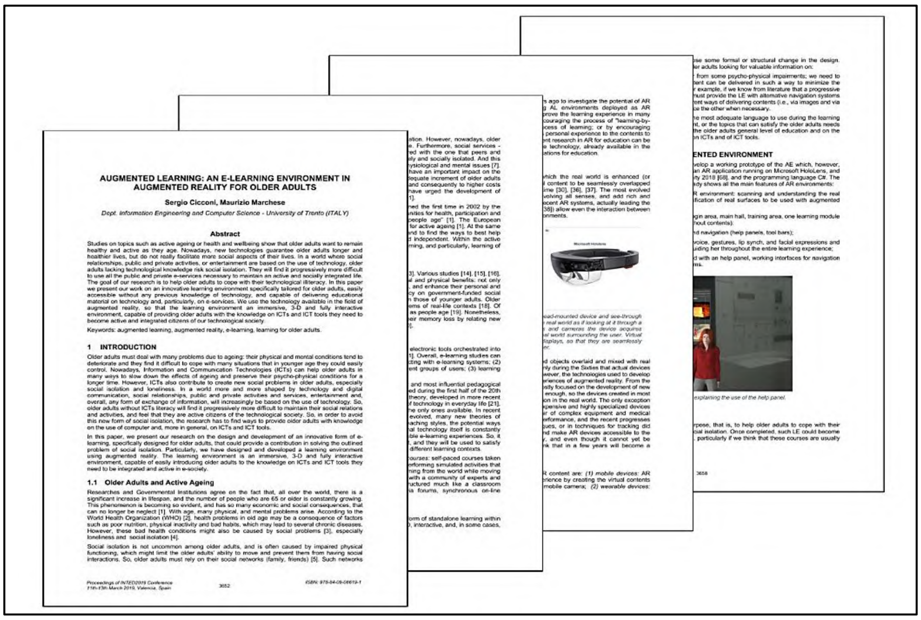
We saw that, during this stage, the development team usually tries to expand and polish the ideas and concepts formulated during the *conception* stage. Here, the team is focused on the production of documentation on the many aspects of the game they are working on.

As for our project, during the pre-production stage, we spent a considerable amount of time in exploring as many scientific works as possible on the many aspects related to Augmented Reality. We also started working on several types of document:

Papers and presentations:

First, we worked on the drafts of two papers, both dealing, from different perspectives, with the Learning Augmented Environment we wanted to develop. We completed the writing of these two papers later on, when we were already working on the production of the prototype. However, having started working on these two papers already at an early stage of development has proved very beneficial, since we could often use the ideas we found for the papers to perfect and polish the design in-progress of the Learning Augmented Environment.

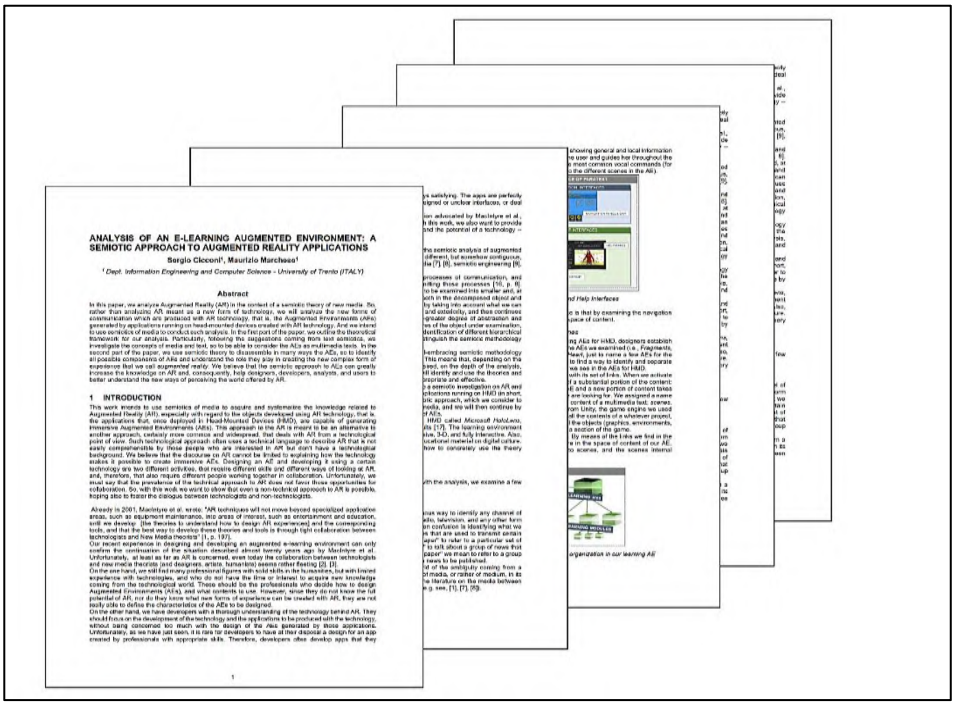
The two papers have been published, respectively, in the *International Technology, Education and Development (*INTED) *2019 Proceedings* (see Figure 29), and in the *International Conference on Education, Research and Innovation* (ICERI) *2019 Proceedings* (see Figure 30). Also, two presentations based on the papers have been presented at the INTED 2019 Conference, and at the ICERI2019 Conference (see Figure 31).


AUGMENTED LEARNING: AN E-LEARNING ENVIRONMENT IN AUGMENTED REALITY FOR OLDER ADULTS

Sergio Cicconi, Maurizio Marchese

Dept. Information Engineering and Computer Science - University of Trento (ITALY)

Figure 29: Cicconi - Marchese, "Augmented Learning: An E-Learning Environment in Augmented Reality for Older Adults," in INTED 2019 Proceedings, 2019.


ANALYSIS OF AN E-LEARNING AUGMENTED ENVIRONMENT: A SEMIOTIC APPROACH TO AUGMENTED REALITY APPLICATIONS

Sergio Cicconi[1], Maurizio Marchese[1]

[1] Dept. Information Engineering and Computer Science - University of Trento (ITALY)

Figure 30: Cicconi - Marchese, "Analysis of an E-Learning Augmented Environment: A Semiotic Approach to Augmented Reality Applications," ICERI2019 Proceedings, 2019.

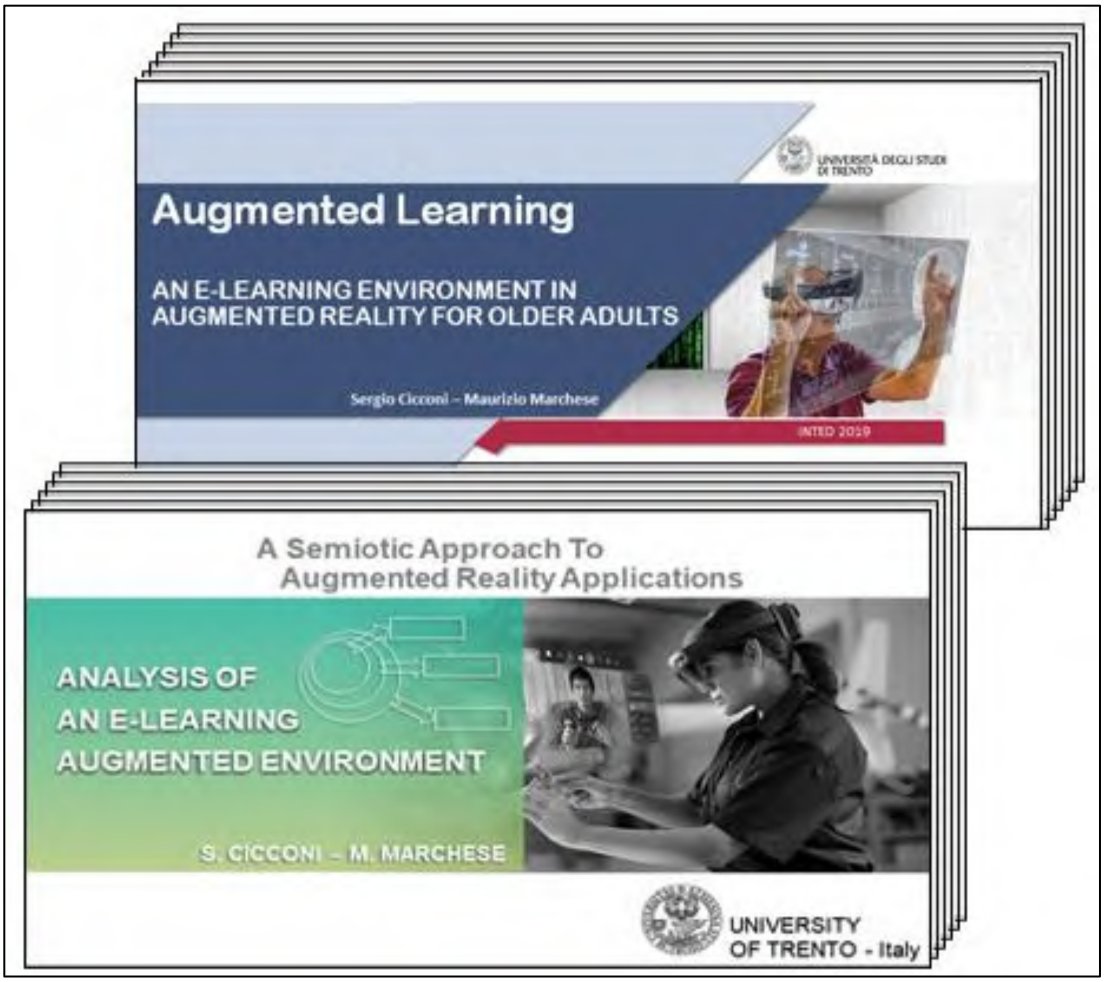


Figure 31: The two presentations on "Augmented Learning" and on "A Semiotic Approach to Augmented Reality Applications" presented at the INTED2019 Conference, and at the ICERI2019 Conference.

The Augmented Environment Design Document

In game development, no matter what the game is, one document cannot be missing: the *Game Design Document* (GDD). It is a living document on many aspects of the game (its origin idea, the art, sketches and notes on its story and characters, its core mechanics, or its definition of the gameplay, and so on) which helps everyone in the development team to have a good grasp of the entire project [131].

We started working on a similar document – we called it the *Augmented Environment Design Document* (AEDD) – during the pre-production stage, and we kept changing it again and again during the whole process of development of the Learning Augmented Environment (see Figure 32). The AEDD we created is a document halfway between a custom development manual and a notebook with informal instructions and considerations on a variety of theoretical and practical aspects related to augmented reality and to the the development of the Learning Augmented Environment. Considering that the AEDD keeps track of all the main stages of development, the problems we had to face, and the solutions we found, we can consider this document the most personal and precious among the many documents produced.

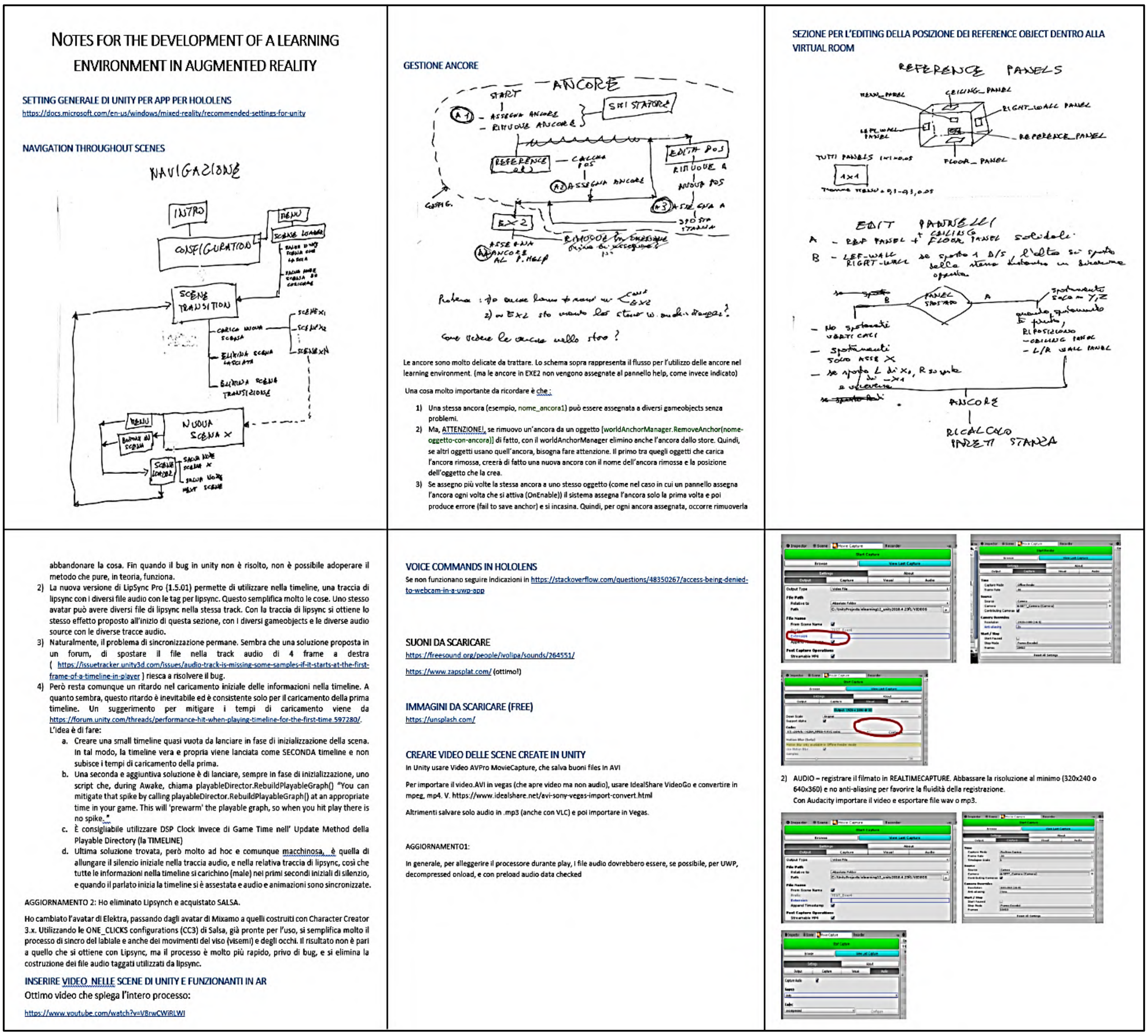
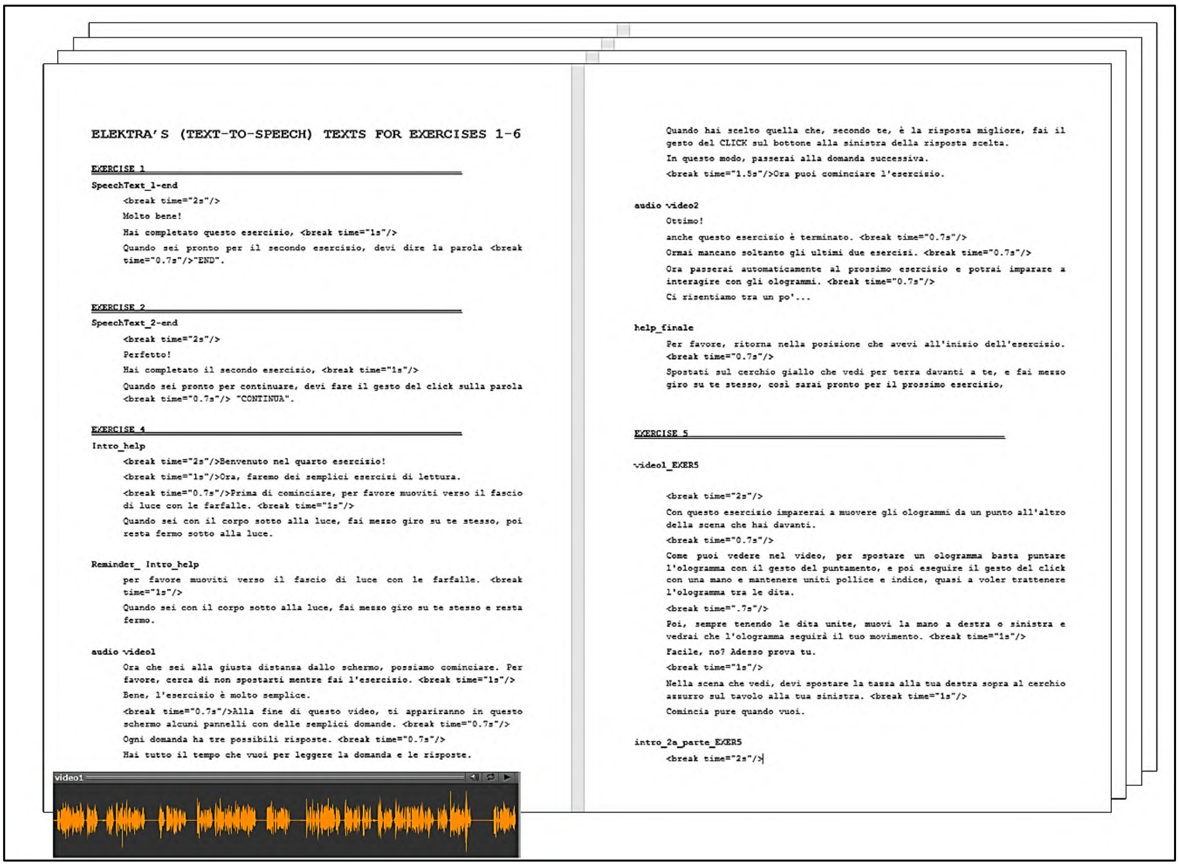


Figure 32: A few sample pages from the Augmented Environment Design Document

Scripts

We worked on three types of script:

- *monologues*: these are written texts with all the sentences pronounced by Elektra either during her interaction with the user, or in the several videos shown throughout the user's immersive augmented experience (see Figure 33). A text-to-speech system (the online Amazon's *Polly*) has been used to convert these written monologues into speech audio files. Such files are then processed in real-time by a lip-synch system integrated into Elektra's avatar, so that, at each moment, she can synchronize the movements of her lips with the words she pronounces.



ELEKTRA'S (TEXT-TO-SPEECH) TEXTS FOR EXERCISES 1-6

EXERCISE 1

SpeechText_1-end

<break time="2s"/>

Molto bene!

Hai completato questo esercizio, <break time="1s"/>

Quando sei pronto per il secondo esercizio, devi dire la parola <break time="0.7s"/>"END".

EXERCISE 2

SpeechText_2-end

<break time="2s"/>

Perfetto!

Hai completato il secondo esercizio, <break time="1s"/>

Quando sei pronto per continuare, devi fare il gesto del click sulla parola <break time="0.7s"/> "CONTINUA".

EXERCISE 4

Intro_help

<break time="2s"/>Benvenuto nel quarto esercizio!

<break time="1s"/>Ora, faremo dei semplici esercizi di lettura.

<break time="0.7s"/>Prima di cominciare, per favore muoviti verso il fascio di luce con le farfalle. <break time="1s"/>

Quando sei con il corpo sotto alla luce, fai mezzo giro su te stesso, poi resta fermo sotto alla luce.

Reminder_ Intro_help

per favore muoviti verso il fascio di luce con le farfalle. <break time="1s"/>

Quando sei con il corpo sotto alla luce, fai mezzo giro su te stesso e resta fermo.

audio video1

Ora che sei alla giusta distanza dallo schermo, possiamo cominciare. Per favore, cerca di non spostarti mentre fai l'esercizio. <break time="1s"/>

Bene, l'esercizio è molto semplice.

<break time="0.7s"/>Alla fine di questo video, ti appariranno in questo schermo alcuni pannelli con delle semplici domande. <break time="0.7s"/>

Ogni domanda ha tre possibili risposte. <break time="0.7s"/>

Hai tutto il tempo che vuoi per leggere la domanda e le risposte.

Quando hai scelto quella che, secondo te, è la risposta migliore, fai il gesto del CLICK sul bottone alla sinistra della risposta scelta.

In questo modo, passerai alla domanda successiva.

<break time="1.5s"/>Ora puoi cominciare l'esercizio.

audio video2

Ottimo!

anche questo esercizio è terminato. <break time="0.7s"/>

Ormai mancano soltanto gli ultimi due esercizi. <break time="0.7s"/>

Ora passerai automaticamente al prossimo esercizio e potrai imparare a interagire con gli ologrammi. <break time="0.7s"/>

Ci risentiamo tra un po'...

help_finale

Per favore, ritorna nella posizione che avevi all'inizio dell'esercizio. <break time="0.7s"/>

Spostati sul cerchio giallo che vedi per terra davanti a te, e fai mezzo giro su te stesso, così sarai pronto per il prossimo esercizio,

EXERCISE 5

video1_EXER5

<break time="2s"/>

Con questo esercizio imparerai a muovere gli ologrammi da un punto all'altro della scena che hai davanti.

<break time="0.7s"/>

Come puoi vedere nel video, per spostare un ologramma basta puntare l'ologramma con il gesto del puntamento, e poi eseguire il gesto del click con una mano e mantenere uniti pollice e indice, quasi a voler trattenere l'ologramma tra le dita.

<break time=".7s"/>

Poi, sempre tenendo le dita unite, muovi la mano a destra o sinistra e vedrai che l'ologramma seguirà il tuo movimento. <break time="1s"/>

Facile, no? Adesso prova tu.

<break time="1s"/>

Nella scena che vedi, devi spostare la tazza alla tua destra sopra al cerchio azzurro sul tavolo alla tua sinistra. <break time="1s"/>

Comincia pure quando vuoi.

intro_2a_parte_EXER5

<break time="2s"/>

Figure 33: Sample pages with the monologues used by Elektra in the exercises created in the Testing Area. In the lower-left box, the text-to-speech audio file created by processing the textual monologue "audio video1" in Exercise 4.

- *texts with plans of action*, similar to the texts of a stage play. Together, these texts can be considered as a form of narrative [134], since they provide instructions on how to manage one or more successions of events (for example, how to navigate from one scene to another (see Section 4.3.2.3), or from one content micro-unit to another (see Section 4.3.3.1) of the Augmented Environment), or provide descriptions of the different scenes, or of the different content micro-units of one scene.

Overall, these scripts contain more or less detailed descriptions of "what is going on", at any given moment, on the augmented stage. We extensively used this type of script in the Testing Area for the description of the exercises therein contained. Section 5.3.1.4 contains the full scripts of all the exercises in the Testing Area.

- *scripts* meant as *lines of code* written in a *scripting language*. In our project, we have used this type of script to add particular functionalities and/or behaviors to the holograms we created in the Learning Augmented Environment (for example, by using a simple script such as the one shown in Figure 34, we can tell a hologram to rotate on the x and y axes with different speeds – we used this script to rotate the holograms in Exercise 1 and Exercise 2 in the Testing Area – see Section 5.3.1.4). The scripting language we used to write these scripts is *C#*.

AutoRotate.cs

```
using UnityEngine;
using System.Collections;

namespace RockVR.Video.Demo
{
    public class AutoRotate : MonoBehaviour
    {
        public int rot1 = 100;
        public int rot2 = 50;

        // Use this for initialization
        void Start()
        {

        }

        // Update is called once per frame
        void Update()
        {
            // Rotate the object around its local X axis at rot1 degree per second
            transform.Rotate(Vector3.right * Time.deltaTime * rot1);

            // ...also rotate around the World's Y axis at rot2 degree per second
            transform.Rotate(Vector3.up * Time.deltaTime * rot2, Space.World);
        }
    }
}
```

Figure 34: A script that, when added to a hologram, makes it rotate on its x- y axes.

It should be noted that even though, for our project, we wrote many of such scripts, we did not write them during the pre-production stage. Indeed, writing code is one of the main activities carried out during the *production* stage. If we mention here this type of script it is just to emphasize the difference between the first two types of script, described above, and this latter type.

Request for approval of a research protocol

All research projects involving humans presented by academics and research groups of the University of Trento must be reviewed by an Ethical Committee and receive approval. Since the test with the HoloLens involves two groups of participants (students from the University of Trento, and older adults), as described in Chapter 7, we had to produce a formal document, the *Request for approval of a research protocol*, containing the detailed description of our project, and many formal statements (such as the *Privacy Notice* statements, or statements on the processing of personal and sensitive data, and so on), so to allow the Ethical Committee to conduct an in-depth examination of the research project and of its ethical implications, and take a decision on whether to provide an approval of the project.

Aware of the complexity of such document, we started working on it since the first stage of development. When the development of the prototype of our Learning Augmented

Environment was almost completed, we submitted the final version of the document to the Ethical Committee, and we later obtained the approval of our project.

The complete *Request for approval of a research protocol* submitted to the Ethical Committee can be found in the **Appendix C1**.

5.2.3.3 Stage 3: Production

This is the stage it took the longest time to complete. We will not talk here about the production stage, since a much more detailed description of what we did during this stage can be found in Chapter 6, which is entirely focused on the development and implementation of the prototype of our Learning Augmented Environment.

5.2.3.4 Stage 4: Iteration & Revision

We saw that revision is a continuous iterative process, made up of many small changes to the code, or the holograms, and the environment, backward and forward, from the design to the prototype, and back to the design, looking for ways to continuously improve the overall quality of the Learning Augmented Environment. To account for such small and continuous changes is clearly a demanding and somehow unnecessary task, so we will not even try to deal with it.

There are, however, at least two key elements of the Learning Augmented Environment that, during the process of revision, went through some major and clearly visible changes, and we are more easily able to document such changes. We are talking about the main navigation interface, the *menu*, and *Elektra*, the virtual assistant helping out the user to orient himself during his immersive experience in the Learning Augmented Environment.

We will examine more extensively the interfaces of our Learning Augmented Environment later in this Chapter (see Section 5.3.1.3). In this section, dealing with revision, we would like to add just a few words to summarize the changes we introduced to the menu and to Elektra during the process of development.

The Old Menu-Bar and the New Navigation Interface

When we started working on the interfaces of our Augmented Environment, we decided to use a navigation interface very similar to the menu-bars usually used in websites: a few clickable buttons, horizontally aligned, one next to the other, all floating in an area in front of the user (see Figure 35, left). It was simple, and users could easily understand how to deal with it. However, as the development progressed, and the number of scenes making up the Learning Augmented Environment started growing, we realized that the navigation bar we initially choose was not as efficient as we thought.

Then, during the revision process, we decided to abandon any reference to the Web and websites, and we re-designed the navigation interface by focusing on a different navigation strategy that, in a 3D space, could easily manage the growing number of scenes (and links). The new navigation menu can be seen on the right side of Figure 35.

Figure 35: Revision of the navigation interface: a simple navigation bar and a panel with lists of vocal commands (left) were changed into a more complex and visually appealing menu (right) with a main panel (center) surrounded by several retractable sub-panels (visible only when required) allowing separated navigations in the different areas of the Learning Augmented Environment.

Elektra: One Virtual Assistant and Three Avatars

Elektra is a virtual assistant, a human-sized avatar, capable of limited forms of interaction with the user, the holograms, and the environment (i.e., she can detect the user's position and turn or move toward the user when talking, she can hand holograms to the user, she can place holograms next to/on real objects, and so on).

The changes she went through are even more extensive and radical than the changes we applied to the menu. We developed the first version of Elektra (Elektra_1) while we were in Japan, working at the *Interactive Media Design Lab*, at the Nara Institute of Science and Technology. At that time, we thought we could run the test that we describe in Chapter 7 with a group of Japanese older adults. And that is the reason why we first provided Elektra with an “Eastern look”, with Eastern facial traits and a traditional dress (see Figure 36, avatar on the left).

When we realized that we could not run the test in Japan[2], we worked on Elektra’s appearance, so to provide her with a Western look (Elektra_2). This first change was mostly visual: we maintained Elektra_1's avatar (i.e., Elektra_2's avatar has the same functionality, capabilities and limitations of Elektra_1's avatar), but we provided her with a new face with Western traits, and new clothes (see Figure 36, avatar on the middle).

The third and (for now) last change we introduced in Elektra was more important and demanding. We did change again Elektra’s appearance, so to make her look less cartoon-like and more human and natural (see Figure 36, avatar on the right). However, this time we also completely changed Elektra’s avatar, so to be able to provide Elektra_3 with more fluid and natural movements, and, most important, with the ability to move her eyes and facial muscles, so to assume a variety of facial expressions, and to synchronize her lips movements with the words she speaks out while interacting with the user.

Figure 36: Revisions of Elektra, the virtual assistant: from the first cartoon-like avatar (left) to the more sophisticated and human-like avatar (right).

5.2.3.5 Stage 5: Finalization

As we saw in 5.2.2, the activities carried out during the finalization stage are focused on cleaning and polishing the alpha version of a game, in order to move on to a beta version, and later to a gold master (and final) version of the game, ready to be released to the public.

At the moment of this writing, we have not yet reached this stage. Or, at least, we have not reached this stage with the general version of our Learning Augmented Environment. It is

[2]Indeed, it became soon evident the existence of a linguistic problem hard to overcome: it resulted quite difficult to maintain the control on the development of a prototype in which all the written and spoken texts, included those spoken out by Elektra, had to be translated and/or processed into Japanese, a language that we do not speak or read. So, we decided to run the test in Italy, with an Italian group of older adults.

fully working, but cannot be considered *feature complete*, since it does not yet provide the user with the contents of the Learning Modules.

On the other hand, we have reached the finalization stage with what, in the game developer jargon, is called a *vertical slide* of the Learning Augmented Environment [131], that is, a fully working, *and* feature complete sample of the immersive experience provided by the Augmented Environment to the user wearing the HoloLens. The vertical slide we are talking about is the *Testing Area*, an area originally conceived to host the usability test and that, in recent times, was expanded, to become something larger than a simple area containing the test, and more ambitious. Indeed, at the time of this writing, the Testing Area still contains the usability test described in Chapter 7. However, it also contains many additional features, not strictly necessary to the test, that enrich the immersive experience and make it more interesting and entertaining. From this perspective, we like to think of the actual Testing Area as a good, first-hand introduction to Augmented Reality.

Section 5.3.1.4 in this Chapter, Chapter 6, and Chapter 7 provide a detailed documentation on how we designed, produced, tested (see Figure 37), revised and cleaned up the Testing Area. The app that we developed and deployed onto the HoloLens can be considered as a fully working, *feature non-complete* version of the general Learning Augmented Environment, containing a fully working, feature complete, and mostly cleaned beta version of the Testing Area.

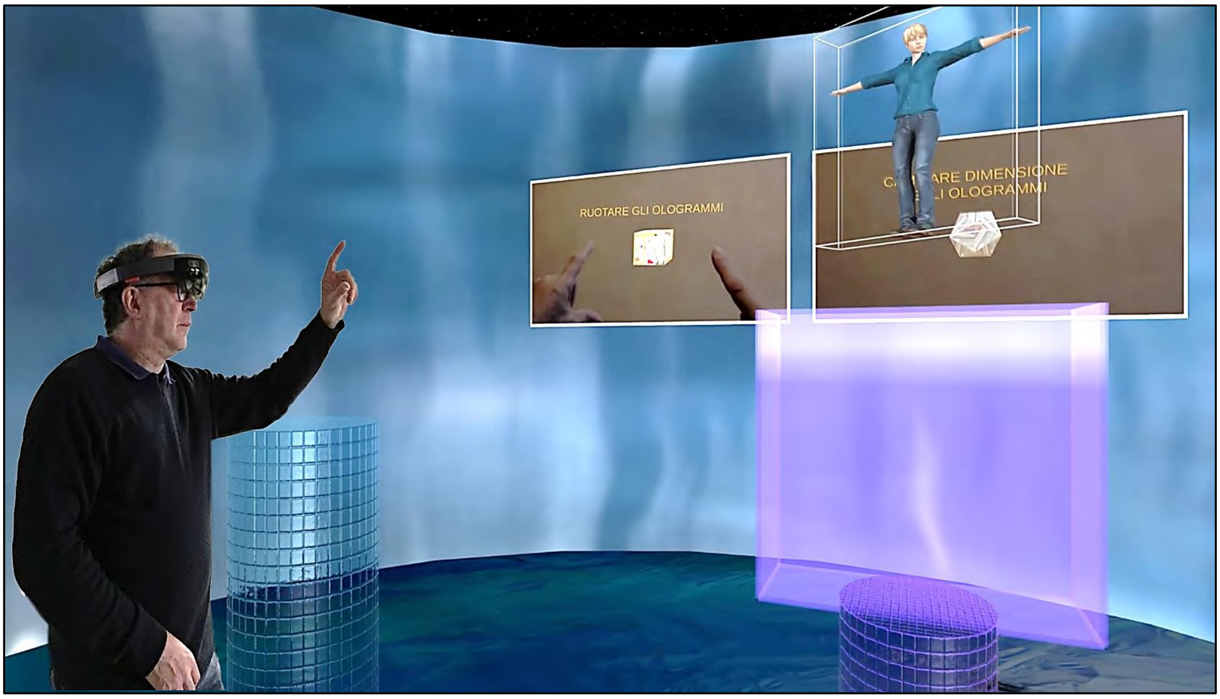


Figure 37: The author of this work wearing the HoloLens and testing the "feature complete" version of the Testing Area. The Testing Area is part of the immersive Learning Augmented Environment generated by the app for Augmented Learning.

5.3 The Design of the Learning Augmented Environment

In the following sections, we will examine more in detail the features of some of the components listed in. *Table 2*.

However, as explained in Section 5.1.1, we will maintain the separation between the *design of the general Augmented Environment*, that will be discussed in Section 5.3.1, and the *design of the Learning Modules*, that will be discussed in Section 5.3.2.

Particularly, Section 5.3.1.1 will shortly analyze the general features of augmented environments that will be considered during the design of our Augmented Environment, while Section 5.3.1.2 will examine in detail the design and features of the *Virtual Room*, a basic, but fundamental component of our Augmented Environment. Section 5.3.1.3 will deal with the design of the interfaces that will help the user to find his way during his immersive experience within the Augmented Environment. Finally, Section 5.3.1.4 will focus on the design of the Testing Area.

As for the design of the Learning Modules, Section 5.3.2.1 and Section 5.3.2.2 will explain how we will proceed to select and organize the learning material that we will use in the Learning Modules. Finally, Section 5.3.2.3 and Section 5.3.2.4 will show the overall design of the Learning Modules, and describe the work necessary to allow their integration within the Learning Augmented Environment.

5.3.1 PHASE 1: THE DESIGN OF THE AUGMENTED ENVIRONMENT

5.3.1.1 General Features of Augmented Environments

As we said, during the design of our Augmented Environment, we want to take full advantage of the features of AR environments to create an Augmented Environment capable of expressing its full potential only as the emerging product of an AR application running on an HMD [83], [6], [86] [94].

Particularly, as we have already seen in Chapter 4, we require our Augmented Environment to be:

1. Immersive
2. Three-Dimensional
3. Augmented (that is, capable of seamlessly combining the real and virtual worlds) in real-time (so that, as the user moves around the real world, the virtual world constantly re-adapts itself to the real world)

The above features are the basic ones − and the most important ones – of any immersive augmented environment. However, we also want our Augmented Environment to have some *extra-features*. Although they are not essential to define augmented environments, they should contribute to increase the user's comfort and sense of familiarity with the augmented world, and should make the learning experience easier and more enjoyable, especially when the users are – as in our case – older adults with little familiarity with technology:

- the Augmented Environment should be designed in such a way that it does not require users to know the technology involved in the creation of the Augmented Environment;
- the Augmented Environment should allow an easy access to its objects and contents (i.e., the interfaces allowing orientation and navigation should be easy to understand and use);
- the Augmented Environment should be easily adaptable to the needs of different types of user (i.e., if necessary, hand-gesture commands controlling interaction can be replaced by vocal commands, and so on);
- Overall, the Augmented Environment should be designed to:
    a. facilitate the learning of visual contents;
    b. encourage the process of "learning-by-doing";
    c. increase the users' involvement and enjoyment in the process of learning;
    d. strongly connect the users' personal experience to the contents to be learned.

Keeping all the above in mind, in order to come up with a design for our Augmented Environment we worked on:

- the definition of the main augmented environment (main module, hall/entrance);
- the definition of the criteria allowing the modularization of the Augmented Environment (i.e., how can the Augmented Environment be divided into sub-spaces/modules);
- the definition of the general features of the modules;
- the definition of the criteria allowing the duplication of the modules;
- the definition of the criteria allowing the modules to be connected one another;
- the definition of the criteria allowing the existence of the virtual objects (holograms) within the general Augmented Environment;
- the definition of the overall rules managing the different forms of interaction among the virtual objects, the user, the real world.

The result of our work is a complex virtual object – we called the *Virtual Room* – that embeds all the properties and features of augmented environments that we have examined so far. Section 5.3.1.2 will deal with the details of the Virtual Room.

5.3.1.2 The Basic Unit of the Augmented Environment: the Virtual Room

Once we have identified the features of the main components involved in the design of the Augmented Environment, we can now see how those components can be integrated into the general design of the Augmented Environment.

The key concept, and the basic unit of the Augmented Environment is the *Virtual Room*. The whole Augmented Environment has been designed and developed around the Virtual Room.

Despite its apparent simplicity, the virtual room is a complex, very flexible, and powerful virtual object displaying the most important features of augmented environments, and we consider it as the core element of our Augmented Environment. Therefore, it seems appropriate to examine it in detail.

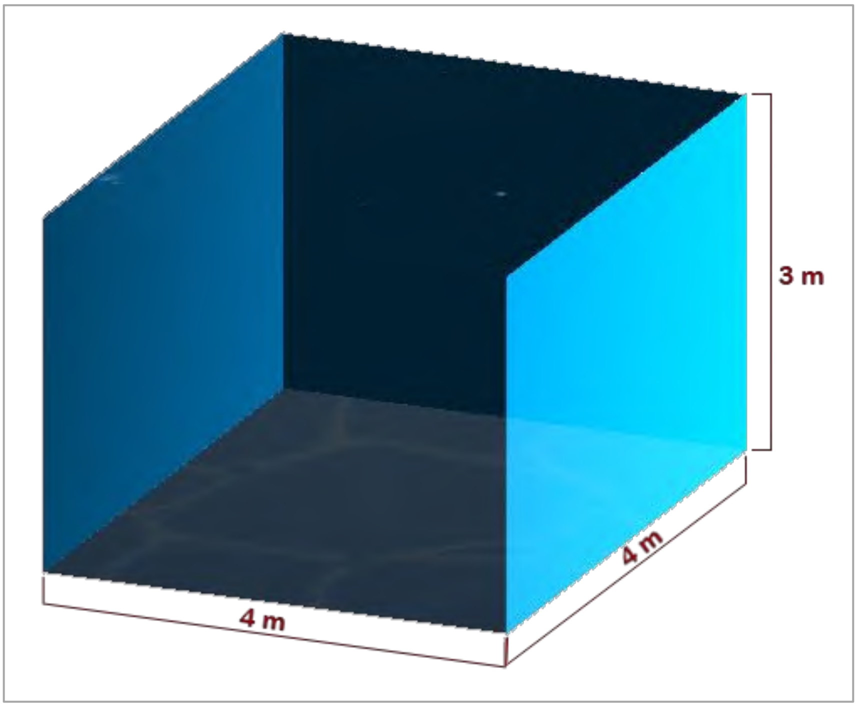


Figure 38: The Virtual Room(the front wall and the ceiling have been removed from the image)

As we can see in Figure 38, the virtual room is, first of all, a hologram shaped like a regular, squared real room, made of 4 virtual walls (4 meters large by 3 meters tall), a virtual ceiling, and a virtual floor (in Figure 38, the ceiling and the front wall have been removed to improve clarity). So, like a real room, the virtual room is a three-dimensional and immersive object.

As a matter of fact, the virtual room *is* an augmented environment delimited by its walls. And it is within the virtual walls of one virtual room that all holograms exist, and can be perceived by the user wearing a head-mounted display.

Here below, we describe some of the main features of the Virtual Room:

- Each Virtual Room is a *scene*, as seen in 4.3.4.1.
- Each scene is entirely self-contained, so that its content can be considered as autonomous.
- Each scene contains all the interfaces described in 5.3.1.3. While the interfaces do not change their general appearance and functionalities (in terms of shape, layout, color, etc.), they can change their positions within the scene (i.e., some panels change their position, and they can also change their visibility status (the user can turn them on/off using gestures and/or vocal commands). Finally, the interfaces do change their content to fulfill the local needs (help, configuration, navigation) defined by the designer for each scene.
- Each scene is designed in such a way that it can contain any kind of hologram, in any possible position within the scene, and with any possible behavior. The number of holograms contained in each scene is limited only by the computation power of the device hosting the app generating the Augmented Environment (in our case, the HoloLens that, when in overload, simply shuts off the visual component of the augmented world).
- Each scene is designed in such a way that it can contain any kind of sound-object (voice, noise, music). Any sound-object can be placed in any possible position within the scene, and can also be connected to any hologram in the scene. All sound objects in a scene contribute to define the Sound Space of the scene.
- Each scene can be easily duplicated, and the newly created scene maintains all the properties of the scene it has been duplicated from;

A whatever augmented environment can be made up of as many Virtual Rooms as necessary to fulfill the purpose set by the designer, and according to the general scope the Augmented Environment has been created for. The number of Virtual Rooms that can be created within one augmented environment is limited only by the storage capability of the device running the app generating the augmented environment (in our case, the HoloLens).

Each Virtual Room is connected to one or more Virtual Rooms by means of the navigation interfaces, so that the entire Augmented Environment is made up with a variety of Virtual Rooms organized according to a hierarchical structure similar to the one shown in Figure 39.

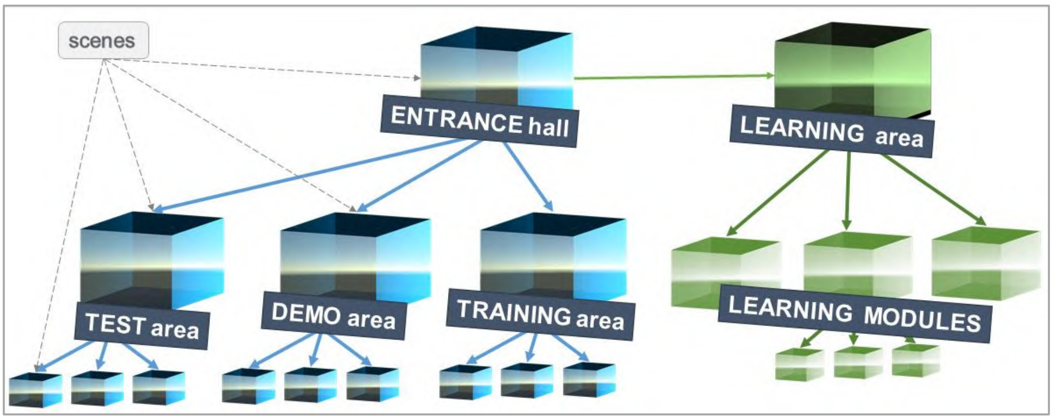


Figure 39: The Augmented Environment is made up with a variety of Virtual Rooms

It should be noted that the user of an augmented environment created according to the criteria defined above is not involved in, and does not perceive –nor does need to perceive – any form of motion – real or virtual – during the transition from one virtual room to another. As we saw in Chapter 4, when the user activates a navigation link, the virtual room (overlapped to the real room) the user is in simply fades away from the user's perception, and a new virtual room, with new content, takes the place of the old one. However, according to the user's perception, the user is always in the same room – the real room – which is augmented with virtual contents that change from time to time.

While talking about the virtual room *overlapped* to the real room the user is in, there is one additional, very important feature of the Virtual Room that we should pay attention to: the virtual room can re-shape itself to account for the existence of the real environment. This feature is strictly connected to the capability the virtual room has of *augmenting reality* − one of the fundamental features of augmented environments − that is, the ability to seamlessly combine real and virtual worlds in real time (see 5.3.1.1).

At first, when the virtual room is generated by the app running on the head-mounted device (the HoloLens), it has no connection with any real room or environment. It only exists as a digital object floating in a digital space. However, the newly generated virtual room immediately begins to interact with the hardware of the head-mounted device (i.e., with its space tracking system). In a short time, by using the spatial maps generated by the device during the scanning process of the environment where the user is in, the virtual room is capable of reshaping itself to match the shapes of the real, scanned environment. Figure 40-Figure 48 show this process in detail.

Figure 40 shows the basic unit of the Augmented Environment: a *Virtual Room* capable of containing any type of virtual object with any behavior.

The virtual room has a fixed (and invisible to the user) "reference element" (here represented as a red square) placed at the center of one of the virtual walls.

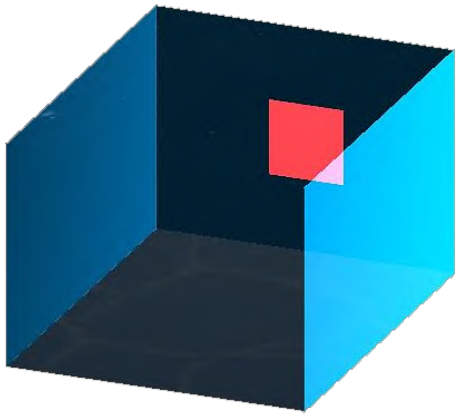


Figure 40: The basic component of the Augmented Environment: the Virtual Room

Figure 41 - The position of one virtual objects existing in the virtual room is relative to the reference element (for example, if the reference element has coordinates (Xr, Yr, Zr) the virtual object V1 will have coordinates (Xr +/- C1, Yr + / - C2, Zr +/- C3) where C1, C2, C3, are values assigned to V1 during the design of the scene).

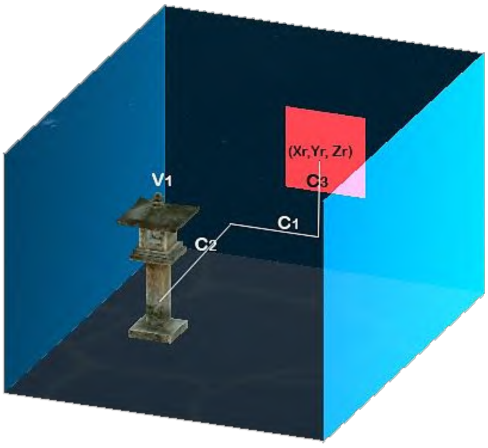


Figure 41: A virtual object in the virtual room

Figure 42 - When the app starts running asks the HoloLens to scan the real environment where the user is in, and to creates different maps of the environment similar to those shown in the figure.

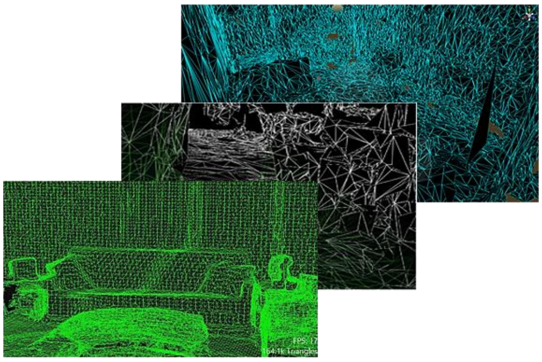


Figure 42: Maps of a real room created by the HoloLens during the scanning process of the room.

Figure 43 - Figure 44 - Once the scanning process is completed and the maps of the real environment (in the figure, the room on the right) have been created, the virtual room (and all the holograms therein contained) is rotated and moved until the virtual wall containing the reference element completely overlaps the real wall (in yellow) that was in front of the user when the HoloLens mapped the environment.

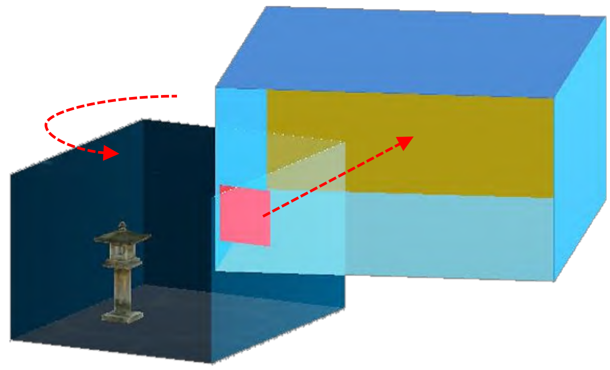


Figure 43: The virtual room (left) and the scanned room (right)

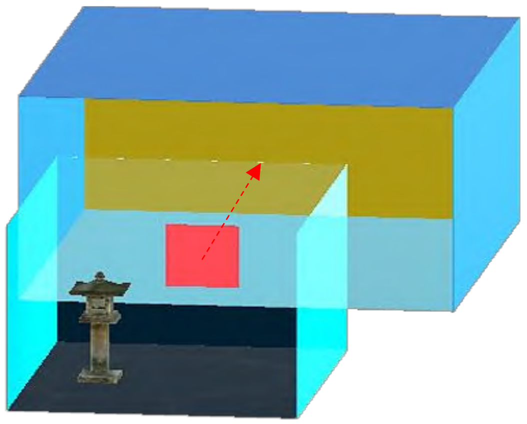


Figure 44: The virtual room aligning itself with the real room

Figure 45 - Once the virtual room is aligned with the real room, it re-sizes its walls to match the size of the walls of the real room.

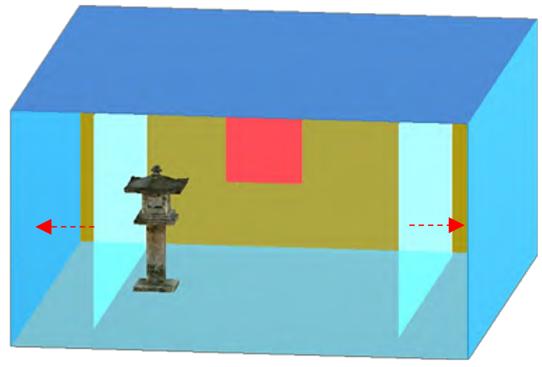


Figure 45: The virtual room resizing itself to match the dimensions of the real room

Figure 46 - Now, the real room and the virtual room completely overlap, and the reference element is centered on the real wall in front of the user.

From this moment, and for the rest of the immersive experience in the Augmented Environment, the virtual room, as well as all the other virtual rooms of the Augmented Environment, will stay locked in this position.

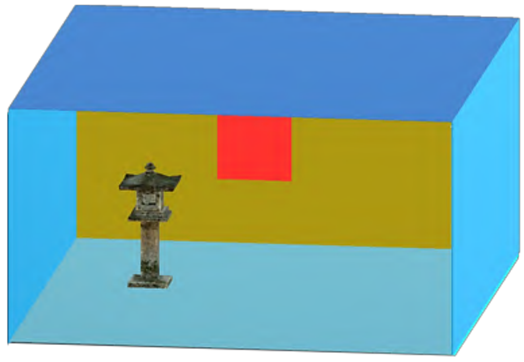


Figure 46: The virtual room and the real room perfectly overlapped

Figure 47 - If, during the scanning process of the real environment, obstacles and vertical or horizontal planes (such as chairs, tables, couches, etc.) are detected, such obstacles and planes are included in the maps of the room.

If necessary, all virtual objects in the virtual room (which, so far, have maintained their positions relative to the red reference object), adjust their positions to take into account the presence of the obstacles or planes included in the maps of the room. For example, let us say that, by design, the virtual object V_1 was set to be at a certain position (where the real chair is). Since V_1 finds out that that position is already taken, it will move away from the chair, looking for a new position, as close as possible to the original position.

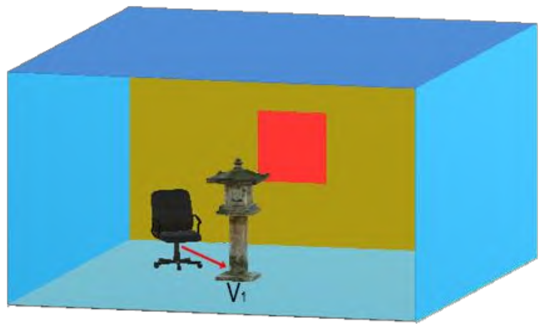


Figure 47: A virtual object moving away from a real object (the chair)

Figure 48 - In some other cases, virtual objects are free to move onto, or next to horizontal and vertical planes previously identified within the real environment (for example, a virtual panel, a virtual picture, or a virtual video player can hang on one real wall, a virtual desk lamp can stand on a real table, and so on).

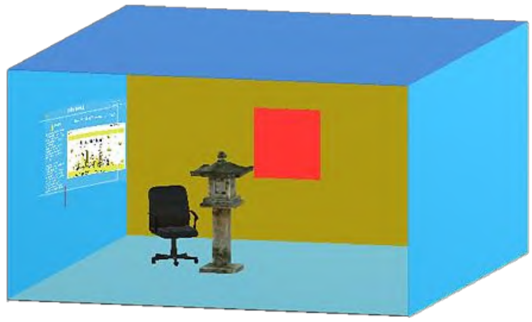


Figure 48: A virtual object (the help panel) hanging on a real wall (left)

It should be clear now why the Virtual Room is the key component of the Augmented Environment. The virtual room is exactly what we need if we want to satisfy that separation of concerns we previously talked about. In fact, a virtual room can exist independently from the existence of any type of content. This means that, if we use the virtual room as the basic component of any sort of augmented environment, we can easily create many new and autonomous augmented environments, with any desired number of virtual rooms, that are connected one another according to a whatever pattern we choose. These augmented environments will be fully working (i.e., they will be immersive and navigable; they will be aware of the real environment the user is in, and they will be responsive to it; they will be predisposed for a lighting system and an audio system, and so on), even though their virtual rooms are completely empty (with the exception, of course, of the interfaces).

The primary content of a whatsoever scene – all the holograms, as well as the narratives (the scripts) used in the scene to manage the temporal, spatial and acoustic organizations of the holograms within the scene – can be defined, designed, and developed at a later time (on paper, with Unity, or with a 3D modeling software), and placed within the empty virtual rooms only when it becomes convenient to do so.

As we saw in 4.3.4, in order to define, organize and manage the holograms belonging to one scene, as well as their behaviors, we can refer to and use the many studies on disciplines such as narratology, narrative, or specific semiotics that study different systems of significations, such as semiotics of theater, semiotics of film, of video and video clips, semiotics of visual communication, semiotics of visual arts, semiotics of photography, semiotics of music, semiotics of marketing, textual semiotics, semiotics of news, and so on. Or we can also refer, as we do in 5.3.2, to the studies on Instructional Design, to understand how to organize and manage learning material (on this, see next section in this Chapter).

The only thing we need to keep in mind while working with the contents of a scene is that these contents will end up being contents of an augmented environment, and will therefore need to display the properties and features of virtual constructs. In the next sections (particularly, in Section 5.3.2.3 and Section 5.3.2.4, focused on the design of the learning experience that our Learning Augmented Environment should offer to its users) we will talk more extensively about this.

5.3.1.3 The Design of the Interfaces of the Augmented Environment

In what follows, we want to focus our discourse on another important area of our Augmented Environment: the *interfaces*. In Chapter 4, we saw that augmented environments can be thought of as complex, digital multimedia texts. And we also saw that the interfaces, as *paratextual* elements (see 4.3.3), can be separately analyzed and designed with the methodologies defined within the domain of Human-Computer Interaction.

With the help of a few studies, such as the Macintosh Human Interface Guidelines [135], Cosenza [100], De Souza [105], LaViola [136], Liarokapis [85], Murray [98], Odom [34], we designed the interfaces of our Augmented Environment that we are going to show in the next sections.

It should be noted that, while working on the design of the interfaces for our Augmented Environment, we had to always keep in mind one of the fundamental features of augmented reality: since the user of an augmented world can freely move within the real environment, the virtual component of the augmented world must constantly (in real-time) and seamlessly combine (that is, re-shape, re-adapt) itself with the real component of the augmented world. And since the interfaces are part of the virtual component of the augmented world, they themselves have to constantly re-shape and re-adapt to the real world.

An example can help to better understand this important aspect of interface design for augmented environments. Let us suppose that a user of an augmented environment is in a real room with a large (real) bookcase in the middle. At a certain moment, he moves in front of the bookcase, at about 2 meters away from it (see Figure 49). What happen to a virtual help panel that, according to the design, is supposed to float in the augmented environment, in front of the user, and at a fixed distance (2.5 meters) from the user? Is the help panel going to be hidden by the bookcase (see Figure 49-A), as it would happen to a real, physical panel in that real room (in which case, however, also the information contained in the help panel is going to be hidden)? Or is the help panel going to jump closer to the user (for example, at 1.5 meters away– see Figure 49-B), so that the information in the help panel is still visible to the user (in which case, however, the panel is no longer entirely visible within the field-of-view of the head-mounted device, so that the user is forced to move his head to the left and to the right to completely read/view the information contained in the help panel)?

The situation presented in this example clearly shows the problem an interface designer must deal with when designing interfaces for augmented environments. The designer working with any kind of augmented environment must always take into account the existence of the real world, which is constantly changing according to the movements of the user of the augmented environment. So, the interfaces of the augmented environment must be designed in such a way that, as the real-world changes around the user, they can re-shape themselves, and change their behavior so to maintain in the user the illusion of living in one single (and augmented) world. (On this, we found many helpful suggestions in Ong, Chapter 8: *Deign and Magic: Best Practices for Design* [35].)

For an additional analysis on this topic, see 5.3.4.

Figure 49: A challenging situation for the interface designer dealing with augmented environments: when a real obstacle (the bookcase) is in the middle of a room, the interface designer must decide in advance how the interface (a simple help panel) will deal with the obstacle. The help panel can either (A) ignore the existence of the obstacle, and maintain a fixed distance from the user (which has been set during the design), or (B) acknowledge the existence of the obstacle and, consequently, move beyond the obstacle, and closer to the user.

Keeping the above recommendation in mind, we designed for our Augmented Environment 3 different types of interface that serve different purposes:

- **Help interfaces**: they help the user with general and local information on many aspects of the Augmented Environment and its Learning Modules. Through the help interfaces, no matter which virtual room the user is in, he is always able to know where he is, and what he can do.
- **Navigation interfaces**: they allow the user to move from one virtual room to another, and, more in general, throughout the whole Learning Augmented Environment.
- **Configuration interfaces**: they allow the user to adjust and personalize some aspects of the immersive experience (visual, acoustic), so as to make it as easy and enjoyable as

possible.
It should be noted that, while we plan to use the configuration interfaces in the final version of the Learning Augmented Environment, we do not use any of such configuration interfaces in the prototype.

5.3.1.3.1 Help Interfaces

We designed 3 different types of help interface:

Elektra: the Virtual Assistant

We already introduced *Elektra* in Section 5.2.3.4, where we discussed about the changes Elektra's avatar went through during the process of development and revision of our Augmented Environment.

Here, we summarize the features of the latest, most evolved and complex Elektra's avatar:

- Elektra is a virtual assistant, a human-sized avatar (see Figure 50, Figure 51, and Figure 52) with synthetic voice, a set of gestures normally used in conversations, a set of facial expressions, eyes movements, and the ability to synchronize the movements of her lips with the words she pronounces.
- Elektra's clothes and hair can be changed to provide her with different looks (see, for example, the Exercise 6 in the Testing Area. The video (Section 6.3.2) and the images from Exercise 6 (Figure 61) show two different Elektras with different clothes and hair).
- Elektra can be considered as a more entertaining and friendly addition to the *Help Panel* (see following sections). She talks to the user and provides him with general and local (additional) information on where he is, what he can do, and where he can go.
- Elektra is capable of limited forms of interaction with the user and the environment (i.e., she can detect the user's position and turn or move toward the user when talking, she can hand holograms to the user, she can place holograms next to/on real objects, etc.).

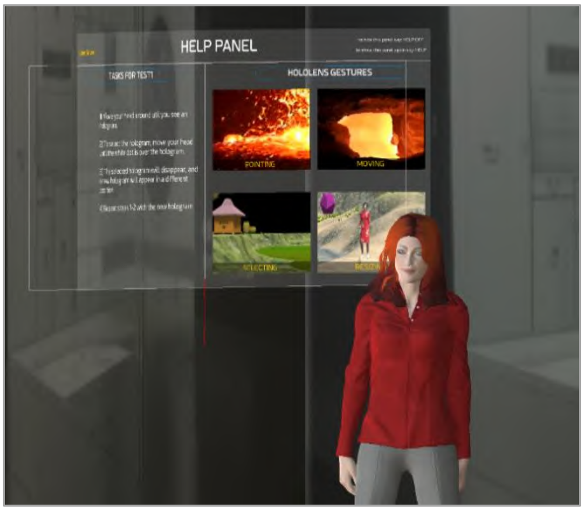


Figure 50: The second version of the Virtual Assistant Elektra explaining the features of the Help panel.

Figure 51: Elektra showing a video wall for the ICT DAYS 2019 at the University of Trento.

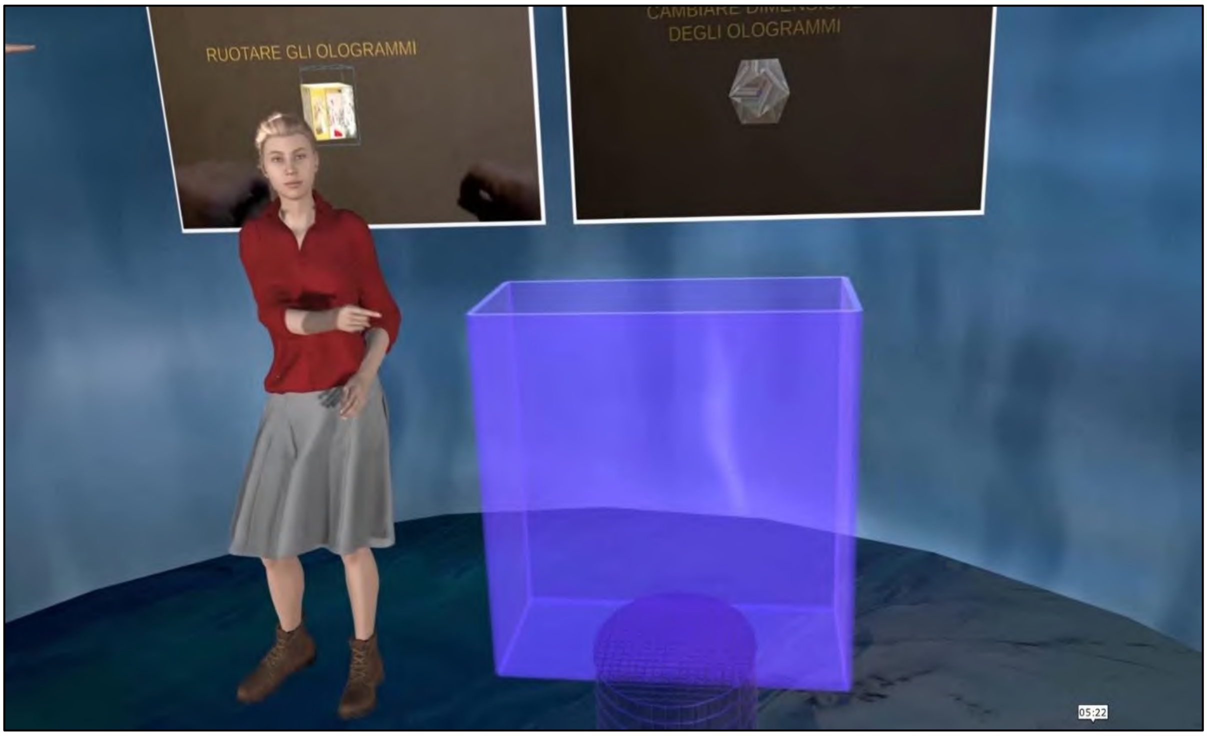


Figure 52: The latest version of Elektra explaining how to solve one exercise created in the Testing Area.

Panels

- *Panels* provide the user with simple descriptions or instructions on how to fulfill a single task (*how to continue the immersive experience, how to start or stop an activity, how to perform a gesture*, and so on).

- The information shown in panels is multimedia (texts, images, videos, buttons, interactive holograms).
- Panels come in different sizes, depending on the amount of information they show.
- Depending on their purpose, panels might float in the space in front of the user, at an apparent distance of 2 meters, or might hang on/next to holograms.

An example of a panel is shown in Figure 53.

Figure 53: A panel in one of the exercises in the Testing Area explaining what to do to move on to the next exercise. The panel also contains the virtual assistant Elektra (avatar version n°2); she provides the user (through her voice) with the same instructions that the user can find written on the panel (in visual form).

Help panel

- The *Help Panel* (see Figure 54) provides extensive information on many aspects of the Augmented Environment and its Learning Modules.
- The Help Panel is always on the left side of the user, hanging on the real wall of the real environment the user is in (see Figure 48).
- The information contained in the Help Panel is multimedia (texts, images, videos, buttons, interactive holograms).
- Contrarily to what happens with the other panels, the information contained in the Help Panel changes from virtual room to virtual room, so that the user can always be updated with help information on the virtual room he is in.
- The Help Panel can be turned OFF (not visible) or ON (visible) by means of *vocal commands* (see 5.3.1.3.1: Navigation interfaces)

Figure 54: The Help Panel in one virtual room in the Testing Area with instructions on how to perform a gesture necessary to complete an exercise (left) and a video showing the gesture (low-right) + training area to train on the gesture before starting the exercise (top-right)

5.3.1.3.2 Navigation Interfaces

We use two navigation systems in our Augmented Environment:

A *Visual navigation system*

In Section 5.2.3.4, we have already introduced the *menu*, a visual navigation system we designed for our Augmented Environment. It is an interactable menu with buttons, hanging in front of the user at an apparent distance of 2 meters (see Figure 55 – the *main menu* is the central menu with blue buttons).

- At any moment, the main menu can be turned OFF (not visible) or ON (visible) by means of *vocal commands* (see next paragraph, the vocal system for navigation).
- The user can activate the buttons in the menu by performing on each button 2 simple gestures that are recognized by the HoloLens (SELECT HOLOGRAMS + CLICK ON HOLOGRAMS – see Section 5.3.1.4 for more information on the gestures used in the AE).
- The main menu contains several buttons with the names of the different areas available in the Augmented Environment. The selection (activation) of one area makes a new sub-menu to pop-up (see, for example, the green sub-menu on the left in Figure 55, allowing the user to access the different exercises in the Testing Area).
    - Each sub-menu shows the navigation options (the different scenes the user can go to) available for the selected area.
    - Once the user clicks on one button, he is moved to the selected scene (the virtual room the user is in is discarded, and the selected virtual room becomes visible around the user).

A *Vocal system for navigation and control*

The Augmented Environment uses voice inputs to control navigation (e.g. *go to scene-name,* or, simply, *scene-name*) and to command the behavior of holograms (e.g. *activate/stop/show/change color of hologram-with-a-name*, and so on).

- The vocal system for navigation and control can be used as an alternative to the visual navigation system, to speed up both the navigation and the control of holograms. In addition, it can result very useful to users with vision impairment.
- A *vocal commands reminder panel* (see the panel on the top in Figure 55) with a list of all vocal commands recognized by the Augmented Environment, helps the user to recall all the vocal commands available in the Augmented Environment. The panel is part of the visual navigation system (the menu) described in the previous paragraph. It can be turned ON (visible) or OFF (not visible) by clicking one of the buttons in the main menu.

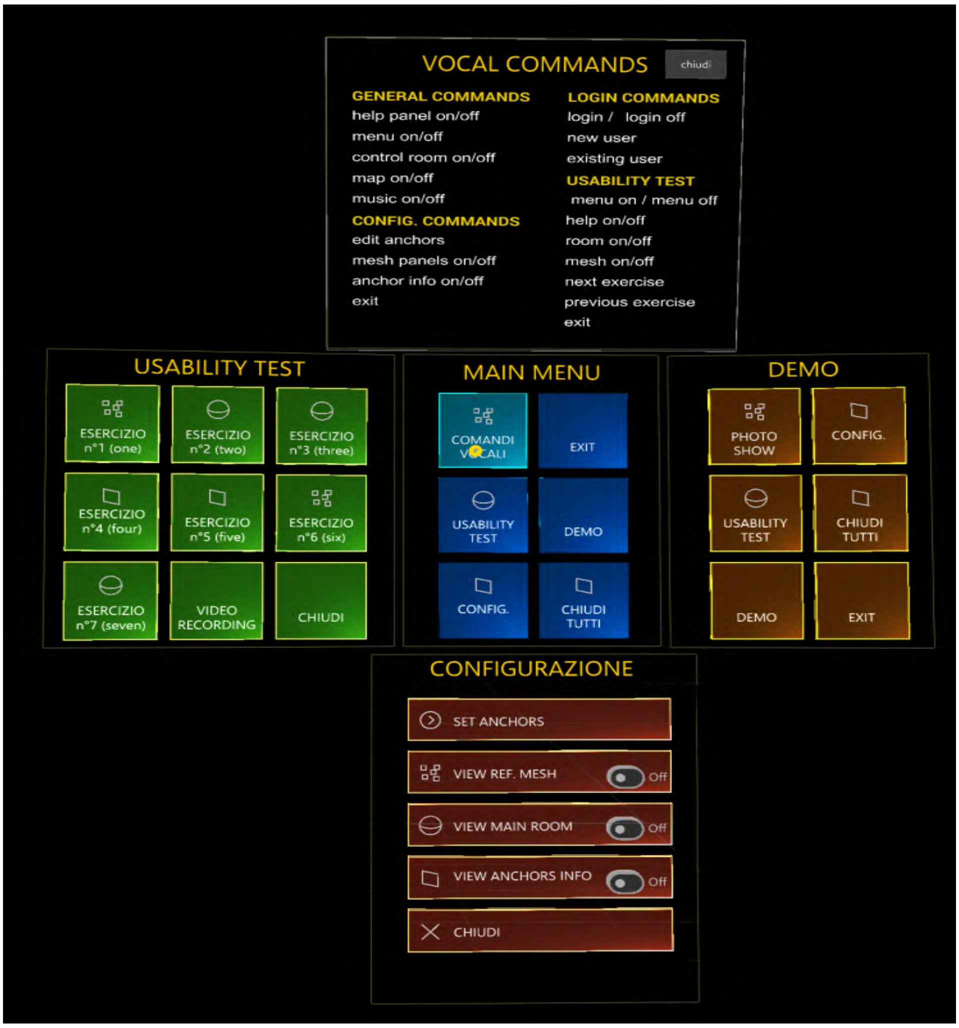


Figure 55: The main menu of the Augmented Environment and its sub-menus

5.3.1.4 The Design of the Testing Area

When we started working on the Augmented Environment, we decided that we would have mostly focused on the design and development of the general Augmented Environment. Instead, we would have worked on the Learning Modules (and on the course on how to use the computer and the digital tools), only at a later time, that is, after having administered the usability test to a group of older adults. Indeed, as we explained in the Introduction to this Chapter, only the analysis and the evaluation of the data from the test can provide us with answers to the questions: are older adults able to use augmented reality? do they show interest in augmented reality, and are they willing to use it? Only the analysis and the evaluation of the data from the test can tell us whether it makes sense to commit resources and spend more time to develop an entire course for older adults using immersive augmented reality.

Then, it has been clear to us from the beginning that we needed to include in our Augmented Environment a fully working testing area, capable of representing and 'embedding' the test through the technology of immersive augmented reality.

So, while we were still working on the design of the general Augmented Environment, we also started working on the design of the Testing Area and, at the same time, on the design of the test.

At the end of January 2020, the development of the Testing Area was almost completed, and we had defined almost all the details of the test. Chapters 6 and 7 of this work document the state of the work on the development of the Testing Area and on the definition of the test. Our plan was to complete the development of the Testing Area as soon as possible, so that we could then administer the test to a group of older adults and, subsequently, to a group of students at the University of Trento, as described in Chapter 7.

Unfortunately, the general lockdown of most of the commercial, social, scientific and cultural activities, imposed in March 2020 by the Italian Government, due to the growing pandemic of Covid-19, prevented us from administering the test as we planned.; the *Centro Socio Ricreativo per Anziani* (a Recreation Center for Older Adults located in Milan), where we had planned to administrate the test, has been closed since the beginning of the lockdown; The University of Trento has been closed, as well.

Unable to run the test and, therefore, unable to work on the analysis of the data, we decided to work on a further development of the Testing Area, and we tried to concretely experiment with some of the features of Augmented Reality that we discussed in Chapter 4.

At the time of writing (August, 2020), the Testing Area has become something larger and more complex than the basic augmented area that we originally designed to host the test. It does still contain the 6 exercises we originally planned to use for the usability test. However, it also contains many new functionalities and features that increase the perceptive and emotional impact the Augmented Environment has on the user, making the user's immersive experience more involving and entertaining. Overall, we can say that the actual Testing Area has acquired a narrative flavor, and a "theatrical mood" usually found in theatrical performances (see Chapter 4 and, particularly, Section 4.3.3.1).

We have completed the design and the development of the Testing Area, which is now fully working and integrated with the general Augmented Environment. Now, we can think of the Testing Area as a fully developed learning area. It is not large and complex enough to provide the user with a fully featured course; yet, it is large and complex enough to be the right place where to experience the usability test, as we originally planned, and, at the same time, a first-hand, and entertaining introduction to the world of Augmented Reality.

The Testing Area (see Figure 56) is divided into seven modules (the virtual rooms described in Section 5.3.1.2): one introductory module, and six additional modules, each of which contains one exercise that the user must complete.

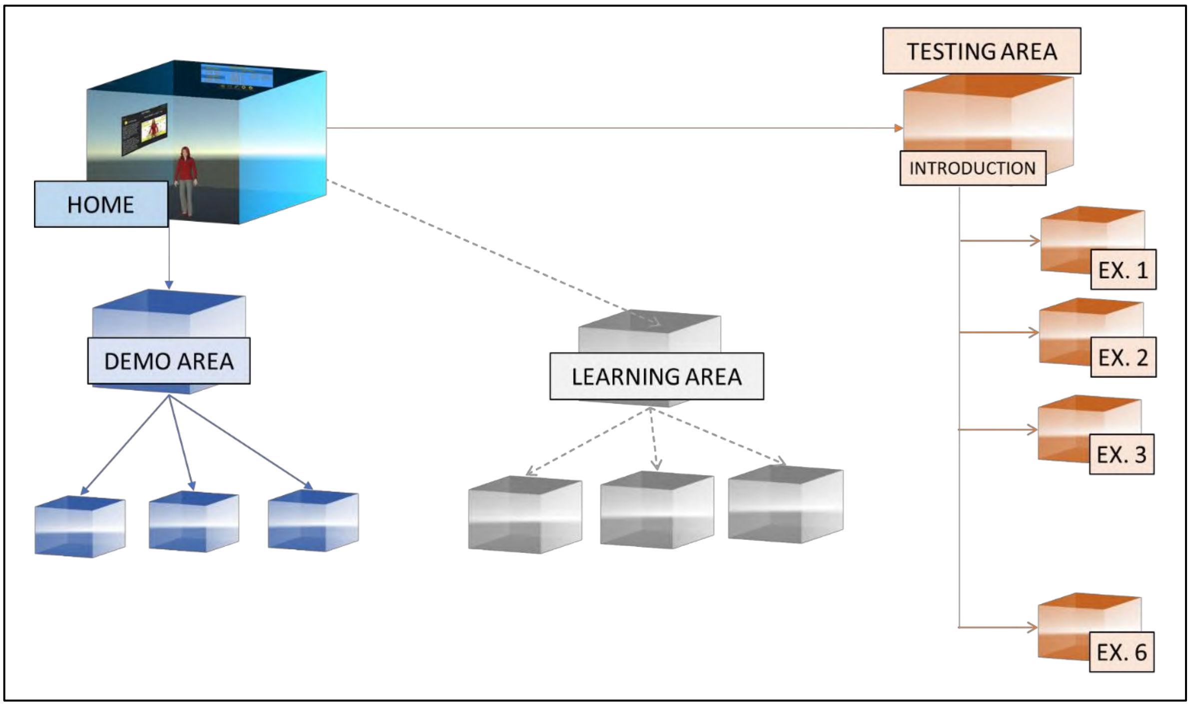


Figure 56: The Learning Augmented Environment with the Testing Area

All the exercises in the Testing Area require the user to perform some gestures with his hands to manipulate some holograms. The exercises created in the Testing Area are meant to (a) *teach* the user all the gestures necessary to manage all possible forms of interaction with holograms and (b) *test* the user on those gestures, to verify whether the user has learned them.

The user wearing the HoloLens is immersed into the first *Introductory Module*, which provides general information and explanations on the main features of the Augmented Environment and the Testing Area. From the Introductory Module, by using one of the navigation interfaces described in Section 5.3.1.3.2, the user can move on to the module containing the first exercise. When the user has completed the first exercise, he is given the opportunity to advance to the next module containing a new exercise, and so on for all the modules in the Testing Area. Upon completion of all exercises, the immersive experience in the Testing Area is completed and the user can leave the Learning Augmented Environment and take the HoloLens off.

For each exercise, audio and visual explanations about the exercise are provided. The user is given the opportunity to train on the gesture(s) that will be used to interact with the holograms in the exercise. When the user is ready to perform the learned gesture(s), he can start the exercise.

For each exercise, instructions are also provided on how to quit/leave (at any time, and for any reason) the exercise and the Augmented Environment, and on how to move on to the next exercise without having completed the current exercise.

In what follows, we provide detailed descriptions (the "**scripts**", meant as *texts with plans of action*, we talked about in Section 5.2.2.2) of the six exercises that together make up the whole Testing Area. All the modules in the Testing Area have been developed according to the directions shown in these *scripts*.

After we completed the development of the Testing Area, we recorded a few videos of the different exercises, so to allow the reader of this work to have a better (and visual) understanding of the immersive experience we created with the Learning Augmented Environment (for more information on these videos, see Section 6.3.2). So, in addition to the above-mentioned scripts on the exercises, we also provide here below a few panels with sequences of images extracted from the videos. The scripts, together with the panels, can be thought of as *storyboards* for the exercises.

It should be noted that all the panels used in the following pages to visually illustrate what is described in the scripts show a *user (*wearing a generic head-mounted display) standing or moving in the virtual rooms in the Testing Area. That user, that in the videos takes the place of the real user, has been inserted only in the videos (and, therefore, in the images extracted from the videos) to visually show the position of the real user during the immersive experience generated by the Learning Augmented Environment. We would like to make it clear that, during the actual immersive experience with the HoloLens, that user does not exist.

5.3.1.4.1 Script 0: The Introductory Module

PURPOSE
To introduce the user to Augmented Reality, to the general features of the Learning Augmented Environment, and to the immersive experience the user will have in the Testing Area

HOLOGRAMS IN SCENE

- The Room (the virtual room) – 4 walls (left, front, right, floor) are visible
- The Help Panel (on the left wall)
- 3 panels with textual and visual content
- Elektra

DESCRIPTION
Elektra introduces the Learning Augmented Environment and the tools for help and navigation. Also, she explains what to do during the test. Particularly:

- Elektra introduces the user to Augmented Reality (Figure 57-A)
- Elektra explains the features of the *menu*, the main navigation interface ((Figure 57-B-C - see also Section 5.3.1.3.2)
- Elektra explains what holograms are through an example: a holographic projector resting on the floor generates a dynamic, 3D projection of the *Solar System* inside the real room the user is in (Figure 57-D);
- Elektra introduces the Testing Area, showing on a large panel hanging on the front wall the images of some key moments of the immersive experience in the Testing Area (Figure 57-E).

Figure 57: Key images from the Introductory Module

5.3.1.4.2 Script 1: Exercise 1 - Pointing at (Selecting) Holograms

PURPOSE

To teach the user the "POINT AT HOLOGRAMS" or "SELECT HOLOGRAMS" gesture, that is, how to use the user's head to point at/select holograms

HOLOGRAMS IN SCENE

- The Room (the virtual room) – 2 walls (left, front) are visible
- The Help Panel (on the left wall)
- 3 panels with textual and visual content
- Elektra
- 6 holograms (same size, spherical shape) in random position

DESCRIPTION

- Panel 1 appears in front of the user with instructions on how to start Exercise 1 (Figure 58-A-B)
- After the user pronounces the word "*start*":
    - Panel 2 appears with new instructions (Figure 58-C);
    - The Room appears around the user;
    - The Help Panel for Exercise 1 appears, hanging on the left wall

- The Help Panel (Figure 58-D-E) shows:
    - a video with instructions on how to perform the gesture necessary to complete Exercise 1
    - a training area where the user can practice the gesture (Figure 58-E)
    - instructions (in textual format) on what to do to start and complete Exercise 1

- After the user pronounces the word "*start*", Exercise 1 begins (Figure 58-F-G):
    - The 6 spherical, rotating holograms are presented to the user, one at the time, at random positions (but in an area in front of the user, so as to avoid large rotations of the user's head and neck).
    - For each hologram, the user must move his head to place the HoloLens pointer over the hologram. On a positive hit, the hologram disappears and a new hologram appears at a different position

- Exercise 1 ends (Figure 58-H):
    - Panel 3 appears with (textual) instructions on how to end the exercise and move on to the next exercise
    - A small Elektra, floating next to the panel, provides information on the user's performance, and explains how to move on to the next exercise

INFO

A video of Exercise 1 can be found here.

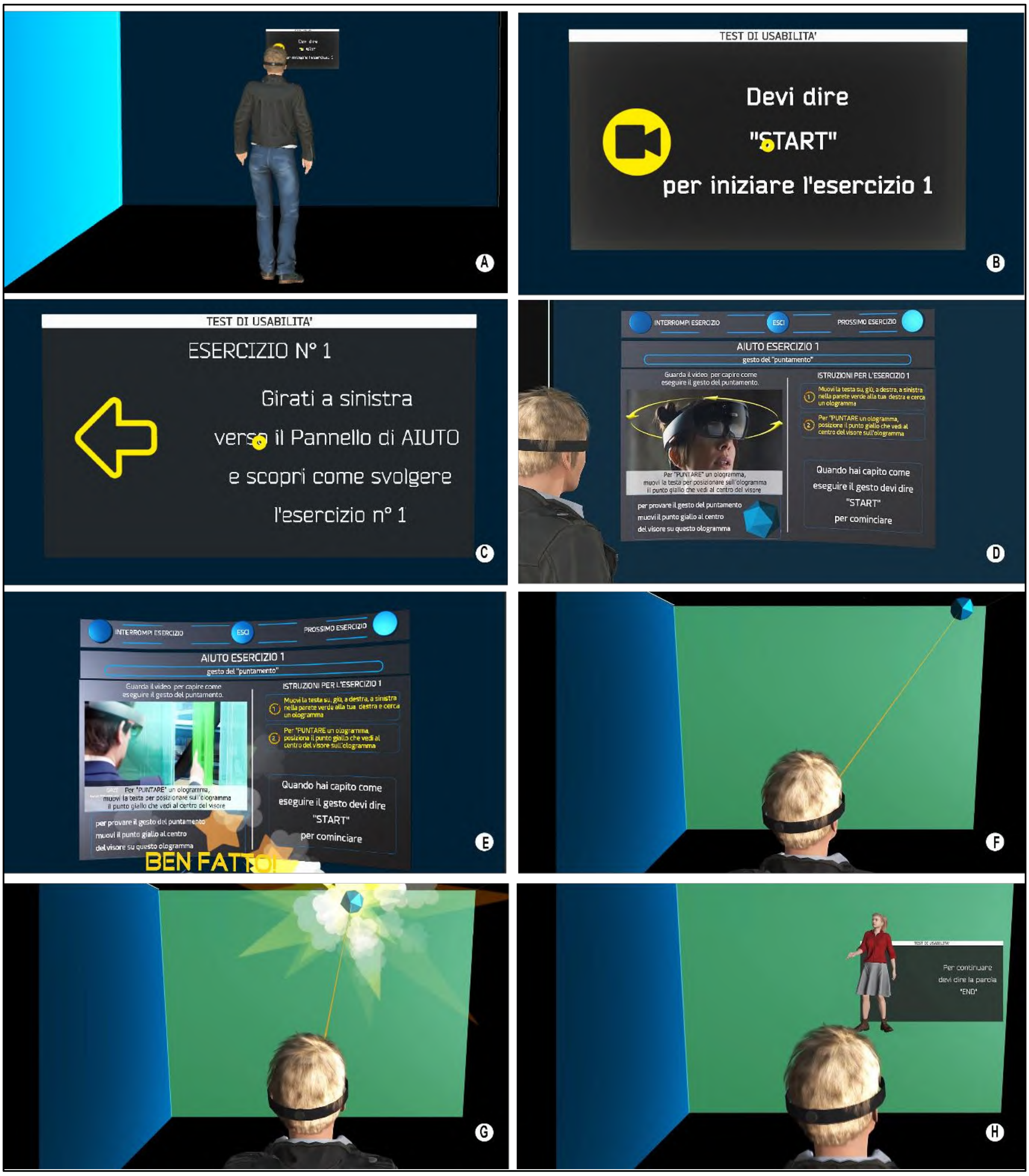


Figure 58: Key images from Exercise 1

5.3.1.4.3 Script 2: Exercise 2 - Clicking on a Selected Hologram

NOTE
Overall, Exercise 2 is similar to Exercise 1. The scene set is the same. The scene contains the same holograms. The only difference between the 2 exercises is in the gesture(s) to be learned and performed. In Exercise 2, the user learns a new gesture ("CLICK ON HOLOGRAMS") while practicing the gesture "SELECT HOLOGRAMS", learned in Exercise 1.

PURPOSE
To teach the user the "CLICK ON HOLOGRAMS" gesture, that is, how to start an action by clicking on a hologram.

HOLOGRAMS IN SCENE
- The Room (the virtual room) – 2 walls (left, front) are visible
- The Help Panel (on the left wall)
- 3 panels with textual and visual content
- Elektra
- 6 holograms (same size, spherical shape) in random position

DESCRIPTION
- Panel 1 appears in front of the user with instructions on how to start Exercise 2 (very similar to Figure 58-A-B)

- After the user performs the "SELECT HOLOGRAMS" gesture (learned in Exercise 1) on the word "*start*":
  - Panel 2 appears with new instructions (Figure 58-C);
  - The Room appears around the user;
  - The Help Panel appears, hanging on the left wall

- The Help Panel for Exercise 2 (similar to Figure 58-D-E) shows:
  - a video with instructions on how to perform the gesture(s) necessary to complete Exercise 2
  - a training area where the user can practice the gesture(s) (similar to Figure 58-E)
  - instructions (in textual format) on what to do to start and complete Exercise 2

- After the user performs the "CLICK ON HOLOGRAMS" gesture on the word" *start*" in the Help Panel, Exercise 2 begins (similar to Figure 58-F-G):
  - The 6 spherical, rotating holograms are presented to the user, one at the time, at random positions (but in an area in front of the user, so as to avoid large rotations of the user's head and neck).
  - For each hologram, the user must perform the "SELECT HOLOGRAMS" gesture to place the HoloLens pointer over the hologram, and then perform the "CLICK ON HOLOGRAMS" gesture. On a positive hit, the hologram that has been clicked disappears, and a new hologram appears at a different position

- Exercise 2 ends (similar to Figure 58-H):
  - Panel 3 appears with (textual) instructions on how to end the exercise and move on to the next exercise
  - A small Elektra, floating next to the panel, provides information on the user's performance, and explains how to move on to the next exercise

INFO
Since Exercise 2 is similar to Exercise 1, we did not record any video of Exercise 2.

5.3.1.4.4 Script 3: Exercise 3 - Selecting and Clicking on Holograms with Different Shapes & Sizes

NOTE

Overall, Exercise 3 is similar to Exercise 2. The scene set is the same. In order to complete this exercise, the user does not need to learn any new gestures. However, contrarily to what happens in Exercise 2, in Exercise 3 the user has to perform the gestures learned in the previous exercises on holograms with varying shapes and sizes.

PURPOSE

To find out the smallest squared/circular shapes the user is able to select (with the "SELECT HOLOGRAMS" gesture) and then click on (with the "CLICK ON HOLOGRAMS" gesture).
[Note: Squared and circular shapes are used to create *buttons* and *check boxes*, usually used in quizzes and forms, and are also used for multi-purpose forms of interaction between the user and the holograms, so it is important to identify the smallest squared/circular shapes that the user is able to manage without problems].

HOLOGRAMS IN SCENE

- The Room (the virtual room) – 2 walls (left, front) are visible
- The Help Panel (on the left wall)
- 3 panels with textual and visual content
- Elektra
- 6 floating panels, each containing one (small, medium, or large) squared or circular shape

DESCRIPTION

Panel 1 appears in front of the user with instructions on how to start Exercise 3 (very similar to Figure 58-A-B)

- After the user performs the "SELECT HOLOGRAMS" gesture (learned in Exercise 1) on the word "*start*":
  - Panel 2 appears with new instructions (Figure 58-C);
  - The Room appears around the user;
  - The Help Panel appears, hanging on the left wall

- The Help Panel for Exercise 3 (similar to Figure 58-D-E) shows:
  - a video with instructions on how to perform the gesture(s) necessary to complete Exercise 3
  - instructions (in textual format) on what to do to start and complete Exercise 3

- After the user performs the "CLICK ON HOLOGRAMS" gesture on the word" *start*" in the Help Panel, Exercise 3 begins (similar to Figure 58-F-G, but with holograms with different shapes and sizes):
  - The 6 panels are presented to the user, one at the time, at a fixed distance (2 meters). Each panel contains one (small, medium, or large) squared or circular shape (i.e., a button). The user must perform the "SELECT HOLOGRAMS" gesture on the shape, and then perform the "CLICK ON HOLOGRAMS" gesture on the shape. On a positive hit, the hologram/button that has been clicked disappears, and a new panel with a different hologram appears.

- Exercise 3 ends (similar to Figure 58-H):
  - Panel 3 appears with (textual) instructions on how to end the exercise and move on to the next exercise
  - A small Elektra, floating next to the panel, provides information on the user's performance, and explains how to move on to the next exercise

INFO

Since Exercise 3 is similar to Exercise 1, we did not record any video of Exercise 3.

5.3.1.4.5 Script 4: Exercise 4 - The User's Physical Body Interacts with Holograms

NOTE

In Exercise 4 we want the user to understand, but also *feel*, what it means to be in an immersive and interactive environment. In this exercise, the user realizes that he can interact with the holograms not only through the learned gestures, but also with his entire body. This is a feature that almost only AR can provide: the real and the virtual are merged into one *augmented* reality.

PURPOSE

Contrarily to what it might seem, the purpose of Exercise 4 is not to check whether the user knows the answers to the questions shown in the monitor (the questions are very easy to answer). The real purpose of Exercise 4 is to make the user aware that his entire body is part of the augmented environment. In addition, we want to find out a usability feature, that is, the smallest font the user can read with ease when a text is shown at a fixed distance (2 meters).

HOLOGRAMS IN SCENE

- The Room (the virtual room) – 2 walls (left, front) are visible
- 1 light beam and a Monarch butterfly swarm, randomly flying around the light beam. The light beam works as a hologram activator: it can detect the presence of the user within the light beam. On detection, it activates a monitor in front of the user (see below).
- 1 large monitor showing (when activated):
  - 2 videos with Elektra (avatar version n°2) providing instructions & information on Exercise 4
  - 4 panels, each containing one exercise (one question with 3 check boxes for multiple-choice answer, and relative answers)
- A circular shape on the floor (capable of detecting the presence of the user on the shape) signaling the position the user must walk to at the end of the exercise.

DESCRIPTION

- When the exercise starts, there is only one orange light beam in the Room, at about 2 meters away from the user (Figure 59-A-B). A swarm of Monarch butterflies is randomly flying around the light beam. Music in the background.
- Elektra's voice-over briefly explains what to do to complete the exercise. The user is also invited to walk toward the butterflies and the light beam, to stop within the beam, and to turn 180 degrees around himself (Figure 59-C-D).
- When the user is within the light beam, the light and the butterfly swarm disappear, and a monitor slides down from the ceiling, at two meters from the user (Figure 59-E).
- In the monitor, a video starts. In the video, Elektra (avatar version n°2) explains the exercise that will be displayed in the monitor at the end of the video (Figure 59-F).
- Once the video is over, a four-question, multiple-choice questionnaire starts. The questions are shown in the monitor one at the time. For each question, three possible answers are available. The four groups of answers use the same font (Arial) but with four different sizes (large, medium1, medium2, small). The user must perform the SELECT HOLOGRAMS and then CLICK ON HOLOGRAMS gestures on the check-box next to what he believes is the correct answer. Once the check-box is clicked, a new question appears in the monitor (Figure 59-G).
- Once the questionnaire is completed, a new video appears in the monitor. In the video, Elektra provides information on the user's performance and explains how to move on to the next exercise. The monitor slides up and disappears through the ceiling (Figure 59-H).
- Elektra voice-over invites the user to walk over a yellow, circular shape on the floor to end the experience with the Exercise 4, and move on to the next exercise (Figure 59-H-J).

INFO

A video of Exercise 4 can be found here.

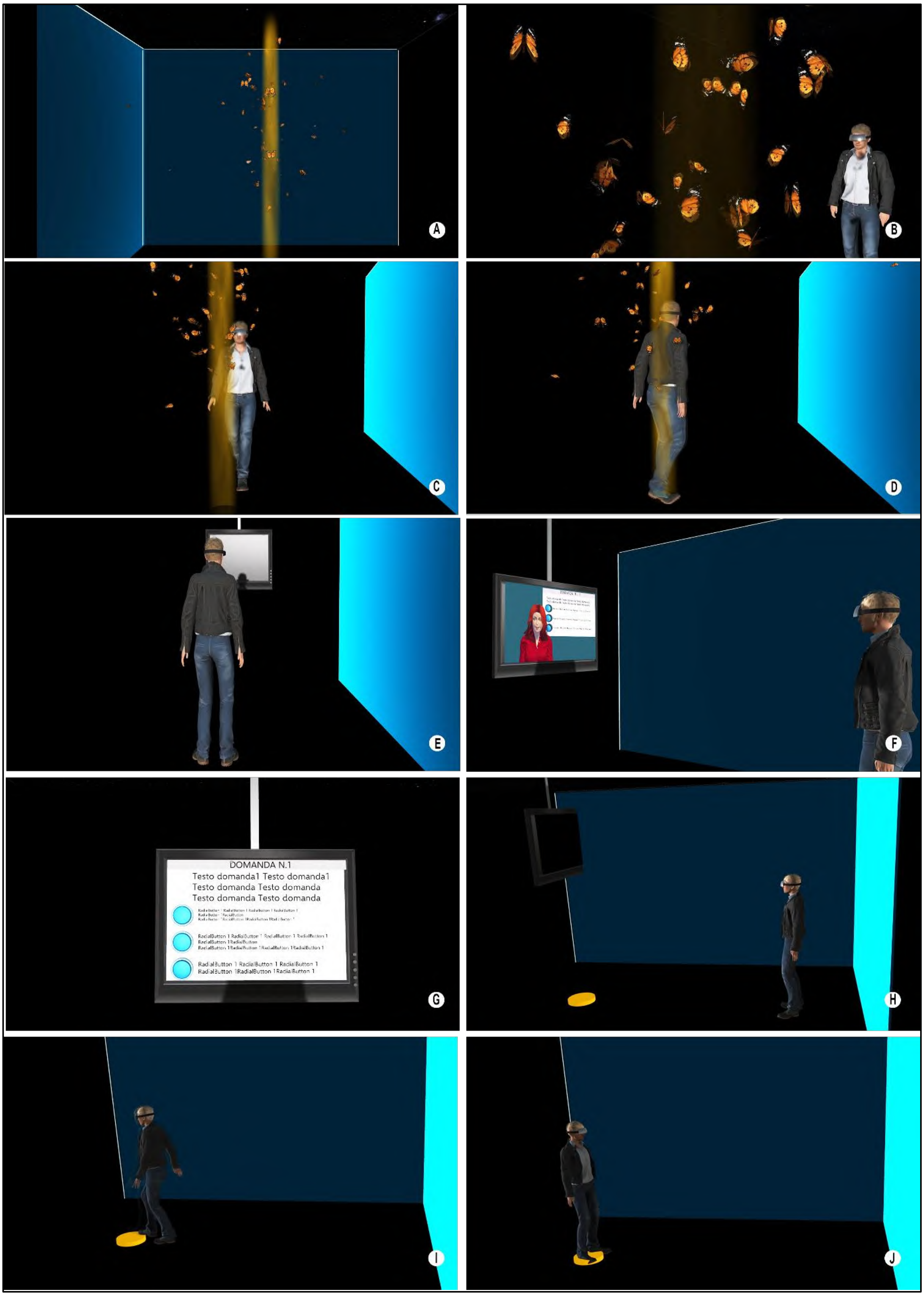


Figure 59: Key images from Exercise 4

5.3.1.4.6 Script 5: Exercise 5 - Moving holograms

NOTE
Exercise 5 is divided into two parts. In the first part, a new gesture (MOVE HOLOGRAMS) is introduced through a video. Then, the user has the opportunity to perform the gesture by moving a cup, resting on a stool on the right side of the stage, onto a table on the left side of the stage. In the second part, the user can practice the MOVE HOLOGRAMS gesture in a different scene set. He will need to move two books resting on a couch on the left side of the stage onto a bookshelf on the right side.
It should be noted that in the second part of this exercise, there is a frame with glass hanging on the front wall. Through the glass, it is possible to see a 3D sculpture of Nefertiti and, at the end of the exercise, Elektra, briefly talking to the user about the exercise. It is important to realize that both Elektra and the sculpture of Nefertiti are *beyond the real wall*, within a virtual room next to the real one. As a matter of fact, the frame encloses a virtual hole which enables the user to see the *virtual world-beyond-the-real-wall.* This is a feature that only AR can provide: again, the real and the virtual are merged into one augmented reality.

PURPOSE
To introduce the user to the new MOVE HOLOGRAMS gesture, and train him (once more) on the SELECT HOLOGRAMS and CLICK ON HOLOGRAMS gestures.

HOLOGRAMS IN SCENE
Scene Set 1:
- The Room (the virtual room) – 4 walls (left, front, right, floor) are visible
- A stool + a cup (on the stool)
- A blue light beam showing the position of the cup to move
- A table set for breakfast, with some light candles on, and a vase with a flower
- A blue, circular shape on the table (the target where the cup has to be moved onto)
- A video on the MOVE HOLOGRAMS gesture
- The Help Panel showing the video on the MOVE HOLOGRAMS gesture

Scene Set 2:
- The Room (the virtual room) – 1 wall (floor) is visible
- A couch +two books (on the couch)
- A few bookshelves
- A violet light beam showing the position of the two books to move
- A red, squared shape on one shelf (the target where the books have to be moved onto)
- 2 plants
- A frame with glass hanging on the front wall (through which is possible to see the 3D sculpture of Nefertiti beyond the wall).
- Elektra (avatar version n° 3)

DESCRIPTION
- When the exercise starts, the user can watch the video on the MOVE HOLOGRAMS gesture displayed in the large video player hanging on the (real) front wall (Figure 60-part1-A-B).
- Throughout the exercise, the looping video on the MOVE HOLOGRAMS gesture is visible also in the Help Panel (on the left, real wall - (Figure 60-part1-C).
-

Scene Set 1:
- Once the video is over, Elektra's voice-over invites the user to perform the MOVE HOLOGRAMS gesture, and a new scene set appears in front of the user (see Figure 60-part1-D÷H), while Elektra still keeps explaining the user how to move the cup, resting on a stool on the right side of the scene, onto a blue target on the table, on the left side of the scene (Figure 60-part1-E÷G).
- Once the user has moved the cup onto the blue target on the table, the target detects that the cup has been correctly moved, and displays a message telling the user that the gesture has been successfully performed Figure 60-part1-H).

Scene Set 2

- Scene Set 1 disappears, and a new scene set (Scene Set 2) takes its place (see Figure 60-part2-A-B).
- Elektra's voice-over explains what to move (the two books on the couch on the left side of the scene) and where (onto the bookshelf with a red target, on the right side of the scene), and invites the user to perform the MOVE HOLOGRAMS gesture.
- When the red target detects that the two books are correctly placed, it displays a message telling the user that the gesture has been successfully performed (Figure 60-part2-C).
- Exercise 5 is now completed. A small Elektra appears within the frame hanging on the front wall and beyond the glass and the wall itself, as if she were in another room next to the one where the user is. She comments on the user's performance, and explains how to move on to the last exercise (Figure 60-part2-D).

INFO

A video of Exercise 5 can be found here.

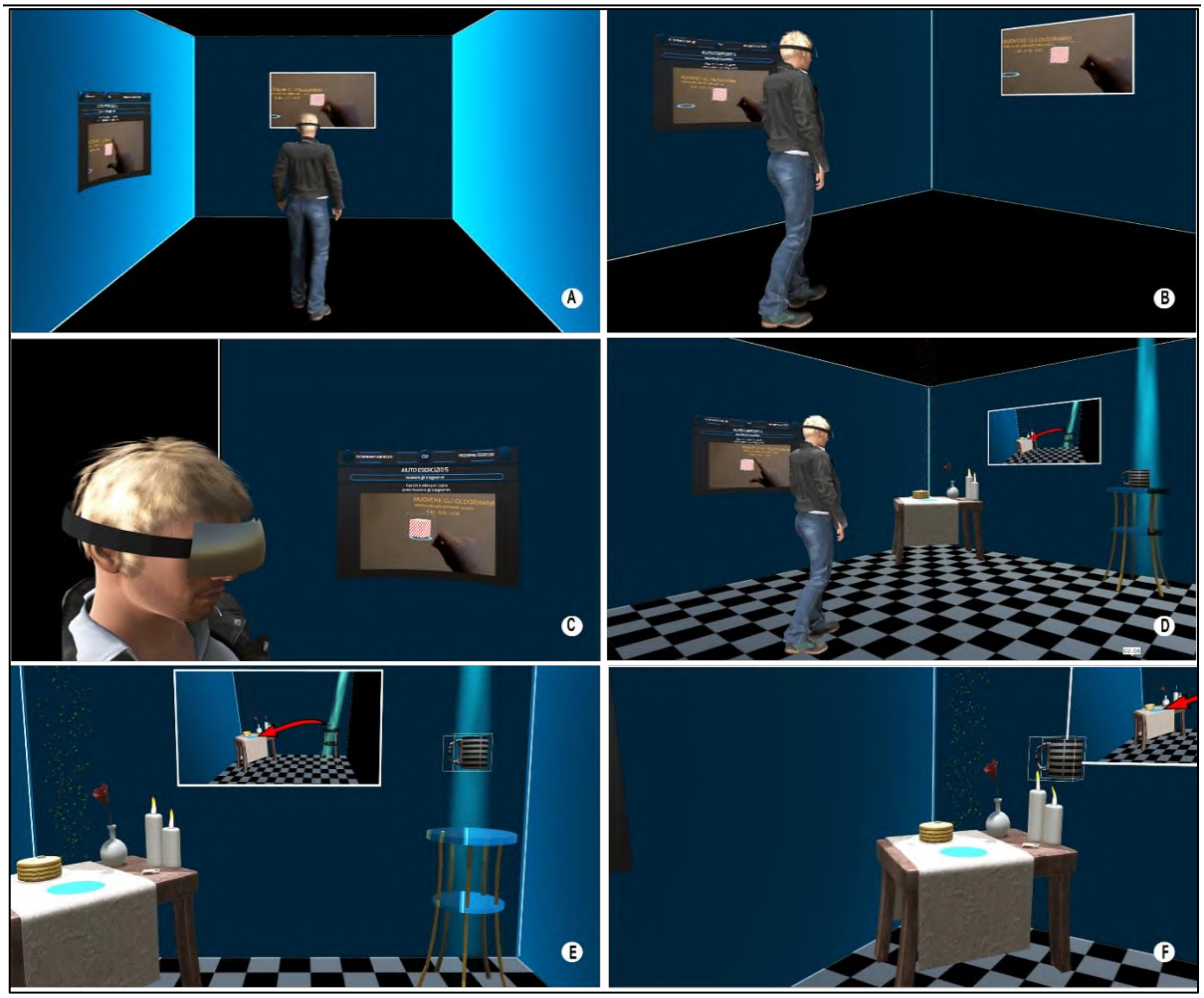


Figure 60: Key images from Exercise 5 - part 1

Figure 60: Key images from Exercise 5 - part 1

Figure 60: Key images from Exercise 5 - part 2

5.3.1.4.7 Script 6: Exercise 6 - Rotating and Resizing Holograms

NOTE

Exercise 6 is divided into two parts. In the first part, Elektra introduces the user to a new gesture, to be performed with both the user's hands: the ROTATE HOLOGRAMS gesture. Then, the user has the opportunity to perform the gesture by moving and rotating a hologram. In the second part, Elektra presents another new gesture: the RESIZE HOLOGRAMS gesture. The user is then challenged to perform all the gestures he learned in the previous exercises to complete the most difficult task of the entire Testing Area.

Exercise 6 is the most complex exercise in the Testing Area. For this exercise, we have designed and developed holograms displaying many of the features of augmented environments examined in Chapter 4. In this exercise, Elektra (in her third and most complex version) interacts with the user, and helps him throughout the exercise. In so doing, she provides a major contribution in making lively and more interesting the immersive augmented experience.

It is also worth noticing the introduction of a scene set that dynamically changes on stage during the exercise. The stage elements do not appear at once on stage – as it happened in the previous exercise – but they rather enter the stage little by little, by means of different strategies: the walls (overlapped with the real walls of the room the user is in) sometimes slide in, some other times slide away disappearing into the floor, or emerge from the floor and rise up to take the place of the previous walls. And the same happens to the scene objects: they fall from the ceiling or rise from the floor, so that the changes are progressive and always visible to the user. This helped us to concretely explore the idea, presented in Section 4.3.3.1, that the scenes of an augmented environment are parts of an augmented theatrical performance.

PURPOSE

To introduce the user to the new ROTATE HOLOGRAMS and RESIZE HOLOGRAMS gestures, and train him (once more) on the SELECT HOLOGRAMS, CLICK ON HOLOGRAMS, and MOVE HOLOGRAMS gestures.

HOLOGRAMS IN SCENE

Scene Set 1:

- The Room (the virtual room) – 3 walls (left, front, floor) are visible
- 1 video on the ROTATE HOLOGRAMS gesture
- Elektra (version avatar n°3)
- 2 sliding bricked walls (left, front)
- 1 wooden box and a suitcase on top
- Several wooden boxes and barrels scattered around
- 1 lighted wooden box (the target where the suitcase must be moved into). At the bottom, a detector plate. When the plate detects that the suitcase has correctly been placed, it displays a message telling the user that the gesture has been successfully performed.

Scene Set 2:

- The Room (the virtual room) – 1 wall (floor) is visible
- 1 video on the RESIZE HOLOGRAMS gesture
- Elektra (version avatar n°3)
- A clone of Elektra (version avatar n°3) with different hair and clothes
- 1 cylindrical wall (the center of the cylinder is where the center of the real room is) + circular floor
- 1 rectangular glass container (the target where the cloned Elektra must be moved into). At the bottom, a detector plate. When the plate detects that the cloned Elektra has correctly touched the bottom of the glass container, it removes the glass container, and activates the clone.
- 2 glass columns supporting Elektra and the rectangular glass container

DESCRIPTION

Scene Set 1:

- When Exercise 6 starts, Elektra introduces the exercise, and explains how to perform the new gesture (ROTATE HOLOGRAMS) that the user will learn during the immersive experience in the exercise (Figure 61-part1-A). A (looping) video on the gesture, hanging on the front wall, visually illustrates Elektra’s explanations (Figure 61-part1-B-C).

- Once the video is over, Elektra invites the user to perform the new gesture.
- On the right side of the scene, next to Elektra, a wooden box slowly falls from the ceiling and rests on the floor. A suitcase follows the falling wooden box and rests on top of it (Figure 61-part1-D).
- On the left side of the scene, a few wooden boxes and barrels fall from the ceiling until they rest, scattered around, on the floor (Figure 61-part1-E-F).
- While the scene elements are falling from the ceiling, two bricked walls (left and front) slide into the scene, and the floor changes its color, so to change the overall scene visual setting and the mood of the immersive experience (Figure 61-part1-D-E).
- Elektra invites the user to perform the MOVE HOLOGRAMS gesture to move the suitcase on top of the lighted, rectangular wooden box which is closest to the user. Then – Elektra continues – the user has to perform the ROTATE HOLOGRAMS gesture to rotate the suitcase until it is aligned with the main axis of the box (Figure 61-part1-G-H).
- At the end of her explanation, Elektra disappears from the scene, so that the user is not distracted by her presence on the augmented stage.
- The user performs the two gestures according to Elektra's explanations: he moves the suitcase on top of the box, and rotates the suitcase until it is aligned with the wooden box. Then, the user stops holding the ROTATE HOLOGRAMS gesture, and the suitcase falls into the box (Figure 61-part1-I).
- When the suitcase hits the bottom of the box, a "well done" message appears in front of the user, and the first part of the exercise is concluded (Figure 61-part1-J).

Scene Set 2:

- The second part of Exercise 6 begins. Elektra appears again on stage. She explains how to perform a new gesture (RESIZE HOLOGRAMS), while a new video on the RESIZE HOLOGRAMS gesture appears on the front wall, next to the video on the ROTATE HOLOGRAMS gesture (Figure 61-part2-A).
- Then, Elektra invites the user to perform the RESIZE HOLOGRAMS gesture (Figure 61-part2-B).
- While Elektra is talking, the scene set changes:
  - the bricked walls slide downward, until they disappear into the floor;
  - a new, blue, circular floor takes the place of the previous floor (Figure 61-part2-C);
  - a cylindrical, blue wall grows up from the floor until the user is completed surrounded by a single, circular wall, as big as the real room the user is in (Figure 61-part2-C-D);
  - two glass columns rise from the floor (on the left side of the user, and in front of him);
  - a clone copy of Elektra (Elektra_B) in blue dress slowly falls from the ceiling and rests on top of the glass column on the left side of the user. Her arms are open to form what is called the "T-position" [a typical position avatar take when they are "at rest"] (Figure 61-part2-D);
  - an empty, rectangular glass container slowly falls from the ceiling and rests on top of the glass column in front of the user (Figure 61-part2-B÷F).
- Elektra explains the user what to do: he needs to perform the MOVE HOLOGRAMS gesture to move Elektra_B on top of the glass container; then, he needs to perform the ROTATE HOLOGRAMS gesture on Elektra_B, so to align her with the main axis of the glass container; finally, he needs to perform the RESIZE HOLOGRAMS gesture to reduce the size of Elektra_B, so that she will be able to fit into the glass container (Figure 61-part2-D÷G).
- At the end of her explanation, Elektra disappears from the scene, so that the user is not distracted by her presence on the augmented stage.
- The user performs the 3 gestures according to Elektra's explanations. When he stops holding the RESIZE HOLOGRAMS gesture, Elektra_B slowly falls into the glass container (Figure 61-part2-h-j).
- The detector plate at the bottom of the glass container detects Elektra_B inside the glass container. The glass container slides down and disappears; the glass column where Elektra_B is standing rises up so that the (by now) small Elektra_B can clearly look at the user (Figure 61-part2-k).
- Elektra_B explains that the experience in the Testing Area is concluded. She thanks the user, and greets him (Figure 61-part2-I÷M).
- The second part of Exercise 6 is concluded, and also the experience in the Testing Area is concluded.

INFO

A video of Exercise 6 can be found here

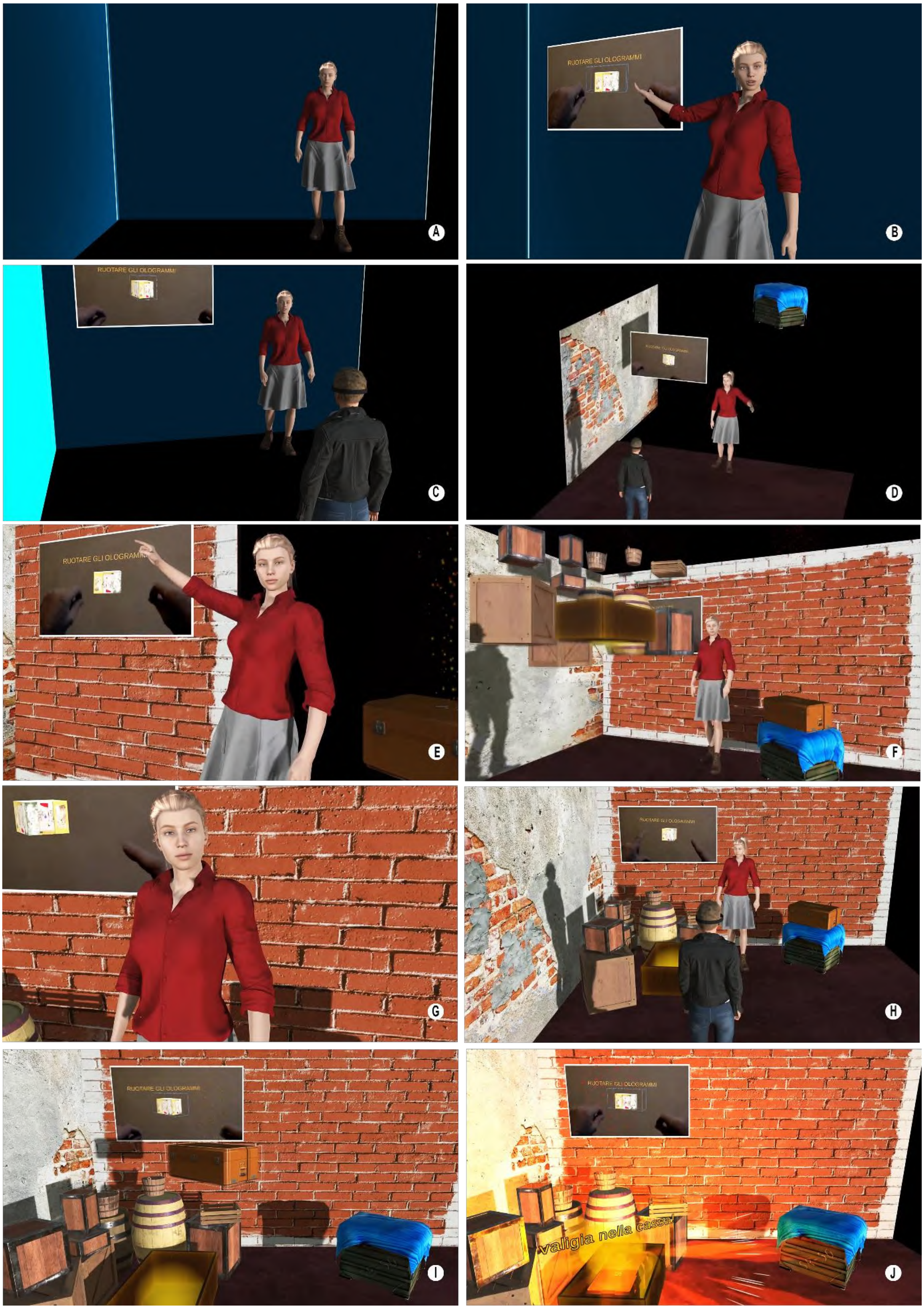


Figure 61: Key images from Exercise 6 - part 1

Figure 61: Key images from Exercise 6 - part 2

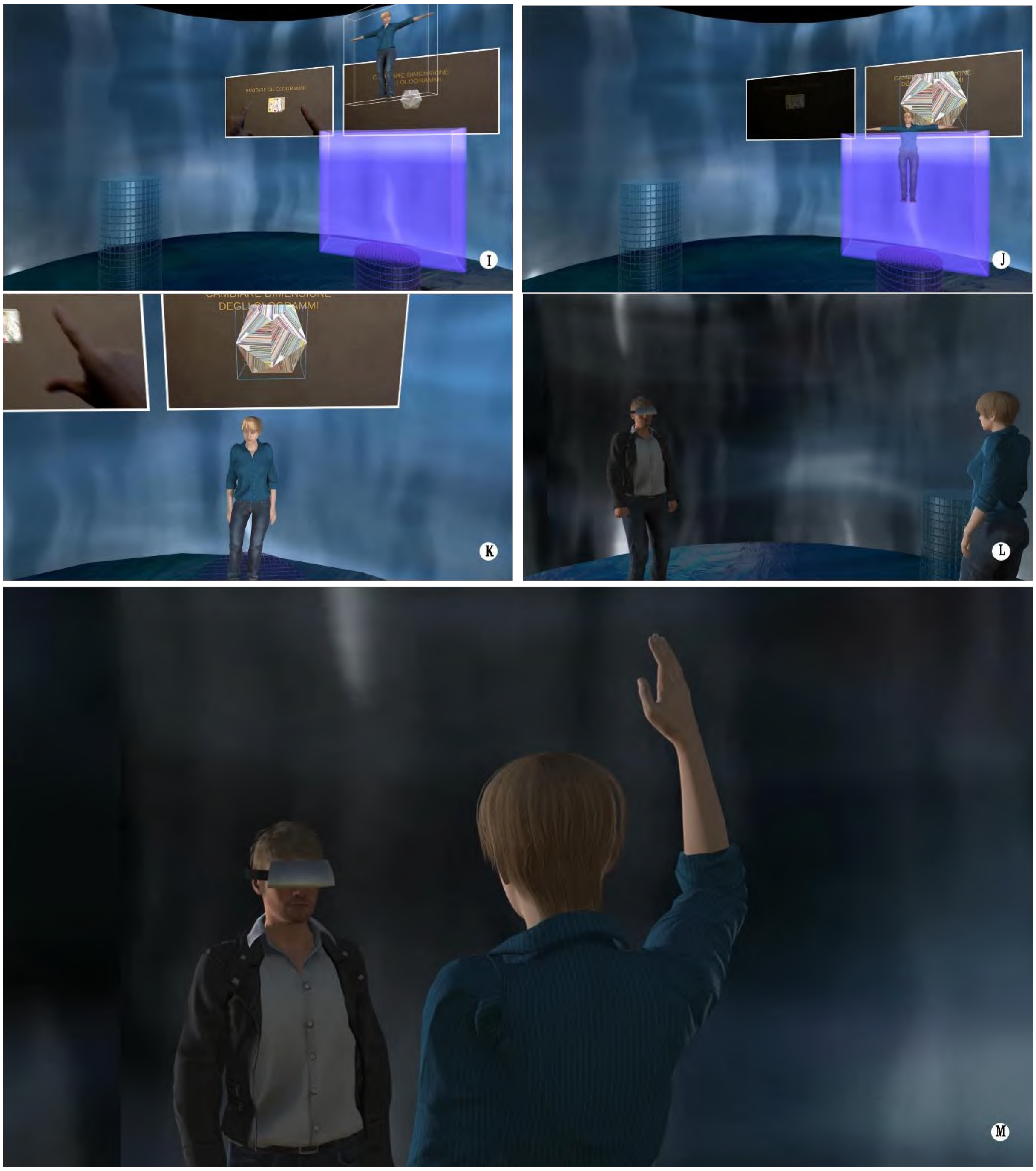


Figure 61: Key images from Exercise 6 - part 2

5.3.2 PHASE 2: THE DESIGN OF THE LEARNING MODULES

In the second part of this chapter on the design of the Learning Augmented Environment, we will deal with the design of the *Learning Modules*. However, we should probably reformulate this statement in a different way. By now, it should be clear that the Learning Modules are virtual rooms, or scenes. Therefore, the Learning Modules, as virtual rooms, have already been designed, as we saw in the previous sections. What we really mean when we say that we will deal with the design of the Learning Modules, is that we will deal with the design of their *contents*. For the moment, the Learning Modules are just empty containers that need to be filled with learning contents, that is, with the course for older adults on the use of computers and digital tools we talked about in Chapter 3.

Particularly, in Section 5.3.2.1, we will try to identify the design principles and methodologies necessary to design a learning course; in Section 5.3.2.2, we will focus on the selection of the learning material we want to use in the course; in Section 5.3.2.3 we will see how to use the identified learning methodologies to organize the learning material into the course on the use of computers and digital tools. Finally, in Section 5.3.2.4, we will deal with the integration of the course into the Learning Modules, that is, with the process of transforming the course into a learning, immersive and augmented experience.

As we explained in the Introduction to this chapter, we did not work out yet the details of the design of the course. So, in the rest of this chapter, we will only produce a general description of the methodologies and the activities we will work on once we have a confirmation (*if* we have a confirmation), from the test with the HoloLens, that the course in augmented reality is an efficacious learning tool for older adults, worth to be developed.

5.3.2.1 Looking for design principles: Features of E-learning On-line Courses

First, we plan to examine the structures and the organizations of the contents of a few open on-line courses (MOOCs) [137], [138], such as Coursera, edX, Udemy, Udacity.

Figure 62: A few on-line e-learning platforms

Particularly, we want to:

a) identify the most common *learning elements/tools* (such as syllabus, calendar, audios, videos, lectures, collaborative and social features, homework management, text-boxes, grades management, resources, tests, navigation tools, links, and so on) used by the on-line platforms to provide users with what should be considered a good *learning experience*.

b) identify *usability/accessibility features* [100], [139]–[141], [142] (such as navigation tools, text alternatives, time-based media alternatives, adaptable contents, distinguishable contents, keyboard accessible, enough time to get contents, easily navigable and readable, predictable, with input assistance, compatible, and so on).

c) identify the *micro- and macro-organizations* of the above learning elements (such as learning activities, learning objects, lessons, modules, chapters, seminars, content aggregations, learning blocks, teaching points, etc.).

Table 3.1÷6 show the form we will use to collect the information from the different on-line courses.

Table 3: The form used to collect information on the features of the different on-line courses

COMPARATIVE ANALYSIS OF E-LEARNING WEBSITES - 1				
		E-Learning online courses		
PARA-TEXTUAL ELEMENTS (in an on-line course, the set of buttons, bars, links, commands that define the type, the number and the order of possible browsing activities performed to access the contents of the course)		**C1**	**C2**	**Cn**
navigation tools				
links in contents				
external references				
other				

COMPARATIVE ANALYSIS OF E-LEARNING WEBSITES - 2				
CONTENT		**C1**	**C2**	**Cn**
course				
lessons/chapters/modules (clusters of related objectives)				
topics/pages/learning objects/events (lower level learning objectives)				
learning activities/blocks/teaching points (several activities connected together to accomplish a learning objective)				
media/technologies (text, pictures, voice, sounds, animations, videos used to present activities)				

COMPARATIVE ANALYSIS OF E-LEARNING WEBSITES - 3				
SERVICES		**C1**	**C2**	**Cn**
integration with social media	S.M.= (list of s.m. used in the course)			
collaborative services	C.S.= (list of c.s. used in the course)			
other				
ACTORS				
instructor				
learner				
tutor/helper/assistant				
other				

COMPARATIVE ANALYSIS OF E-LEARNING WEBSITES - 4				
ACCESSIBILITY / USABILITY		**C1**	**C2**	**Cn**
PERCEIVABLE Information and user interface components must be presented to users in ways users can perceive.	text alternatives			
	time-based media alternatives			
	adaptable contents (that can be presented in different ways)			
	distinguishable contents			
OPERABLE User interface components and navigation must be operable	keyboard accessible			
	enough time to get contents			
	against seizure			
	easily navigable (with help)			
UNDERSTANDABLE Information and the operations to be performed in user interfaces must be understandable	readable			
	predictable			
	with input assistance			
ROBUST Content must be robust enough so that it can be reliably interpreted by a wide variety of user agents, including assistive technologies	compatible			
Other				

The reason for this type of analysis should be clear: we don’t intend to reinvent the wheel, and create new courses from scratch. On the contrary, we want to take advantage from the fact that we can re-use already existing materials, tools, structures, functionalities, pedagogical strategies and principles. They do already work on popular on-line platforms devoted to e-learning, and we do not see any reason to avoid using them.

Most of these online courses come in the format that, in Chapter 3 (see 3.6.1), we identified as *standalone courses*: self-paced courses taken by a solo learner, with no classroom or classmates, and with a teacher who (somehow) interacts with the learner by showing him images, videos, written documents, exercises, and so on. And the course we want to set up in augmented reality obviously shares many of the same features: it is a self-paced course taken by a solo learner; no other classmate shares the augmented experience; the teacher is a virtual teacher – or rather Elektra, a virtual assistant – who (somehow) interacts with the learner and helps him to move around the Augmented Environment, and uses images, video and audio files, documents, exercises, and, more in general, any kind of learning material useful to accomplish a learning experience; finally, the learning material is organized according to some didactical principles and logic which, during the design of the course, have been defined or chosen for a specific target.

5.3.2.2 Contents of the Course on the use of computers and digital tools

The content of the course on the use of computers and digital tools will mostly deal with a few important public and private e-services (such as e-government, e-health, home-banking, social media, e-commerce, e-entertainment) accessible through the Web. However, since our target users often lack of computer literacy, we will need to provide them with at least a basic background knowledge on the usage of the computer and the Web (e.g. on browsing, searching, safe navigation, security, social media, and so on).

To identify and select the content to be used with the Learning Modules, we will rely on a few introductory books or manuals on ICTs, computers and digital tools, such as Lunghezzani et al. [143], Tomasi [144], White & Downs [145], Harper [146], [147]. We will also refer to specialized Websites focused on active ageing and learning for older adults, such as Skillful Senior [148], the Senior's Guide to Computers [149], the Goodwill Community Foundation [150], Meganga - Free Computer Lessons For Seniors And Beginners [151], TechBoomers [152]. Many of these Websites propose introductory courses and tutorials on the new technologies, the Internet, and the Web.

5.3.2.3 Designing the Course on the use of computers and digital tools

For the design of the course, we will mostly rely on the *instructional design* methodologies described in Bates [49], Dirksen [153], Gagne & Briggs [154], W. Horton [79], W. Horton & K. Horton [155], Lee & Owens [156], Murray [157].

In order to define the organization of the contents of the course that will be hosted in the different Learning Modules, we will:

- segment the primary contents of the course, identified in 5.3.2.2, into many basic pieces of learning content, or *learning units*.Each learning unit: (a) contains the information on what to present in one learning activity;

    (b) accomplishes a single learning objective;

    (c) might contain one or more mini-tests to verify that the user has learned the piece(s) of learning content presented in the learning unit.
- define the rules according to which the learning units can be combined together to create new learning units with a higher level of complexity (e.g. topics, lessons);
- define the whole learning experience with the learning course on the use of computers and digital tools as a hierarchical structure of learning units with different levels of complexity.

Figure 63 shows an example of such segmentation of a portion of the primary content of the course dealing with the Internet.

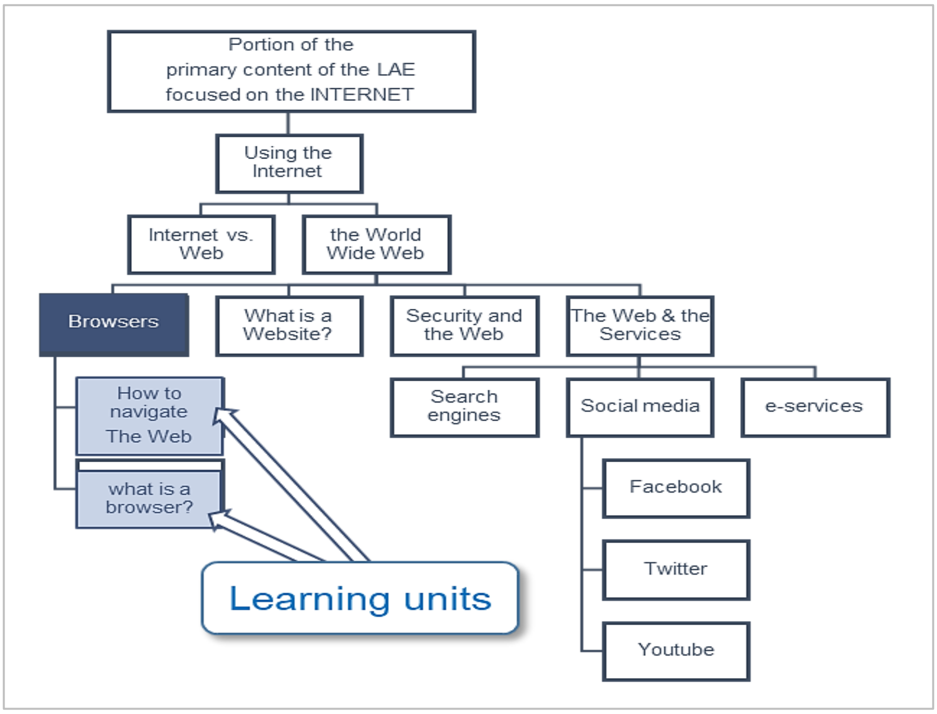


Figure 63: Segmentation of the primary content of one portion of the course on the use of computers and digital tools

By assembling together different learning units, we can create learning units of higher and higher levels of complexity, up to the highest possible learning unit, which includes the whole course, as shown in Figure 64.

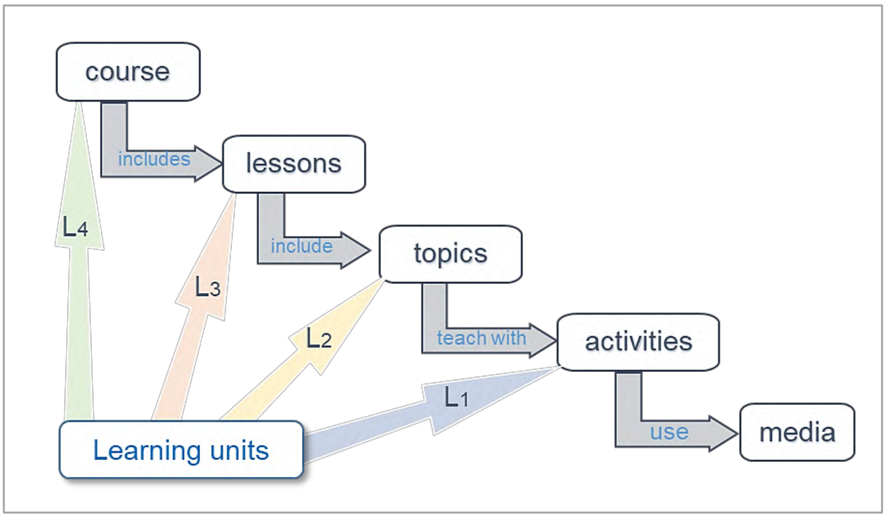


Figure 64: Learning Units and their components. At the lowest level of complexity, we find learning activities, each of which uses one or more multimedia forms of communication. By assembling together several learning activities we create topics; lessons are created by assembling different topics together. Finally, a Learning Unit which includes the whole course is made up of all the lessons in the course.

It should be noted that when we say that learning units are created by *assembling together* learning activities, or learning units belonging to a lower level, we mean: we connect together activities, or learning units, according to some *pedagogical principle,* in order to fulfill some learning objectives.

Many of these pedagogical principles or suggestions can be found in the literature on e-education, and are normally used by instructional designers as guidelines during the design of a whatsoever e-learning course. So, they can be used during the design of our course, as well.

Of course, given that the target users of the course we want to build are older adults, while selecting the learning material and, particularly, while choosing the most efficacious pedagogical principles to use in order to organize the learning material, we must consider the features of our target users (as we do in Chapter 7).

The final product should be a standalone course on the use of computers and digital tools specifically tailored for older adults with little or no knowledge on technology.

Once we will have completed the design of such a course, we will be able to select all the learning units (that is, their contents, together with their content organizations) with a medium level of complexity (e.g. topics or lessons) and *import* them into the empty Learning Modules of our Augmented Environment. At that point, our Augmented Environment will be filled with primary content. At that point, we will finally be able to think of the whole learning experience with the Learning Augmented Environment as the experience of learning by exploring/navigating through the Learning Modules – each of which deals with one or more specific topics – organized into a complex hierarchical structure similar to the one shown in Figure 39.

5.3.2.4 Integration of the Course into the Learning Modules

In the previous paragraph, we said that, by importing the course on the use of computers and digital tools into our Learning Augmented Environment, we will transform the course into a learning augmented experience. This, of course, is correct. However, by simply saying that the course will be *imported* into our Learning Augmented Environment, we largely oversimplify the description of the complex *process of transformation* the whole course goes through when it is imported.

We have already seen that, when we design an augmented environment, we are dealing with the design of something that implies the existence of a new medium. This means that every rule that we want to use with this new medium, every pedagogical principle or suggestion, every form of communication produced with other media, needs to be processed while keeping carefully in mind the features and the properties of the new medium. Everything we want to import needs to be *transformed/modified/changed* according to the features and the properties of the new medium.

To make it short: the process of importing is not always (almost never) neutral or transparent.

So, it should be clear that the real challenge, here, is not to design the course on the use of computers and digital tools according to a set of by now well-established instructional design methodologies. Surely, that task is complex, and it might require a good amount of time to be accomplished. However, it is not particularly challenging. Or, at least, it is not challenging if compared to the task of *importing* the course into our Learning Augmented Environment. The real task is to transform an e-learning course, which, after all, could work in many different media, into a course, or rather a *unique learning experience*, that is possible only in augmented reality.

An example might help to clarify why the importing process is so complex and problematic. Let us say that we plan to use a video in one learning activity within a Learning Module. Then, we should keep in mind that, according to a simple pedagogical suggestion, no matter what the content of the video is, that *video should be short.* Long videos are often perceived as boring and belonging by now to a pre-digital and old-fashion era. After a while, users lose their attention, with the result that they often miss part of the contents the videos wanted them to get familiar with. So, generally speaking, a *video should be short*, independently from the medium used to show the video (e.g. a player on a Web page vs. a TV set in a living room) and the context within which the video is placed (e.g. YouTube vs. Coursera). And if we look at several videos in Web pages of different courses on-line, we see that this pedagogical principle has often been ‘embedded’ into the structures of the courses. If one typical lesson (a complex learning unit) dealing with one or more topics (learning units with lower complexity) uses some videos, no matter what the videos are about, they all tend to follow the above suggestion: they are short.

So, now we ‘import’ that principle into our Learning Augmented Environment: we choose a short video (we can use a video from a webpage), and we smoothly import it as a video file. Finally, the video is inside one of the Learning Modules, and can be watched through a virtual video player, and everything seems to be fine.

However, we soon realize that, all of a sudden, we have to cope with problems related to the existence of that video in the Augmented Environment, problems that we didn’t have at all when the same video was on a webpage. For example, we are forced to wonder: given that the users of our Augmented Environment can freely move in the 3D immersive environment, where do we –as designers– place the video player, so that the users are able to watch the video in the best possible conditions, within the context of the scene designed for that Learning Module? Considering that the video player is a hologram, and that, therefore, can be of any size, and considering also that the users are wearing a head-mounted device (the HoloLens) with a quite limited field-of-view, how big should the video player be in order to provide the users with the best possible experience with the video? Should we allow the users to change the size and the position of the video player at their will (with what consequences?)? Or should we design the video player with pre-defined size and position, so that the users can only use it as-it-is (with what consequences?)?

We already saw similar problems when we talked about the interfaces (see Section 5.3.1.3). And the reason why we saw similar problems while talking about different things is that these are the typical problems we have when dealing with *objects existing in an augmented environment*. These are the typical problems we have to cope with every time we import into an augmented environment a whatever object originally created elsewhere, and with whatever medium different from Augmented Reality.

It should be clear now why we said that, when dealing with the design of the Learning Area of the Learning Augmented Environment, the real challenge is to understand and account for what happens when the course on the use of computers and digital tools is imported into the Learning Augmented Environment. All multimedia objects and learning activities – just to name the simplest components of any learning unit – must be thought of as virtual objects existing in a (virtual) augmented environment.

5.4 Conclusion

In this Chapter, we focused on the design of the Learning Augmented Environment for older adults.

While working on the design of the general Augmented Environment, we often had to cope with problems similar to the ones we just discussed in the previous section. And we will have to cope with similar problems also during the design of the Learning Area. When we will focus our attention toward the Learning Modules, certainly we will have to decide what contents to use for the Learning Modules, how to segment them into learning units, and how to assemble these learning units into larger, more complex learning units. However, this is, after all, what instructional designers do when they work on the design of an e-learning course, be it a standalone course or a virtual classroom, a course for children or one for older adults.

However, as designers of the Learning Augmented Environment, we believe that the real challenge is to find, through the design, the ways to transform an e-learning course, which, after all, could work in many different media, into a course, or rather a *unique learning experience*, made possible only by augmented reality.

As designers, we have to constantly try to answer the question: how can we give shape to an abstraction – the learning unit – so that users can really “visit” the learning unit, enter into it, be part of it, make experience of it, and learn from it, it in ways that other media will not allow?

CHAPTER 6

6. Development & Implementation of the Prototype

The prototype we have developed is based only on the design of the Augmented Environment defined in 5.3. In the previous Chapter, we explained the reasons for this choice (see 5.1.1). On the other hand, we also saw that the Learning Modules are nothing more than particular virtual rooms capable of containing learning content. Consequently, it should be clear that when we say that we have developed a prototype without the Learning Area, what we mean is that we have not yet inserted any specific learning content into the Learning Modules.

As we saw in the previous Chapter, before we start working on the development of the Learning Area, we need to find the answers to the important questions that, so far, have driven our research: are older adult *willing* to use augmented reality? are older adults *capable* of using augmented reality? are older adults capable of using Augmented reality *efficiently*? can we really use augmented reality to develop a useful learning tool for older adults?

We designed a test that, at the same time, provides older adults with the opportunity to enjoy a short immersive augmented experience – so that they can have a first taste of augmented reality – and provides us with data that we can analyze, looking for the answers to the above questions. And we added to our Augmented Environment – and, therefore, to our prototype – a Testing Area (we have extensively examined it in the previous Chapter (see Section 5.3.1.4), and we will further examine it in Chapter 7), that is, a set of virtual rooms that, through a series of exercises, help the user to get familiar with augmented reality, and with the typical gestures necessary to interact with holograms.

6.1 System requirements for developing AR applications

When we started this project, the only head-mounted device available on the market capable of satisfying our needs (that is, capable of producing 3D, immersive and interactive augmented environments) was *Microsoft HoloLens* (see Figure 65). And since HoloLens applications have to be compiled to Universal Windows Platform (UWP) applications by the .NET Native compiler, which only runs on Windows, we were somehow forced to develop the whole project on the Learning Augmented Environment on a *PC with Windows 10 Pro*. Particularly, we used a 64-bit PC supporting virtualization in its BIOS, with 12 Intel Core i7-8750H CPUs (2.2GHz) and 32 GB of RAM.

Figure 65: Microsoft HoloLens

As for the software, we must remember that building holographic applications is a relatively new endeavor. Therefore, there are no software tools that have been specifically designed to build and deploy such applications. Nevertheless, we were able to find several software tools, originally created for different, but somehow similar purposes, that could also be used to deal with holograms in 3D spaces. Particularly, we are talking about tools that have been used to create computer games and video games, and that have been modified and extended to create holographic applications for the HoloLens [36].

6.1.1 Unity 2018

Unity [158] is the most important among such tools. Indeed, Unity is the main tool we used to develop our prototype. Unity is a *game engine*, that is, a tool for building and testing interactive 3D apps. Originally, it was built for 3D game development. However, over the years, developers have added to it prototyping tools for AR apps, so that now it has become one of the most popular tools among AR developers.

In Unity, every basic 3D scene must include a camera, a source of light, and some 3D objects (i.e., for AR apps, the holograms) called *GameObjects* [159]. In a standard game, the camera is either a first-person or a third-person view of the scene, while the camera for AR apps is strictly first-person view.

Several windows in the Unity editor (see Figure 66) allow the creation and configuration of the GameObjects placed within a scene. The GameObjects' behavior is controlled by *scripts* (see also Section 5.2.2.2) that are either provided by Unity or written (in C#) *ad hoc* by developers to fulfill particular needs.

The Unity editor also comes with a built-in player, so it is possible, during the development, to run a scene in the editor and interact with the game through the keyboard and the mouse. When dealing with the development of AR applications, Unity can bypass the build-in player, and play the scene in the head-mounted device, so that developers can test the scene they are working on and manipulate holograms directly in the immersive 3D space.

6.1.2 VISUAL STUDIO & OTHER SOFTWARE

Besides Unity, we also used a variety of software tools. For example, we made an extensive use of *Visual Studio*, a full-featured programming environment that interfaces smoothly with Unity, and that helps developers to write and debug the codes (the scripts) used to provide GameObjects with behaviors. Moreover, we used Visual Studio to build a *Universal Windows Platform app* from the project we created with Unity, and to deploy the app into the HoloLens.

As for the creation of the contents to be imported into Unity, we used from time to time the tools that we found most useful, from *Photoshop*, *Blender* or *Mixamo*, to *Character Creator*, *iClone*, *Reallusion*, *Vegas Movie Studio*, *Amazon Polly TTS*, *Balabolka TTS*, and *Audacity*.

Finally, we need to mention to the *HoloToolkit* [35], which is an essential part of HoloLens development. The HoloToolkit is a very useful set of scripts integrated in Unity, and has provided us with many of the tools needed to handle all important aspects of development, from loading into Unity the right settings for AR applications, to enabling gestures or spatial mapping.

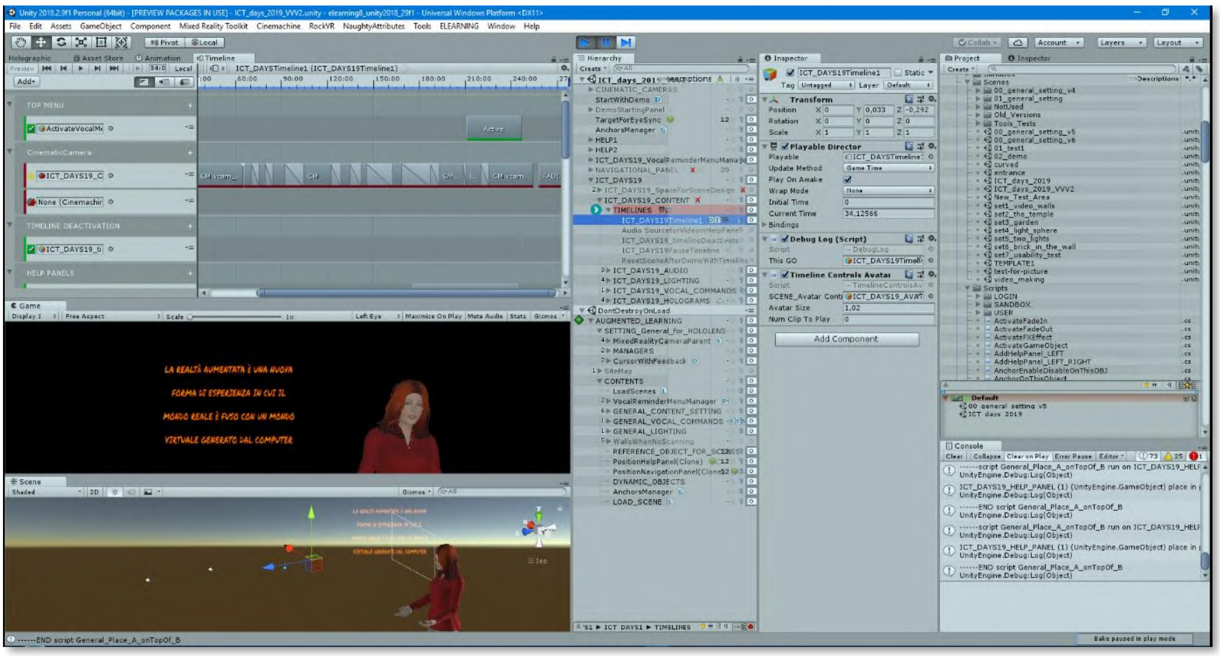


Figure 66: The Unity editor with different windows allowing the creation and organization of Game Objects. On the lower-left area, the built-in player (with black background), allowing developers to test the scene they are developing.

6.2 Developing the prototype of the Learning Augmented Environment

Overall, the Augmented Environment is divided in two main areas: the *Configuration Area* and the *Immersive Area*.

- *The Configuration Area* (General Settings & Augmented Environment Building) contains Configuration Modules defining the conditions for the existence and the behavior of all the Immersive sub-Areas (Learning, Demo & Training, Testing) and their contents.
- The *Immersive Area* is made with all the different Immersive sub-Areas that, together, make the part of the Learning Environment the user makes experience of. Each Immersive sub-Area is made with several interconnected Augmented Modules/Rooms (Virtual Rooms).

As we explained in Chapter 5, the Virtual Room is the basic component and the core of the whole Augmented Environment. The Configuration Area was built around one original virtual room, by adding up Configuration Modules to that original virtual room.

Each configuration Module provides the virtual room and its components with additional features and properties.

Overall, the configuration modules take care of:

- Setting up the different devices and sensors present in the Microsoft HoloLens (the environment tracking cameras, the video camera, the depth camera, the four microphones, the see-through displays, the speakers) used to manage all processes of input/output from/to the user and from/to the environment.
- Setting up the different "virtual tools" the user needs to see and interact with holograms (such as the *mixed reality camera*, a virtual camera ideally placed in the user's head, which sees the augmented environment exactly from the user's point of view; or a virtual pointer – a colored dot – placed at the center of the user's field of view, and used to point at (select) holograms).
- Managing the scanning process of the user' surroundings, and creating several 3-D maps (visual and acoustic) of the environment. These maps are constantly updated so that, at any instant, no matter what the user's position is, the HoloLens knows what real objects are around, and where they are (see Figure 42÷Figure 48).
- Finding out horizontal and vertical planes (like chairs, couches, tables, windows, doors, etc.) that are in the environment the user is in, and adding those planes to the maps of the environment. The HoloLens uses the updated maps to manage the positions of the holograms within the augmented stage (pictures or videos on walls, virtual characters sit on chairs or the couch, virtual objects on tables, and so on).

- Creating one Virtual Room, adapting it to the size and position of the real room/environment, and locking its position for the entire duration of the immersive experience.
- Creating the different interfaces (see 5.2.2) and placing them within the Augmented Environment (taking also into account the real elements of the real environment).
- Handling the user login process.

Figure 68 shows the architecture of the Learning Augmented Environment with the different modules that, during the development of the Augmented Environment, have been implemented in Unity 2018. Each orange module in Figure 68 represents a Configuration Module (or a combination of sub-modules) and has its correspondent Module (or a combination of sub-modules) in Unity 2018, as shown in Figure 67. The same applies to the Modules of the Immersive Areas, in blue in Figure 68, with their correspondent Modules in the blue area in Unity (see Figure 67).

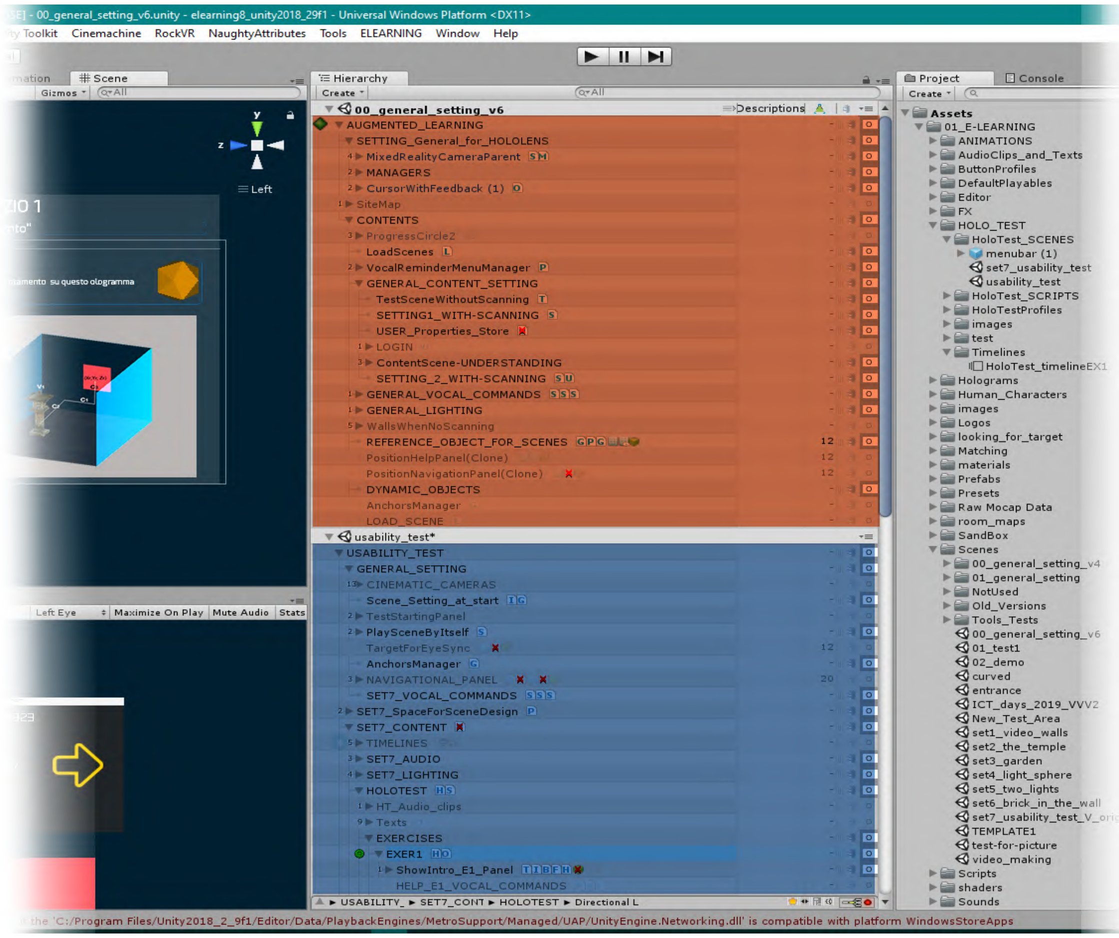


Figure 67: General Architecture of the Augmented Environment in Unity 2018

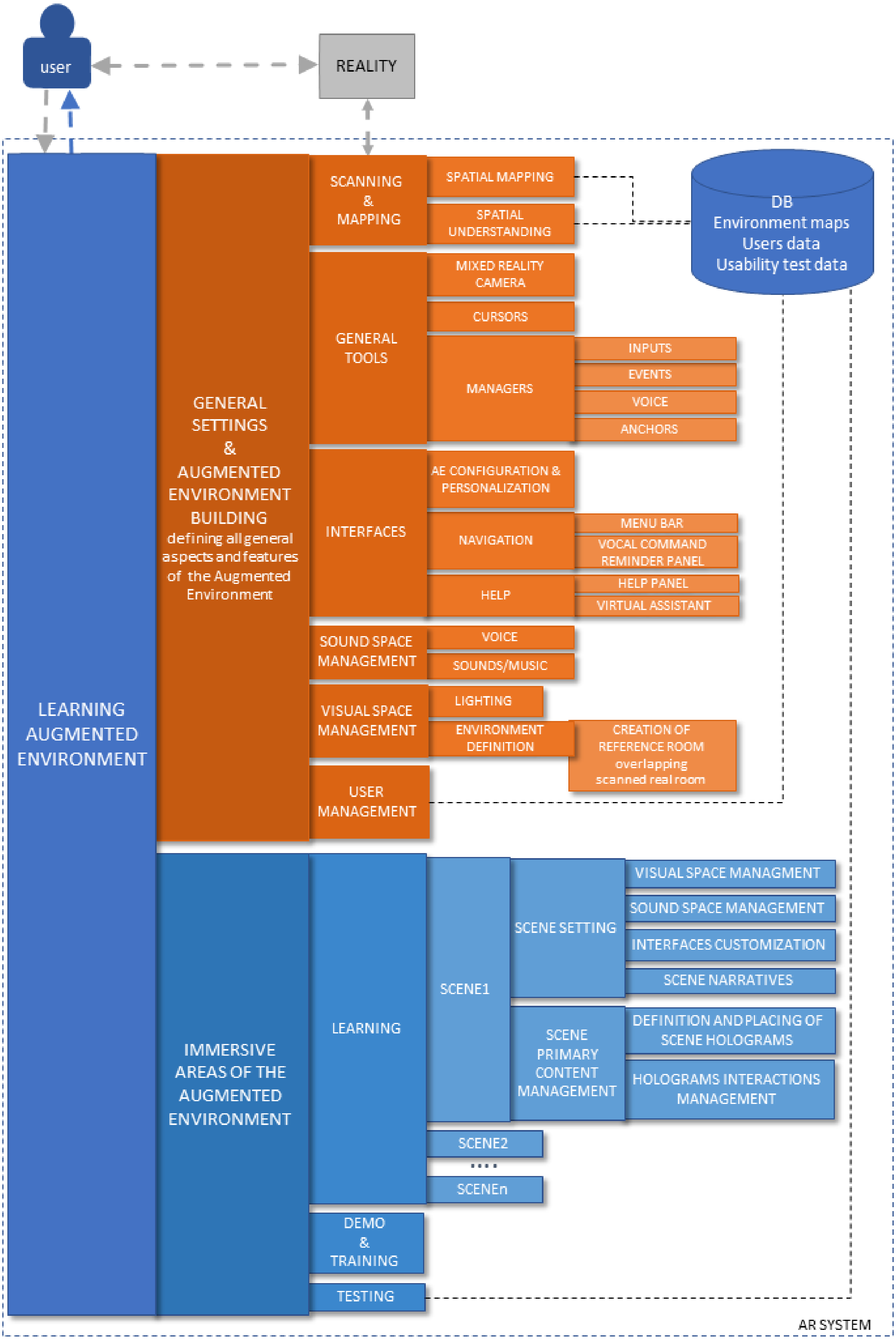


Figure 68: The architectures of the Learning Augmented Environment

6.3 Implementation Results

6.3.1 The App of the Learning Augmented Environment Running on the Microsoft HoloLens

Once deployed on the HoloLens, the app with the prototype of the Augmented Environment is ready to be run:

1. At start time, the app loads one after another the Configuration Modules defined in the Configuration Area.
2. All input/output devices and the virtual tools are activated and set;
3. Spatial and sound maps are generated after the first scanning of the environments;
4. One virtual room is generated; then, it is resized and repositioned to match the size and position of the scanned room/environment;
5. The interfaces are placed into the virtual room and, if necessary, are repositioned to account for the existence of real objects in the real room;
6. The size and position of the virtual room are locked, and will not change for the rest of the immersive experience in the Augmented Environment;
7. The User Management Module helps the user to login.

Once all the configuration modules have completed their tasks, the app starts loading the modules defined in the Immersive Area. Particularly:

8. The Module with the virtual room created during the configuration process loads the contents of the first immersive room the user will be immersed in, the *main hall*, or the *Introductory Scene* of the Augmented Environment.
9. Finally, the *Introductory Scene* Module is activated and becomes visible to the user.

The user is now ready to begin his immersive experience with the Augmented Environment. From the *Introductory Scene* Module, by means of the different navigation interfaces, the user can move from one immersive module to another. Each time the user selects a new module, the app loads the required module around the user, and the old module the user was in is discharged.

6.3.2 Website and Videos

To allow the reader of this work to have a better (and visual) understanding of the experience a user wearing the HoloLens can have when he is immersed in our Augmented Environment, we recorded a few videos of the different Exercises in the Testing Area (see Section 5.3.1.4).

Particularly, we recorded the videos of Exercise 1, Exercise 4, Exercise 5, and Exercise 6. In addition, we also recorded a video of the *Presentation of the ICTDays 2019 Event* (see Section 8.1.4 for more information on the event).

The above videos are visible on a simple Website (see Figure 69) available at the following url: https://tinyurl.com/y26crano .

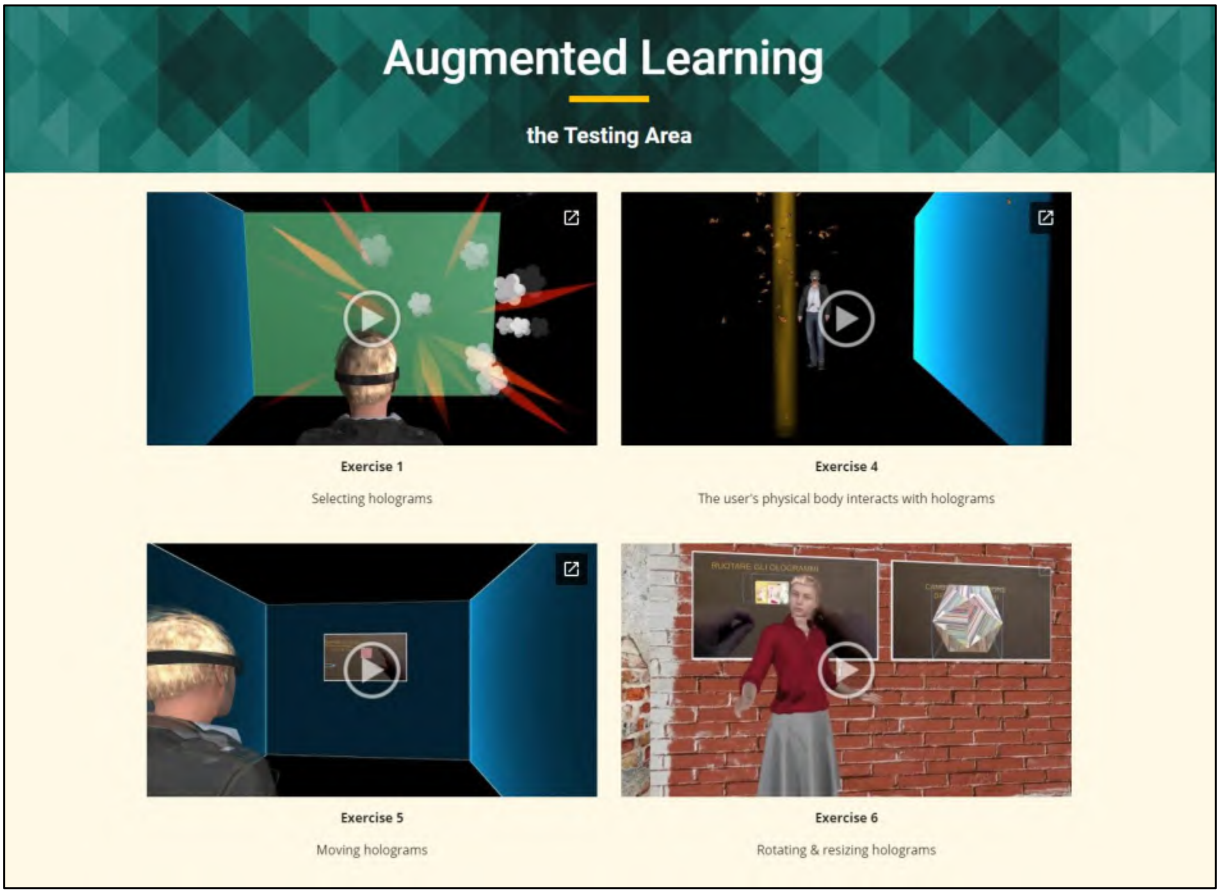


Figure 69: The Website with the videos of the Exercises in the Testing Area

As we explained in Section 5.3.1.4, the *user* visible in the videos (wearing a generic head-mounted display) has been created only for the sake of showing in the videos the position of the user during his immersive experience. During the actual immersive experience with the HoloLens, that user is replaced by the real user.

6.4 Conclusions

With this Chapter, we completed the discourse on the creation of the Learning Augmented Environment. In Chapter 4, we proposed an innovative and theoretical approach to Augmented Reality, using semiotics to open up and closely examine augmented environments, that is, the forms of communication produced with augmented reality meant as a system of signification. In Chapter 5, we focused on the design of the augmented environments that we defined and examined in the previous Chapter. Particularly, we dealt with the design of an immersive augmented environment capable of hosting a learning environment especially tailored for older. Finally, in this Chapter, we showed the main aspects of the process of development (the production stage) of a prototype of the Augmented Environment that we previously designed.

This whole process of creation of the Learning Augmented Environment, as described in the three chapters, is summarized in Figure 70.

Now, we have a fully working prototype of the Augmented Environment, as described in 5.2. The prototype is in the form of a piece of software – an app – that can be deployed on the Microsoft HoloLens and that, once running, is capable of generating an immersive, 3-D and interactive Augmented Environment.

The prototype does not contain yet the Learning Area we introduced in 5.3.2. However, it does contain the Testing Area, a set of modules based on the Virtual Room, with a set of exercises meant to help the user to get familiar with Augmented Reality. The Testing Area will allow us to test the functionality and usability of the prototype with a group of older adults, as well as with a group of students (for more details on this, see Chapter 5, Section 5.3.1.4, and Chapter 7, entirely dedicated to the test with the prototype).

We believe that during the development of the prototype we were able to define a few development strategies that not only have speeded up the development of our prototype, but will also prove significant for the development of any kind of augmented environment, no matter what its contents are.

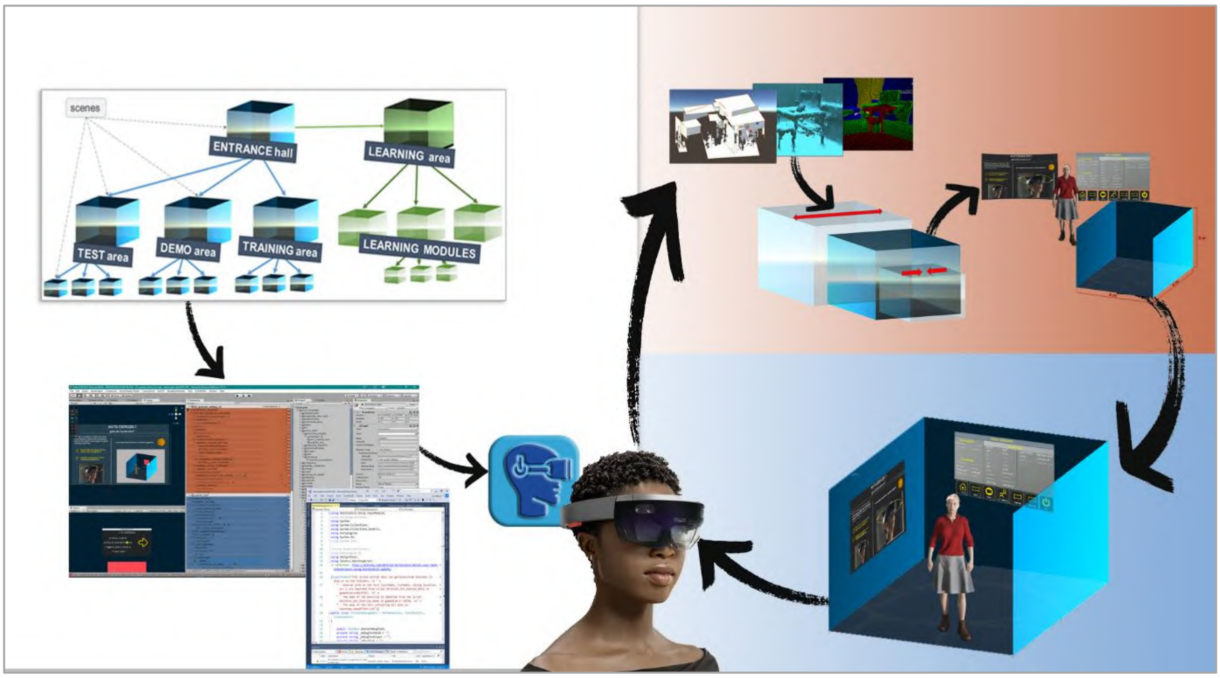


Figure 70: Creating the Learning Augmented Environment:from the design to the immersive experience

Moreover, we believe that the clear-cut separation we were able to obtain between the Configuration Area and the Immersive Area – made possible by the existence of the Virtual Room – is an important contribution in the development of applications for Augmented Reality, and a first step toward the definition of a Content Management System (CMS) for Augmented Reality similar to the CMSs, very popular nowadays, used for the creation of websites.

Finally, we believe that the existence of the Virtual Room has facilitated the development of our Augmented Environment. We must remember that any virtual room (together with its interfaces) has the capability of readapting itself to the real environment the user has around during an immersive experience. Therefore, while developing a scene of an augmented environment, we can create the entire scene directly within a virtual room, without the need to referring to any real room (and without going through the consequent and tedious process of scanning the environment each time we want to test a whatever change in our code). Exactly because of the way we designed the virtual room, we know that whatever we do in the virtual room will work with any real room, once the app is up and running. We can even design and develop one scene directly in the virtual room. In fact, thanks to Unity, that is constantly connected to the HoloLens, we can immerge ourselves, at any moment, into the scene we are developing, and see in real-time the look and behavior of all the holograms we are creating or modifying.

Part III: Evaluation

CHAPTER 7

7. Testing the Prototype with Microsoft HoloLens

7.1 Introduction

As we saw in the previous Chapter, we now have a working prototype of our Augmented Environment. In this Chapter, we will show how we test the prototype, that is, how we use the prototype with groups of selected users (older adults, and students.

Particularly, we want to use the prototype for the following **purposes**:

1) We want to examine the usability of the interfaces of the Augmented Environment. This will allow us to identify any problem that might reduce the usability of the Augmented Environment. The information acquired during the test will be used to solve the identified problems, and to refine the design of the Augmented Environment and its interfaces.
2) We want to understand whether older adults are *able to use immersive augmented reality* (that is, (a) they are able to perform the gestures necessary to interact with the holograms, and (b) they are able to perform particular sequences of gestures necessary to complete a few assigned tasks).
3) We want to understand whether older adults are *able to use augmented reality efficiently* (that is, they are able to use AR at a reasonable speed, and with sufficient ease, so that AR can reasonably be used to create a learning platform for older adults).
4) We want to acquire information on the *relationship older adults have with new technologies*, and particularly with augmented reality. This information will allow us to better understand whether older adults are willing to accept – and to what extend – augmented reality as a new technological tool for learning.
5) We want to understand, as a consequence of (2)-(4), whether it is (a) *possible* and (b) *reasonable to use augmented reality* in order to create a learning platform for older adults.

To find answers to these questions, we designed a test, made up of three different "testing parts", or *testing sections*, each of which, by using different tools and methodologies, will allow us to acquire sets of data of different types.

Particularly, in the first section of the test, we will deal with the immersive experience through the HoloLens. We will examine again the Testing Area that we introduced in the previous Chapters, and the Exercises therein contained. The data captured by the HoloLens during the users' immersive experience in the Testing Area will be analyzed in order to identify some usability features of our Augmented Environment, impossible to find out before the test. Also, from the analysis of the data coming from the HoloLens, we will be able to have detailed information on all the activities that the users perform while trying to complete the Exercises proposed in the Testing Area.

As for the second section of the test, we have developed a Questionnaire to evaluate the usability of the entire Augmented Environment. The feedback from the users who have had the immersive experience in our Augmented Environment, will allow us to identify the possible usability issues that we did not yet identify and solve in the actual prototype, or that we did not consider during the design and the development of the Augmented Environment.

Finally, in the third section of the test, through a focus group with all participants who used the HoloLens, we will acquire qualitative information on their immersive experience, and on their relationship with new technologies.

Through the analyses of the data and information acquired with the different methodologies and tools, we will be able to define a multi-perspective view of our Augmented Environment, and we will also be able to provide answers to the questions we set above.

At the moment of this writing (January 2020), we did not have yet the opportunity to complete the administration of the real test. However, we managed to carry out a pilot test with a few participants. The pilot test allowed us to explore the efficacy (and the weaknesses) of some of the analytical tools that we intend to use during the real test. Indeed, because of the pilot test, we had the opportunity to make changes and corrections to some of the tools.

We will soon complete the development of the prototype, and we plan to start the administration of the test in the coming months (March-April 2020).

NOTE (August, 2020):

The lockdown of most economic, social and cultural activities, imposed by the Italian Government as a way to fight the pandemic spread of Covid-19, blocked our work as well. From February 2020 on, we were forced to stop any kind of activity related to the administration of the test. As a result, we have no data from the test with the HoloLens, from the Questionnaire for the Evaluation of Usability of Augmented Environments, and from the Focus Group, and we will not be able to have these data in the near future.

As a consequence, the following Sections in this Chapter have not been updated with the data from the real test. The data used in all the tables and graphs in this Chapter still refer to the pilot test administered in December 2019.

7.2 Participants

If we want to fine-tune the design of our Learning Augmented Environment so to tailor it for older adults, we need to have a better understanding of what, in Chapter 4, we defined as the model receivers of our Learning Augmented Environment: older adults. This means we need at least to identify older adults' needs, interests and capabilities, so to be able to adjust the design accordingly. However, we do not need a too complex definition of “older adults”; we only need to identify those psycho-physical or behavioral traits typical in older age that force some formal or structural changes in the design. Particularly, we look for valuable information on:

Psycho-physical traits: older adults might suffer from some psycho-physical disabilities; we need to take such disabilities into account, so that the content of the Learning Augmented Environment can be delivered in such a way to minimize the disadvantages due the possible disabilities. For example, if we know from literature [160] that a progressive loss of sight or hearing occurs in older age, we must provide, as we did, the Learning Environment with alternative navigation systems (e.g. a *Visual navigation system* vs. a *Vocal system for navigation and control* – see Section 5.3.1.3.1), or different ways of delivering contents (e.g. via images and via oral narration), so that one system/way can replace the other when necessary.

Education level & Digital knowledge: to select the most adequate language to use during the learning experience, or the level of in-depth of the content, or the topics that can satisfy the older adults needs and interests, we need to have information on the older adults’ general level of education and on the knowledge they have on the use of computers, and on digital tools.

In addition to the participants in the Older Adults Group, we will also involve in the test another group of participants (the Students Group) made up with students enrolled in the Master or Doctoral Programs at the University of Trento - Department of Information Engineering and Computer Science (DISI). We will use such group as the *control group*. The data coming from the Students Group will be compared with the data coming from the Older Adults Group, to find out how two very different generations of users with very different levels of digital knowledge and competence deal with Augmented Reality.

Here below, we provide the features of the two profiles we will use in the test.

7.2.1 INCLUSION CRITERIA

Older adults (65-80), men and women, in good health (autonomous) and with no impaired mobility of the upper limbs and head, i.e. able to perform some simple movements with their head (turn their head slightly to the right or left, up or down), or with their hands (simple gestures with two fingers of one or two hands) or their arms. Participants should not be familiar with new technologies and, particularly, with augmented reality.

Students (from UNITN -DISI), men and women, 18+, in good health and with no impaired mobility of the upper limbs and head. Participants should not be familiar with augmented reality.

7.2.2 EXCLUSION CRITERIA

Older adults: Tremors in their head, arms and hands. Impaired mobility of their upper limbs and head. Problems, or unwillingness, to wear the *Microsoft HoloLens* device on their head. Annoyance or lack of interest in new technologies. Familiarity with new technologies and, particularly, with augmented reality.

Students: Impaired mobility of their upper limbs and head. Familiarity with augmented reality.

7.2.3 PARTICIPANTS RECRUITMENT

Older adults: A *Call for participation* in the project (see Appendix B1) is displayed in public spaces available in selected Cultural and Recreation Associations and Centers for Older Adults. Among those who volunteer to participate, 12/14 (men and women) are selected through a *Screening Questionnaire* (see Appendix A), aimed at verifying that the minimum conditions for participation (above) are met.

Students: The immersive experience in augmented reality is administered to a group of students from the Master's or Doctoral programs at DISI - UNITN. A *Call for participation* in the project (see Appendix B2) is displayed in public spaces available at DISI. Among those students who volunteer to participate, 12/14 (men and women) are selected through a short interview aimed at verifying that the minimum conditions for participation are met.

7.3 General Framework

As we previously said, the test as a whole is made up of three different “testing moments”, or testing sections, each of which uses different tools or methodologies to acquire different data sets. In this section, we will provide the general framework for each testing moment, and introduce the methodologies or tools used therein.

7.3.1 The Testing Area in the Prototype

Following the design principle we described in 5.1.1, we kept the design and development of the Augmented Environment separated from the design and development of what can be considered the general Learning Area, where the primary contents of the Learning Augmented Environment are. The Testing Area that we developed for the purpose of carrying out the test with older adults can be considered as a smaller and simpler version of the general Learning Area.

We have extensively discussed about the Testing Area and its Modules in Chapter 5 (Section 5.3.1.4). Therefore, here, we will not go again through the detailed descriptions.

In this Chapter, we will examine the Testing Area from a different perspective. That is, we will focus on the data captured by the HoloLens during the test.

We need, however, to recall at least a few details about the Testing Area.

The Testing Area is divided into 7 sections, that is, different immersive modules, as shown in Figure 71, each of which, with the exclusion of the Introductory Module, contains one exercise that the user must complete.

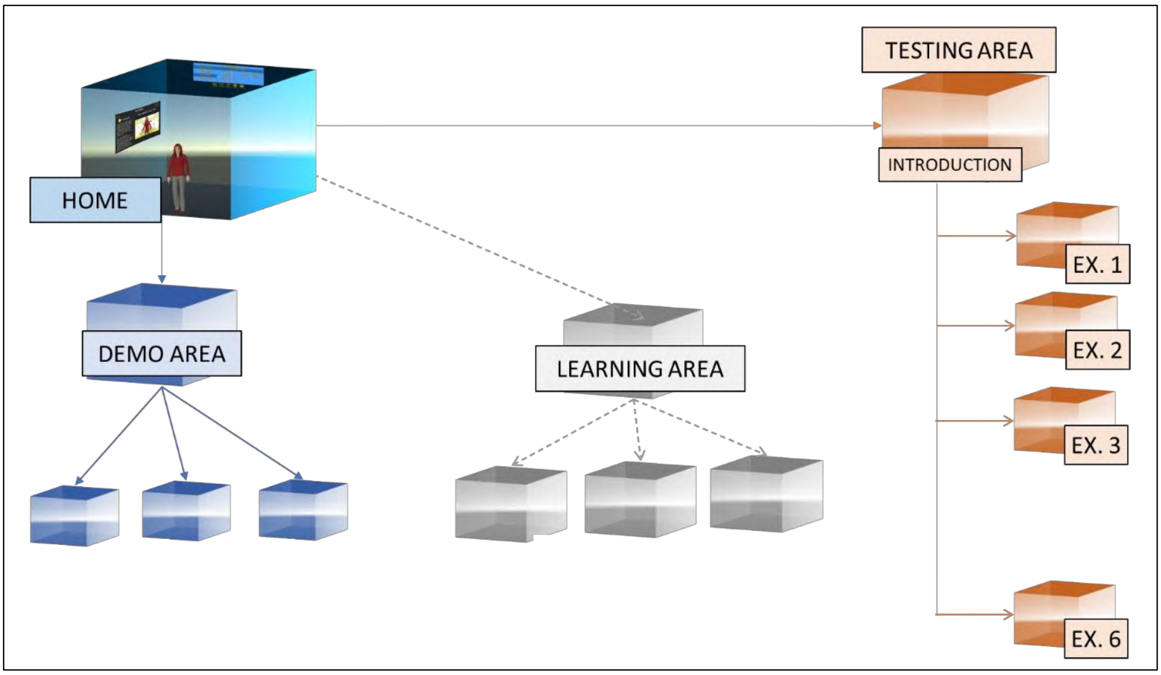


Figure 71: The Augmented Environment with the Testing Area

The exercises created in the Testing Area are meant to (a) *teach* the user all the gestures necessary to manage all possible forms of interaction with holograms and (b) *test* the user on those gestures, to verify whether the user has learned them.

At the beginning of the immersive experience with the Testing Area, the user wearing the HoloLens is immersed into the *Introductory Module*, which provides general information and explanations on the main features of the Augmented Environment and the Testing Area. From the Introductory Module, by using one of the navigation interfaces described in Section 5.3.1.3.2, the user can move on to the module containing the first exercise. When the user has completed the first exercise, he is given the opportunity to advance to the next module containing a new exercise, and so on for all the modules in the Testing Area. Upon completion of all exercises, the immersive experience in the Testing Area is completed and the user can leave the Learning Augmented Environment and take the HoloLens off.

All the exercises in the Testing Area require the user to perform some gestures with his hands to manipulate some holograms. The app takes care that the HoloLens stores all data on those gestures, so that these data can be later exported to a computer and analyzed.

Table 4 shows the data captured by the HoloLens during the test.

Table 4: Data on user's gestures acquired by the HoloLens

Day and **time** of the test
Test Name
User Name
Exercise Name/number
ID/Name of the hologram involved in the exercise
Type of gesture performed by the user on the hologram: (enter/exit the area where the hologram is defined, select, click, hold (1 or 2 hands), move (1 or 2 hands), rotate (2 hands), resize (2 hands)
Gesture **execution time** (if applicable, i.e., hold gesture with move, rotate, resize)
Amount of time the user needs to complete one task
Initial Position of one hologram (if the user is required to move the hologram);
If the hologram is moved, **duration** and **direction** of the movement;
If the hologram is rotated, **duration of rotation** and **amount of rotation** (degrees);
If the hologram is resized, **duration of resizing** and the **percentage of resizing** (%).

7.3.1.1 Testing Area: the Modules with the Exercises

All the modules in the Testing Area have been developed following the directions shown in the Table 5-A÷G.

Table 5-A: Test with HoloLens: Introductory Module

SECTION	INTRODUCTORY MODULE
HOLOGRAMS IN SCENE	• The Room (the virtual room) – 4 walls (left, front, right, floor) are visible • The Help Panel (on the left wall) • The menu (the visual navigation interface) • Elektra
DESCRIPTION	For a detailed description of see Chapter 5, Section 5.3.1.4.1
PURPOSE	To introduce the user to Augmented Reality, to the general features of the LAE, and to the immersive experience the user will have in the Testing Area

Table 5-B: Test with HoloLens: Exercise 1

SECTION	EXERCISE 1
HOLOGRAMS IN SCENE	• The Room (the virtual room) – 2 walls (left, front) are visible • The Help Panel (on the left wall) • 3 panels with textual and visual content • Elektra • 6 holograms (same size, spherical shape) in random position
WHAT IS ANALYZED	head movements: - use of the head-pointer
DATA ACQUIRED	• user behavior (with video) • total duration of the exercise • type of gesture performed • amount of time the user needs to complete each task
DESCRIPTION	For a detailed description of see Chapter 5, Section 5.3.1.4.2
PURPOSE	• To teach the user the "POINT AT HOLOGRAMS" or "SELECT HOLOGRAMS" gesture, that is, how to use the user's head to point at/select holograms • To find out the average time it takes to perform the "SELECT HOLOGRAMS" gesture

Table 5-C: Test with HoloLens: Exercise 2

SECTION	EXERCISE 2
HOLOGRAMS IN SCENE	• The Room (the virtual room) – 2 walls (left, front) are visible • The Help Panel (on the left wall) • 3 panels with textual and visual content • Elektra • 6 holograms (same size, spherical shape) in random position
WHAT IS ANALYZED	• head movement: - use of the head-pointer • gesture: - 1 hand - click
DATA ACQUIRED	• user behavior (with video) • total duration of the exercise • type of gesture performed (point at (head), click (1 hand) • amount of time the user needs to complete each task
DESCRIPTION	For a detailed description of see Chapter 5, Section 5.3.1.4.3
Purpose	• To teach the user the "CLICK ON HOLOGRAMS" gesture, that is, how to start an action by clicking on a hologram. • to find out the average time it takes to perform the "SELECT HOLOGRAMS" + "CLICK ON HOLOGRAMS" gestures

Table 5-D: Test with HoloLens: Exercise 3

SECTION	EXERCISE 3
HOLOGRAMS IN SCENE	• The Room (the virtual room) – 2 walls (left, front) are visible • The Help Panel (on the left wall) • 3 panels with textual and visual content • Elektra • 6 floating panels, each containing one (small, medium, or large) squared or circular shape
WHAT IS ANALYZED	• head movement: - use of the head-pointer • gesture: - 1 hand - click
DATA ACQUIRED	• user behavior (with video) • total duration of the exercise • type of gesture performed • amount of time the user needs to complete each task
DESCRIPTION	For a detailed description of see Chapter 5, Section 5.3.1.4.4
PURPOSE	To find out the smallest squared/circular shapes the user is able to select (with the "SELECT HOLOGRAMS" gesture) and then click on (with the "CLICK ON HOLOGRAMS" gesture). [**Note**: Squared and circular shapes are used to create *buttons* and *check boxes*, usually used in quizzes and forms, and are also used for multi-purpose forms of interaction between the user and the holograms, so it is important to identify the smallest squared/circular shapes that the user is able to manage without problems]. It is expected that time of response increases as the box/circle size decreases. *Info on training*: by analyzing the average time the user needs to perform the 2 gestures (head + 1 hand) and other info (from video) on the user's behavior, we can gain further info on training sessions and we might also be able to answer questions such as: Did the user learn the 2 gestures presented in the previous exercises? Was the number of holograms presented in the previous exercises big enough to train the user on the gestures? Does the user need a larger number of examples to learn and manage one gesture? etc.).

Table 5-E: Test with HoloLens: Exercise 4

SECTION	EXERCISE 4
HOLOGRAMS IN SCENE	• The Room (the virtual room) – 2 walls (left, front) are visible • 1 light beam and a Monarch butterfly swarm, randomly flying around the light beam. The light beam works as a hologram activator: it can detect the presence of the user within the light beam. On detection, it activates a monitor in front of the user (see below). • 1 large monitor showing (when activated): ▪ 2 videos with Elektra (avatar version n°2) providing instructions & information on Exercise 4 ▪ 3 panels, each containing one exercise (one question with 3 check boxes for multiple-choice answer, and relative answers) • A circular shape on the floor (capable of detecting the presence of the user on the shape) signaling the position the user must walk to at the end of the exercise.
WHAT IS ANALYZED	• head movement: - use of the head-pointer • gesture: - 1 hand - click
DATA ACQUIRED	• user behavior (with video) • total duration of the exercise • type of gesture performed • amount of time the user needs to complete each task
DESCRIPTION	For a detailed description of see Chapter 5, Section 5.3.1.4.4
PURPOSE	Contrarily to what it might seem, the purpose of Exercise 4 is not to check whether the user knows the answers to the questions shown in the monitor (the questions are very easy to answer). The real purpose of Exercise 4 is to make the user aware that his entire body is part of the augmented environment. In addition, we want to find out a usability feature, that is, the smallest font the user can read with ease when a text is shown at a fixed distance (2 meters). It is expected that time of response increases as the font size decreases, making more difficult to read the text of the questions and the answers. *Info on training:* (see previous section)

Table 5-F: Test with HoloLens: Exercise 5

SECTION	EXERCISE 5
HOLOGRAMS IN SCENE	*Scene Set 1:* • The Room (the virtual room) – 4 walls (left, front, right, floor) are visible • A stool + a cup (on the stool) • A blue light beam showing the position of the cup to move • A table set for breakfast, with some light candles on, and a vase with a flower • A blue, circular shape on the table (the target where the cup has to be moved onto) • A video on the MOVE HOLOGRAMS gesture • The Help Panel showing the video on the MOVE HOLOGRAMS gesture *Scene Set 2:* • The Room (the virtual room) – 1 wall (floor) is visible • A couch +two books (on the couch) • A few bookshelves • A violet light beam showing the position of the two books to move • A red, squared shape on one shelf (the target where the books have to be moved onto) • 2 plants • A frame with glass hanging on the front wall (through which is possible to see the 3D sculpture of Nefertiti beyond the wall). • Elektra (avatar version n° 3)
WHAT IS ANALYZED	• head movement: - use of the head-pointer • gesture: - 1 hand/ click+ hold/ move
DATA ACQUIRED	• user behavior (with video) • total duration of the exercise • type of gesture performed • amount of time the user needs to complete each task • duration of hold/move gesture
DESCRIPTION	For a detailed description of see Chapter 5, Section 5.3.1.4.6
PURPOSE	• To introduce the user to the new MOVE HOLOGRAMS gesture, and train him (once more) on the SELECT HOLOGRAMS and CLICK ON HOLOGRAMS gestures. • find out average time it takes to perform the CLICK ON HOLOGRAMS gesture • find out the average time it takes to perform the HOLD gesture (which is part of the CLICK ON HOLOGRAMS gesture)

Table 5-G: Test with HoloLens: Exercise 6

SECTION	EXERCISE 6
HOLOGRAMS IN SCENE	*Scene Set 1:* • The Room (the virtual room) – 3 walls (left, front, floor) are visible • 1 video on the ROTATE HOLOGRAMS gesture • Elektra (version avatar n°3) • 2 sliding bricked walls (left, front) • 1 wooden box and a suitcase on top • Several wooden boxes and barrels scattered around • 1 lighted wooden box (the target where the suitcase must be moved into). At the bottom, a detector plate. When the plate detects that the suitcase has correctly been placed, it displays a message telling the user that the gesture has been successfully performed. *Scene Set 2:* • The Room (the virtual room) – 1 wall (floor) is visible • 1 video on the RESIZE HOLOGRAMS gesture • Elektra (version avatar n°3) • A clone of Elektra (version avatar n°3) with different hair and clothes • 1 cylindrical wall (the center of the cylinder is where the center of the real room is) + circular floor • 1 rectangular glass container (the target where the cloned Elektra must be moved into). At the bottom, a detector plate. When the plate detects that the cloned Elektra has correctly touched the bottom of the glass container, it removes the glass container, and activates the clone. • 2 glass columns supporting Elektra and the rectangular glass container
WHAT IS ANALYZED	• head movement: - use of the head-pointer • gesture: - 2 hands / hold / rotate / resize
DATA ACQUIRED	• user behavior (with video) • total duration of the exercise • type of gesture performed • amount of time the user needs to complete each task • duration of hold/resize gesture
DESCRIPTION	For a detailed description of see Chapter 5, Section 5.3.1.4.7
PURPOSE	• To introduce the user to the new ROTATE HOLOGRAMS and RESIZE HOLOGRAMS gestures, and train him (once more) on the SELECT HOLOGRAMS, CLICK ON HOLOGRAMS, AND MOVE HOLOGRAMS gestures. • *Info on training:* (see previous section)

7.3.2 Questionnaire for the Evaluation of Usability of Augmented Environments

7.3.2.1 Framework for the Definition of Usability Evaluation Criteria

Many different systems are used for the evaluation of usability of Websites (for example, the System Usability Scale (SUS), the Questionnaire for User Interface Satisfaction (QUIS), the IBM Computer System Usability Questionnaire (CSUQ), the Microsoft Product Reaction Cards, WAMMI, Relevant View) [161], [162] [163], [164]. However, often these systems cannot easily be adapted to also account for the features of augmented environments.

Among these evaluation systems, we found one that seems flexible enough to meet our needs: the *Usability Inspection Method* [165], [166] , [167], based on Nielsen's Heuristic Evaluation (NHE) [168]. Usability Inspection is a way to evaluate user interface designs based on the judgment of groups of *inspectors*. The competences of these inspectors can vary, depending on the purpose of the inspection: the groups can be made of usability experts, as well as of real users of the interfaces to be inspected. In Usability Inspection, the judgment is used as a source of evaluative feedback on specific elements of a user interface. Individual inspection methods vary based on how this evaluation is obtained and on the *heuristics* (usability evaluation criteria) that inspectors should base their evaluation on [165].

We used Nielsen's *heuristics* [169] and Ssemugabi and Villiers' *evaluation criteria* [170] [171] as starting points to create our own set of heuristic criteria for the usability evaluation of augmented environments. Particularly, Ssemugabi and Villiers define a very useful set of criteria for the evaluation of web-based learning applications. To come up with our own set of evaluation criteria, we modified some of Ssemugabi and Villiers' criteria, and added new ones, so to be able to account for features that only exist in AR applications. While working on the definition of these criteria we found valuable suggestions on usability of Augmented Reality applications in Hunsucker [172].

Our set of criteria for the evaluation of AR applications (that is, for augmented environments generated by AR applications) is shown in Table 6.

Table 6:Usability evaluation criteria for augmented environments

General Usability evaluation criteria for Augmented Environments	
1	**System feedback** - The augmented environment keeps the user informed about what is going on through constructive, appropriate and timely feedback. - The system responds to user-initiated actions. There are no surprise actions by the augmented environment or tedious data entry sequences (in AR data entry trough the virtual keyboard should be avoided).
2	**Match between the system and the real world** - Language usage such as terms, phrases, symbols, concepts, and metaphors (the use of metaphors might apply to AEs and even to our completed Augmented Environment; however, it does not apply to the prototype) is similar to that of users in their day-to-day environment. - Symbols, icons and names usage corresponds to real-world objects/concepts, e.g. understandable and meaningful symbolic representations are used to ensure that the symbols, icons and names used are intuitive within the context of the performed task. - Information is arranged in a natural and logical order.
3	**User control and freedom** - Users control the system (not applicable for the prototype). - Users can exit the system at any time - Users can skip the module they are in and go to the next one
4	**Consistency and adherence to standards** Common platform standards are followed. There are not yet standards for AR applications, but some “rules” that apply in Web are used in AR as well: - The same concepts, words, symbols (icons), situations, or actions refer to the same thing. - navigation standards are followed (In AR, visual navigation (with menu-bar) is similar to Web, but without the idea of going “back” or “forward”. In AR, navigation is through links to click or vocal commands that move the user to different modules/areas) - standards for links activation are followed (however, contrarily to what happen in Web, any hologram in the Augmented Environment can be used as a link)
5	**Navigation** - Users should know where they are - Users should know where they can go next - The navigational options are adequate so as not to overwhelm the user. - navigation criteria are clear and simple and navigation tools are visible - users should understand the new form of navigation (only possible with AR) which uses the user’s body to activate links (not applicable to the prototype)
6	**Error prevention** - The system is designed such that the users cannot easily make serious errors. However, the concept of “error” as defined for Web applications cannot really be used with our Augmented Environment, and we need to redefine errors in AEs. It should be noted that in AR there is no concept of error similar to the one defined in the web (i.e., undo, re-open a closed window). In AR, errors, or rather, *problematic events*, can be defined as follows: **gesture execution errors:** - the *select* gesture is not performed (for example, if the target is too small to be centered) - a simple gesture (*select, click, hold*) is not performed correctly - complex gestures (*move, rotate, resize)* are made up with particular sequences of simple gestures ((*select, click, hold*). It might happen that one of the simple gestures is not performed correctly

	task execution error: - the user does not (is not able to) perform what is required (e.g. moving one hologram on top of another) **errors related to a wrong position of the user in the augmented environment:** - the user moves too much in the real space and walks out of the immersive area defined for the module - the user gets too close to a hologram and loses sight of it - the user touches/enters a hologram and loses sight of it Each of those problematic events can have consequences that must be taken into account. However, given the nature of such problematic events, it is difficult to establish a way to prevent some of them from happening. For example, when a user is not able to execute one of the gestures, or when a user moves too close to a hologram; in these cases, the only possible form of "prevention" is to provide the user with suggestions on how to deal with such events. On the other hand, it is possible to prevent other kinds of problematic events. For example, in order to avoid the user moving away from the borders of the immersive area, it is possible to make these borders visible, so that the user is always aware of the boundaries of the immersive area.
7	**Solving problematic events (errors)** - When a user is in a problematic situation, the Augmented Environment provides the user with an appropriate feedback message. - Feedback messages are expressed in plain (written or vocal) language. - Feedback messages define problematic situation precisely and give quick, simple, constructive, specific instructions for avoiding the problematic events
8	**Recognition rather than recall** - Objects to be manipulated, options for selection, and actions to be taken are visible. - The user does not need to recall (visual, acoustic, or textual) information from one hologram to another. - Related information is placed together. - Important visual information (such as a feedback message, or help panels) is defined within the field-of-view of the user (that is, the f-o-v allowed by the head-mounted device), and at a convenient distance from the user - The use of important visual information contained in areas larger than the field-of-view is minimized.
9	**"Augmentation", flexibility and efficiency of use** - The Augmented Environment and its holograms adapt to the real environment, including the real room and the real objects therein contained. - The Augmented Environment caters for different levels of users, from novice to experts (it might apply to AEs in general; however, it does not apply to our Augmented Environment, which is tailored for older adults) - Shortcuts or accelerators, unseen by novice users, are provided to speed up interaction and task completion by frequent users (it might apply to AEs and even to our completed Augmented Environment; however, it does not apply to the prototype) - The system is flexible to enable users to adjust settings to suit themselves, i.e. to customize the system. (it applies to our completed Augmented Environment, but it does not apply to the prototype)
10	**Aesthetics and minimalism in design** - The Augmented Environment does not contain irrelevant or rarely needed (visual, acoustic, or textual) information, which could distract the user as he performs tasks.
11	**Help** - The Augmented Environment has one or more help facilities to support users' needs. - Information in these facilities is easy to find, task-focused, and lists concrete steps to accomplish whatever task is required. - Instructions on how to use the system are visible or easily retrievable whenever appropriate. - It is easy for the user to understand and remember the information told by the Virtual Assistant - The presence of the virtual assistant makes the immersive experience more involving

7.3.2.2 The Usability Evaluation Questionnaire

The *Usability Evaluation Questionnaire*, to be filled out by the users of our Augmented Environment to evaluate its usability, has been developed following Gillham's [173] and Ssemugabi and Villiers' [170] principles. For each criterion defined in Table 6, one or more statements were generated, based on the sub-criteria defined within the criterion. Each statement is created in such a way as to verify the presence of a certain functionality, or feature, of particular components or areas of the Augmented Environment which favors the usability of the Augmented Environment (for example, the statement 5.6 states that *the navigational tools are clearly visible*). The user can agree (*completely agree* - *agree*), or can have an uncertain opinion (*maybe*), or disagree (*disagree* - *completely disagree*) with what is asserted in the statement.

The complete Usability Evaluation Questionnaire is shown in Table 7.1 ÷ Table 7.11.

Table 7.1: The Usability Evaluation Questionnaire- System feedback

1. System feedback

1.1 The augmented environment keeps me informed about what is going on through feedback.				
Strongly agree	Agree	Maybe	Disagree	Strongly disagree

1.2 I understand what the feedback means				
Strongly agree	Agree	Maybe	Disagree	Strongly disagree

1.3 I get feedback within a reasonable time				
Strongly agree	Agree	Maybe	Disagree	Strongly disagree

1.4 For every action I make, I can see or hear the results of that action				
Strongly agree	Agree	Maybe	Disagree	Strongly disagree

1.5 The system does not react in a manner that surprises me and it does not do anything unexpected				
Strongly agree	Agree	Maybe	Disagree	Strongly disagree

1.6 Write down any particular problem(s) you found in the Augmented Environment in relation to this section

Table 7.2: The Usability Evaluation Questionnaire- Contents, language and icons

2. Contents, language and icons in the Augmented Environment

2.1 The language is clear, and terms, phrases, and concepts are similar to those I use in my day-to-day environment				
Strongly agree	Agree	Maybe	Disagree	Strongly disagree

2.2 Symbols, icons, and names used in the Augmented Environment are clear and intuitive				
Strongly agree	Agree	Maybe	Disagree	Strongly disagree

2.3 Contents are organized and presented in a logical order (i.e., from simple to complex)				
Strongly agree	Agree	Maybe	Disagree	Strongly disagree

2.4 Write down any particular problem(s) you found in the Augmented Environment in relation to this section

Table 7.3: The Usability Evaluation Questionnaire- User freedom

3. User freedom

3.1 The system allows me to abandon the Augmented Environment at any time				
Strongly agree	Agree	Maybe	Disagree	Strongly disagree

3.2 The system allows me to leave the exercise I'm working on and move on to a new exercise				
Strongly agree	Agree	Maybe	Disagree	Strongly disagree

3.3 The tools for leaving the Augmented Environment or for moving on to the next exercise are clearly visible				
Strongly agree	Agree	Maybe	Disagree	Strongly disagree

3.4 The system allows me to move freely in all areas of the Augmented Environment				
Strongly agree	Agree	Maybe	Disagree	Strongly disagree

3.5 Write down any particular problem(s) you found in the Augmented Environment in relation to this section

Table 7.4: The Usability Evaluation Questionnaire- Consistency

4. Consistency

4.1 Words, symbols, and icons maintain the same meaning throughout the Augmented Environment				
Strongly agree	Agree	Maybe	Disagree	Strongly disagree

4.2 Write down any particular problem(s) you found in the Augmented Environment in relation to this section

Table 7.5: The Usability Evaluation Questionnaire- Navigation

5. Navigation

5.1 The system keeps me informed about my current position within the Augmented Environment				
Strongly agree	Agree	Maybe	Disagree	Strongly disagree

5.2 I clearly understand where I am (what exercise I'm going to deal with)				
Strongly agree	Agree	Maybe	Disagree	Strongly disagree

5.3 I clearly understand where I can go (what exercise I'm going to do next)				
Strongly agree	Agree	Maybe	Disagree	Strongly disagree

5.4 The number of navigational options is adequate to take me everywhere in the Augmented Environment without confusing me				
Strongly agree	Agree	Maybe	Disagree	Strongly disagree

5.5 The navigational options are clear and simple				
Strongly agree	Agree	Maybe	Disagree	Strongly disagree

5.6 The navigational tools are clearly visible				
Strongly agree	Agree	Maybe	Disagree	Strongly disagree

5.7 Write down any particular problem(s) you found in the Augmented Environment in relation to this section

Table 7.6: The Usability Evaluation Questionnaire- Prevention of problematic situations

6. Prevention of problematic situations

6.1 The system clearly shows the borders of the space where I can move and perform the exercises				
Strongly agree	Agree	Maybe	Disagree	Strongly disagree

6.2 The system helps me to correctly perform the required gestures				
Strongly agree	Agree	Maybe	Disagree	Strongly disagree

6.3 Write down any particular problem(s) you found in the Augmented Environment in relation to this section

Table 7.7: The Usability Evaluation Questionnaire- Solving problematic situations

7. Solving problematic situations

7.1 If I cannot complete a task/exercise, the system provides me with appropriate feedback messages				
Strongly agree	Agree	Maybe	Disagree	Strongly disagree

7.2 the feedback clearly explains the problematic situation I'm in, and how to overcome it				
Strongly agree	Agree	Maybe	Disagree	Strongly disagree

7.3 Write down any particular problem(s) you found in the Augmented Environment in relation to this section

Table 7.8: The Usability Evaluation Questionnaire- Recognition rather than recall

8. Recognition rather than recall

8.1 Holograms I've been asked to manipulate are clearly visible				
Strongly agree	Agree	Maybe	Disagree	Strongly disagree

8.2 Related information is placed together				
Strongly agree	Agree	Maybe	Disagree	Strongly disagree

8.3 The system doesn't ask me to recall (visual, acoustic, or textual) information from one exercise to another				
Strongly agree	Agree	Maybe	Disagree	Strongly disagree

8.4 I can clearly catch at once important visual information, such as feedback messages, or help panels (the information is visible at once within my field-of-view)				
Strongly agree	Agree	Maybe	Disagree	Strongly disagree

8.5 Important visual information are displayed at a convenient distance, so that I can see/read it with ease				
Strongly agree	Agree	Maybe	Disagree	Strongly disagree

8.6 The use of important visual information contained in areas larger than my field-of-view is minimized.				
Strongly agree	Agree	Maybe	Disagree	Strongly disagree

8.7 Write down any particular problem(s) you found in the Augmented Environment in relation to this section

Table 7.9: The Usability Evaluation Questionnaire- Augmentation and easiness of use

9. Augmentation & easiness of use

9.1 The Augmented Environment and its holograms adapt to the real room and the real objects therein contained				
Strongly agree	Agree	Maybe	Disagree	Strongly disagree

9.2 The Augmented Environment is tailored for people like myself, with my level of knowledge and my capabilities				
Strongly agree	Agree	Maybe	Disagree	Strongly disagree

9.3 **I can use the Augmented Environment with ease**				
Strongly agree	Agree	Maybe	Disagree	Strongly disagree

9.4 **Write down any particular problem(s) you found in the Augmented Environment in relation to this section**

Table 7.10: The Usability Evaluation Questionnaire- Aesthetics and minimalism in design

10. Aesthetics and minimalism in design

10.1 The Augmented Environment does not contain irrelevant or rarely needed (visual, acoustic, or textual) information, which could distract me as I perform the required tasks				
Strongly agree	Agree	Maybe	Disagree	Strongly disagree

10.2 Write down any particular problem(s) you found in the Augmented Environment in relation to this section

Table 7.11 The Usability Evaluation Questionnaire- Help

11. Help

11.1The Augmented Environment has one or more help facilities to support my needs throughout my immersive experience				
Strongly agree	Agree	Maybe	Disagree	Strongly disagree

11.2 Information in these facilities is easy to find, task-focused, and lists concrete steps to accomplish any task I'm asked to perform				
Strongly agree	Agree	Maybe	Disagree	Strongly disagree

11.3 Instructions on how to use the Augmented Environment are visible or easily retrievable whenever appropriate.				
Strongly agree	Agree	Maybe	Disagree	Strongly disagree

11.4 It is easy for me to understand and remember the information told by the Virtual Assistant (the woman introducing the Augmented Environment in the beginning of my immersive experience)				
Strongly agree	Agree	Maybe	Disagree	Strongly disagree

11.5 The presence of the virtual assistant makes the immersive experience more involving				
Strongly agree	Agree	Maybe	Disagree	Strongly disagree

11.6 Write down any particular problem(s) you found in the Augmented Environment in relation to this section

Overall, the Questionnaire aims at identifying usability issues in many different aspects of our Augmented Environment. Particularly, the last statement of each section of the Questionnaire, which allows an open answer, should encourage users to name usability problems that they experienced and that have not been foreseen during the design of the Augmented Environment or during the creation of the Questionnaire.

7.3.3 Focus group with older adults

After all participants have completed the immersive experience with the HoloLens, and have filled out the *Usability Evaluation Questionnaire*, we will organize a Focus Group to have a discussion with the participants on their experience with the HoloLens.

Focus groups are particularly useful for the exploration of the participants' opinions and personal experiences [174], [175], [176]. By taking advantage of the dynamics of discussion and comparison, and by using the knowledge acquired and shared during the discussion, the focus group will allow us to define a rich and articulated framework of the participants' experiences, both in rational and emotional terms. Such framework will greatly help us to find answers to some of the questions we introduced in 7.1, and that cannot be answered only through quantitative analysis [177], [178] [179].

Table 8 shows the Discussion Guide for the Focus Group we intend to conduct.

Table 8: The Discussion Guide for the Focus Group

INTRODUCTION TO THE FOCUS GROUP
- Short presentation of the objectives of the Focus Group [talking together about the immersive experience in augmented reality with the HoloLens device]. - Introduction to the dynamics of the meeting [a focus group is not a test, so there are no right or wrong answers; all participants should take part to the conversation; each participant is free to express his or her opinions; and so on.] - A brief round of introduction of the participants.
DISCUSSION
Reconstruction of expectations
- Before this experience with the HoloLens, what did you expect?
Verification of understanding
- After this experience, what do you think augmented reality is? - What about the holograms you've seen? What do you think they are? - If you were to tell your experience to someone who doesn't know anything about augmented reality and holograms, and doesn't know the HoloLens, what would you say?
Narration of the experience
- Can you tell us about the experience you had with the HoloLens? - What did you do? - How did you find the exercises? (easy, difficult, etc.) - How did the interaction with holograms affect you? - How did you feel during the experience? (embarrassed, at ease, annoyed, bored, scared, etc.) - Can you explain the reasons for these emotions? - What about Elektra? What do you think about her? - What did you feel when you had to follow her instructions? - During the immersive experience, were you aware of the outside world?

Evaluation of the experience	
-	What did you particularly like about this experience? [eventual ranking: what is in the first place? etc.]
-	What did you dislike about this experience? [understanding their motivations: because it was difficult, unclear, tiring, boring, etc.]
-	Is augmented reality useful in your opinion? Funny? Useless? Other?
-	Would you like to have another experience with augmented reality, but with different contents? [What content?]
Collection of suggestions	
-	What improvements would you introduce to the immersive experience to make it more pleasant, entertaining, interesting? [easier to use, with more graphics, more action, more music, more videos, less complicated, etc.]
-	Are there any other tips or comments you would like to give to those who have created the immersive experience you had?

7.4 The test – data acquisition

7.4.1 Presentation of the test

Before using the HoloLens, which generates an individual experience, all the selected participants will take part in a short presentation (about 15 minutes) during which they will be introduced (through appropriate language and with the help of images and 1 video) to the concepts of *augmented reality* and *holograms*. In this way, they will be able to better understand the tasks they will be asked to perform during the immersive experience with the HoloLens.

During the presentation, participants will also be able to see and touch the HoloLens and understand how to wear it, so as to have the opportunity to get familiar with the head-mounted device and, more in general, with the idea of using (and wearing) a new immersive technology.

Participants will also be provided with written and visual instructions (images) on the few (3-4) gestures that will be required during the immersive experience to interact with the holograms and complete the exercises they will find in the Testing Area.

7.4.2 Immersive Experience with the HoloLens

During the immersive experience with the HoloLens[3], we will guide and assist each participant in order to make the entire experience as easy and enjoyable as possible. Before starting the immersive experience, we will help each participant to wear the HoloLens. We will also remind each participant that the experience with HoloLens can be interrupted at any time and for any reason, without the need to provide any explanation.

The experience with the HoloLens will last about 15-20 minutes. Each participant will be asked to complete all the exercises by performing simple movements with his head (i.e., slight rotations of his head to the right or left, up or down, to select the holograms), or with his hands (simple gestures with the fingers of one or two hands to "hold" the holograms and move, resize or rotate them).

For each participant, the HoloLens will capture a set of data, as described in Table 4, that will later be used for quantitative analyses. In addition, each participant's immersive experience will be video recorded, so to also allow qualitative analyses of data.

[3] All participants in the test must read and sign, *before* the administration of the test, a few statements on data privacy and data protection. We have included these statements in the *Request for approval of a research protocol* (particularly, the *Allegati* H÷J). We talked about this document in Section 5.2.3.2. For the complete version of the document, see Appendix C.

7.4.3 Administration of the Usability Evaluation Questionnaire

At the end of the experience with the HoloLens, each participant will be asked to fill out the *Usability Evaluation Questionnaire* (see 7.3.2) with questions on the usability of the Augmented Environment. Given that the experience with the HoloLens might result tiring for some of the participants, we will allow the participants to fill out the Questionnaire at a later time, and at a different location (for example, at home). However, we will suggest participants to fill out the Questionnaire as soon as possible, in order to avoid forgetting the details of their immersive experience.

7.4.4 Focus group

Once all participants from the Older Adults Group will have completed their immersive experience with the HoloLens, and filled out the Usability Evaluation Questionnaire, we will ask the participants to take part to a Focus Group to freely discuss about their immersive experience and, more in general about their relationship with new technologies (see the *Discussion Guide of the Focus Group* in 7.3.3).

Since the group is made up of 12-14 participants, and focus groups should have not more than 6-7 participants, we will organize two Focus Groups, each with 6-7 participants. Each Focus Group will be about 1½ hour long, and will be guided by the researcher involved in this project. Also, each Focus Group will be audio-recorded[4].

[4] Once all participants have signed their approval to video-record the Focus Group session – see Appendix C – Allegati H÷J.

7.5 Analysis of the Results

In Section 7.3 we introduced the different tools and methodologies we intend to use for the analyses of the data and information we are able to capture through the *immersive experience with the HoloLens* (see 7.3.1), the *Usability Evaluation Questionnaire* (see 7.3.2), and the *Focus Group* (see 7.3.2).

In this section we are going to use those tools to conduct different analyses on different sets of data. Particularly, by analyzing the data, we want to:

1. Identify some usability features of our Augmented Environment that we were not able to define before the test: *through the analysis of data collected by the HoloLens;*
2. Identify possible usability problems in our Augmented Environment: *through the analysis of data collected through the Usability Evaluation Questionnaire;*
3. Find out whether older adults are able to use augmented reality: *through the analysis of data collected by the HoloLens;*
4. Find out whether older adults are able to use augmented reality efficiently*: (a) through the analysis of data collected by the HoloLens; (b) through the comparison of data collected by the HoloLens in the two groups of participants (older adults, students);*
5. Understand what is the relationship older adults have with new technologies and, particularly, with Augmented Reality: *(a) through the analysis of the data collected through the Screening Questionnaire; (b) through the analysis of the information acquired during the Focus group;*
6. Understand whether it is possible (and reasonable) to use Augmented Reality to develop a learning platform for older adults: *this depends on what we find in (3), (4), and (5).*

At the time of this writing (January 2020), it was not yet possible to complete the administration of the test as described in 7.4, with the two groups of participants (older adults and students) with the features described in 7.2.1, and selected according to the criteria described in 7.2.2.

However, we decided to conduct a pilot test with a small sample of participants (2 women and 2 men, aged 55-60). Even though we did not select the participants through the *Screening Questionnaire* (see 7.2.2), we know that the participants' level of digital knowledge is almost certainly higher than the level we expect in the target users of our Augmented Environment. On the other hand, before the test, we made sure that none of the participants were familiar with augmented reality.

It should be noted that, given the limited number of participants in the pilot test, we cannot draw any reliable conclusion from the data we acquired (some authors, such as Nielsen

[180], or Ssemugabi and Villiers [170] show that at least 12-14 (and up to 20) participants are required to obtain sufficiently reliable results with qualitative studies).

Moreover, the pilot test:

(a) does not provide us with enough data: we do not have data from the Focus Group with older adults, so we cannot answer point (3); we do not have data from the immersive experience with the HoloLens from the group of students, so we cannot answer point (5); consequently, we cannot answer point (6).

(b) does not provide us with realistic data, since the participants in the pilot test do not really match the target users of our Augmented Environment.

Despite these limitations, we proceeded with the pilot test, in order to have at least some indications on the effectiveness of the analytical tools we have selected, and on the overall features of the test we have designed.

Indeed, the analyses we conducted on the data acquired during the pilot test allowed us to identify a few usability issues (see 7.5.1.2) and to fine-tune the details of the real test that we will conduct with the two target groups of participants (older adults, students).

7.5.1 Usability Features and Usability Problems

We start by analyzing usability features of our Augmented Environment. Also, we look for possible usability issues.

7.5.1.1 Identifying Usability Features Through the Analysis of the HoloLens Data

In Table 5-A÷H (see 7.3.1), we examined the design of the different exercises defined in the Testing Area of the Augmented Environment. In this section, we are going to analyze the data captured by the HoloLens during the immersive experiences of different users performing those exercises. Particularly, Table 9 shows the data stored in the HoloLens during the immersive experience of the 4 participants in the pilot test dealing with Exercise 1. In other cases (for example, with the Exercises 4÷6, requiring the users to move, rotate or resize holograms), the HoloLens also stored data not visible in Table 9, such as d*uration of gesture, amount of motion of object n., direction of motion, rotation, and amount of resize*.

The data in Table 9 have been worked out to create the graphs in Table 10-A, showing the performances of the participants for the Exercise 1. Particularly, the left graph of Table 10-A shows the time users need to perform the *select gesture* (move their head around, left or right, up or down, until the yellow dot at the center of their field of view is over a hologram) with six different holograms; the upper-right graph shows the mean time users need to perform the gesture on each hologram; the bottom-right graph shows the time users need to complete Exercise 1.

Table 10-B÷G show similar information on the users' performances with Exercise 2 ÷ 6.

Table 9: Sample data captured by the HoloLens during the immersive experience with Exer. 1

Day	Time	Duration Exercise (s)	User	Test Name	Exercise Name	OBJECT	Event	Duration Event (s)
14/10/19	10:05:22	21	user1	HoloTest	Exer1	OBJ1	SelectOnEnter	5
14/10/19	10:05:27		user1	HoloTest	Exer1	OBJ2	SelectOnEnter	4
14/10/19	10:05:31		user1	HoloTest	Exer1	OBJ3	SelectOnEnter	3
14/10/19	10:05:34		user1	HoloTest	Exer1	OBJ4	SelectOnEnter	4
14/10/19	10:05:38		user1	HoloTest	Exer1	OBJ5	SelectOnEnter	2
14/10/19	10:05:40		user1	HoloTest	Exer1	OBJ6	SelectOnEnter	3
14/10/19	11:12:35	23	user2	HoloTest	Exer1	OBJ1	SelectOnEnter	6
14/10/19	11:12:41		user2	HoloTest	Exer1	OBJ2	SelectOnEnter	4
14/10/19	11:12:45		user2	HoloTest	Exer1	OBJ3	SelectOnEnter	4
14/10/19	11:12:49		user2	HoloTest	Exer1	OBJ4	SelectOnEnter	4
14/10/19	11:12:53		user2	HoloTest	Exer1	OBJ5	SelectOnEnter	3
14/10/19	11:12:56		user2	HoloTest	Exer1	OBJ6	SelectOnEnter	2
14/10/19	11:48:17	22	user3	HoloTest	Exer1	OBJ1	SelectOnEnter	4
14/10/19	11:48:21		user3	HoloTest	Exer1	OBJ2	SelectOnEnter	4
14/10/19	11:48:25		user3	HoloTest	Exer1	OBJ3	SelectOnEnter	4
14/10/19	11:48:29		user3	HoloTest	Exer1	OBJ4	SelectOnEnter	3
14/10/19	11:48:32		user3	HoloTest	Exer1	OBJ5	SelectOnEnter	4
14/10/19	11:48:36		user3	HoloTest	Exer1	OBJ6	SelectOnEnter	3
14/10/19	15:03:39	24	user4	HoloTest	Exer1	OBJ1	SelectOnEnter	5
14/10/19	15:03:44		user4	HoloTest	Exer1	OBJ2	SelectOnEnter	5
14/10/19	15:03:49		user4	HoloTest	Exer1	OBJ3	SelectOnEnter	4
14/10/19	15:03:53		user4	HoloTest	Exer1	OBJ4	SelectOnEnter	3
14/10/19	15:03:56		user4	HoloTest	Exer1	OBJ5	SelectOnEnter	3
14/10/19	15:03:59		user4	HoloTest	Exer1	OBJ6	SelectOnEnter	4

Table 10-A: Data from the HoloLens in Exercise 1

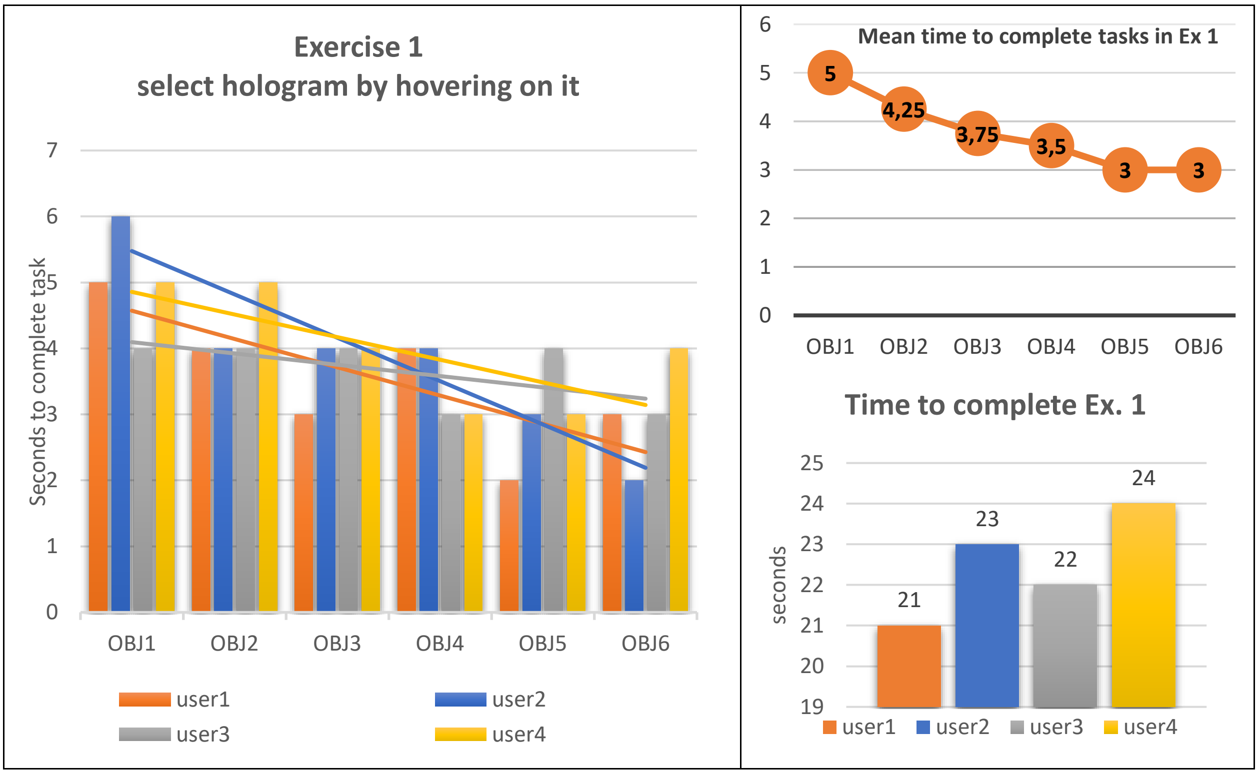


Table 10-B: Data from the HoloLens in Exercise 2

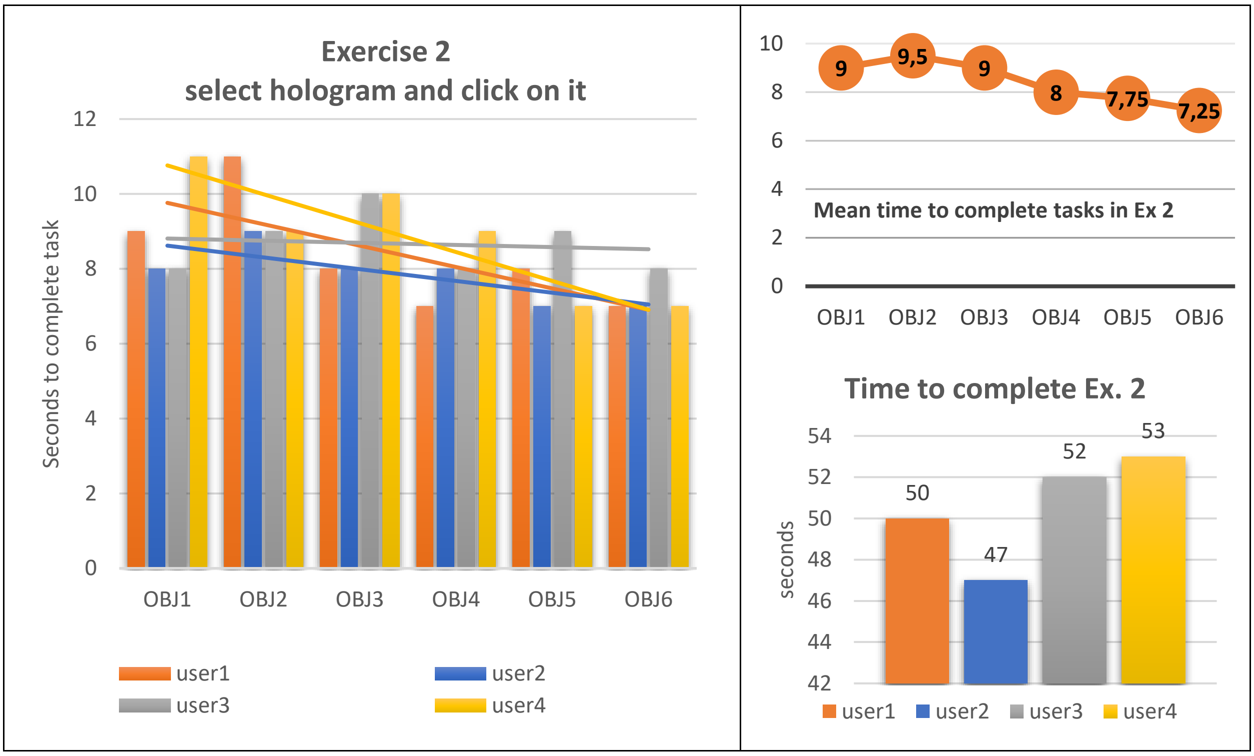


Table 10-C: Data from the HoloLens in Exercise3

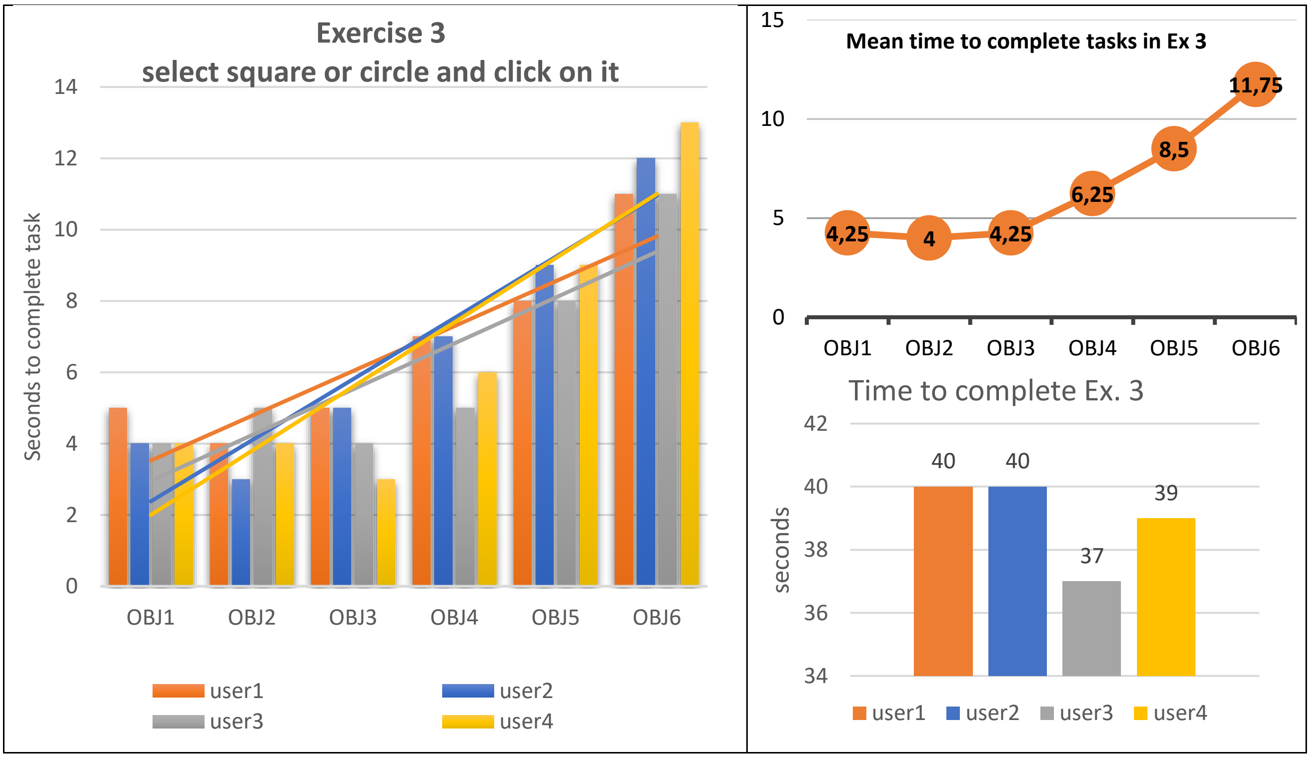


Table 10-D: Data from HoloLens in Exercise 4

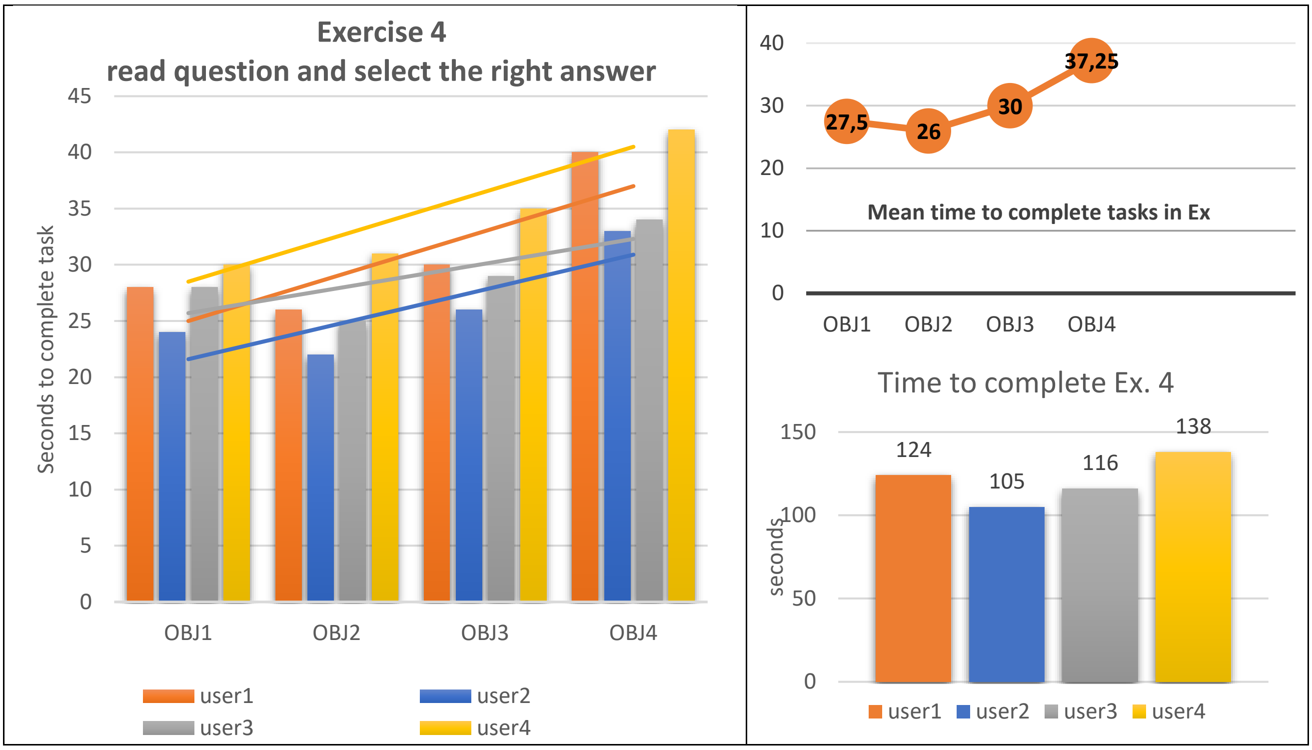


Table 10-E: Data from HoloLens in Exercise 5

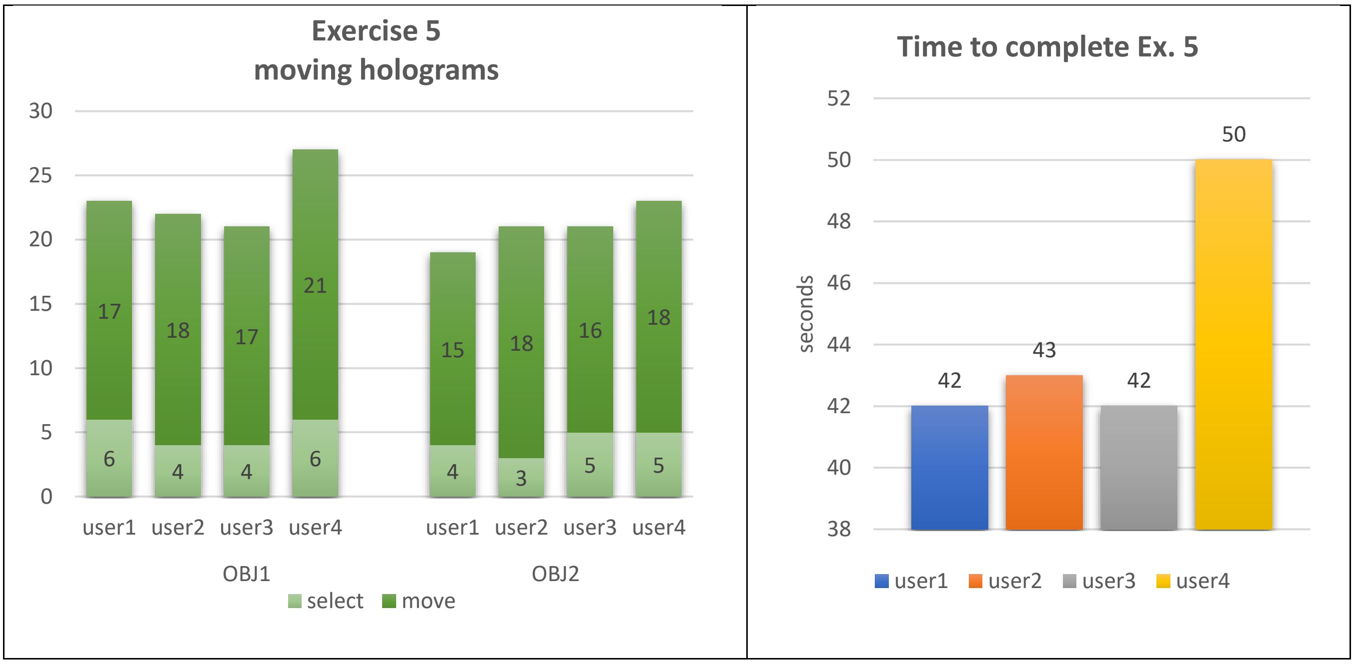
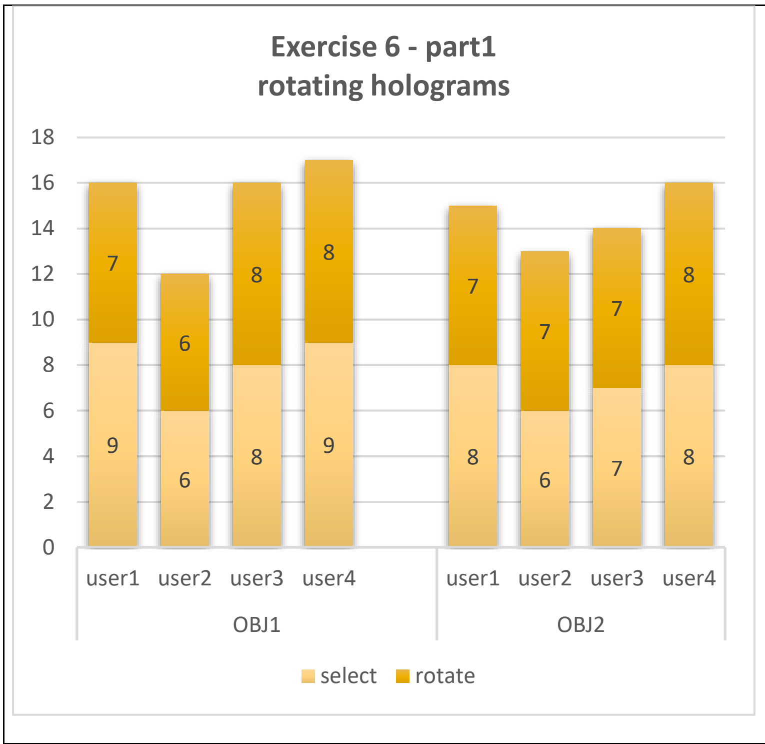


Table 10-F: Data from HoloLens in Exercise 6 – part1



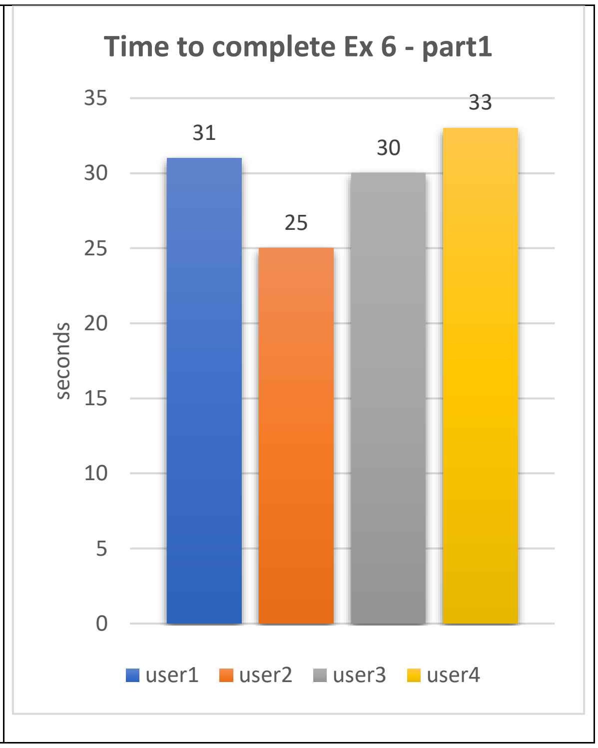
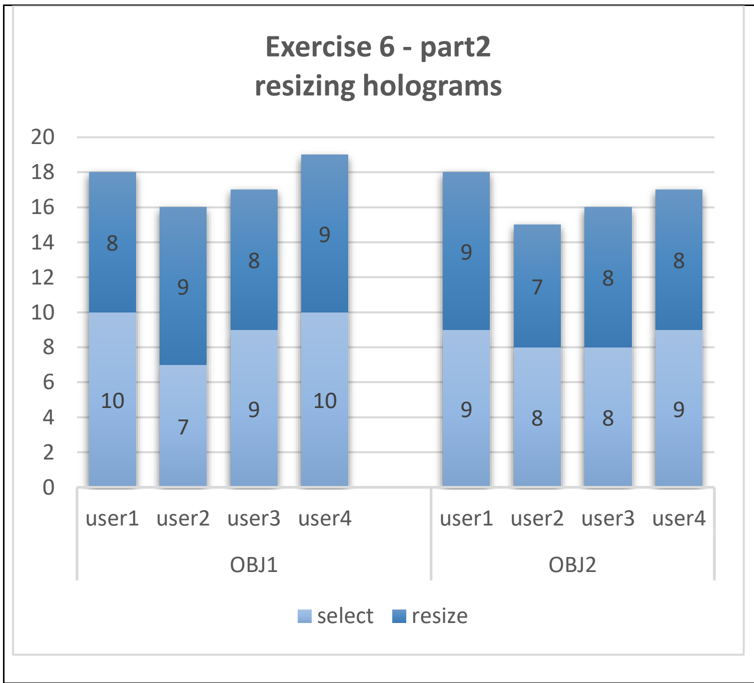
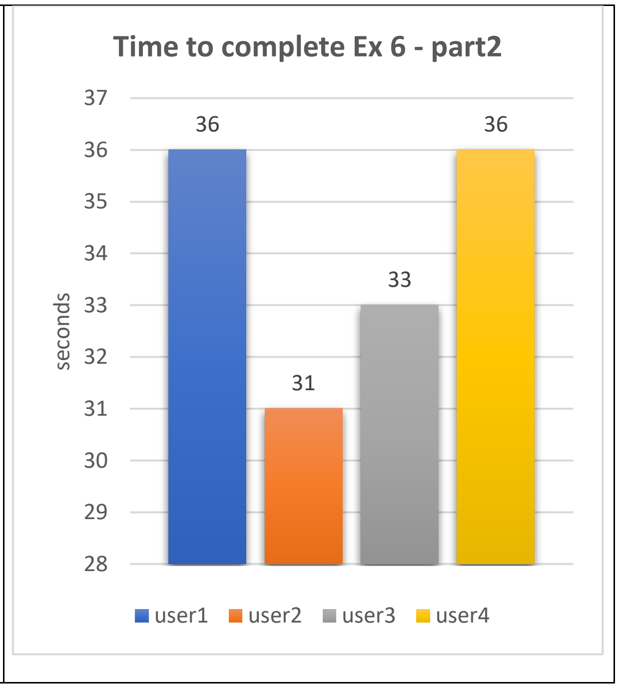


Table 10-G: Data from HoloLens in Exercise 6 – part2





By analyzing the data captured by the HoloLens during the immersive experience, we were able to identify some important usability features of some elements of our Augmented Environment that were impossible to define before the pilot test was administered.

Particularly, Exercise 3 and Exercise 4 were designed to detect features of some elements of our Augmented Environment related to usability. As we can see in

Table 5-D, the Exercise 3 is meant to find out the smallest squared/circular hologram that the user is able to “select” with ease (that is, without loss in the user’s performance). This is an important piece of information, since almost all forms of interaction with holograms require the user to be able to "select" the holograms he will interact with. Then, with Exercise 3 we try to establish the smallest size a hologram can have before the user begins to find it difficult to "select" the hologram. From the graphs in Table 10-C we can clearly see that the amount of time users need to complete the different tasks increases with the decreasing of the size of the hologram to be selected. Consequently, we can see that the ideal dimensions a hologram should have to allow a "selection" without problems or loss in performance are those of objects 1 to 3.

We must take this piece of information into account when we will deal with the design and development of the Learning Area and the holograms therein contained. From now on, we know that in order to maintain a good user's performance, all the holograms that have any kind of interaction with the user should not be smaller than object 3.

A similar analysis applies to Exercise 4, described in

Table 5-E. Here, we try to identify the smallest font size we can use for a comfortable reading of any kind of textual information shown in the Augmented Environment. If we examine Table 10-D, we see that, as in the previous case, the amount of time users need to complete the different tasks increases with the decreasing of the size of the font used in the exercise. A degradation in the users' performance begins with the font size used in hologram 3 (OBJ3). Therefore, as in the previous case, we will have to take this piece of information into account when we will use written texts to communicate with the user (as it happens with all the help panels).

7.5.1.2 Identifying Usability Problems Through the Usability Evaluation Questionnaire

A different set of data, coming from the *Usability Evaluation Questionnaire* (see 7.3.2), allows us to identify possible usability issues and problems that the data from the HoloLens are not able to provide.

We are aware that a possible limit of our approach to usability evaluation (as explained in 7.3.2) is in the choice of the *evaluators* who are going to provide the feedback through the Questionnaire. Nielsen, as well as other authors [166], [165], [169], [170] [171] do not exclude the feedback from the final users. However, they rather suggest the use of three to five *usability-expert evaluators* that, through their feedbacks, can provide designers and developers with the necessary professional suggestions to improve the overall usability of the system that is evaluated.

In our case, the evaluators are the final users themselves, that is, older adults and students (or the four participants selected for the pilot test), who clearly do not have the competences necessary to provide a *professional* evaluation of the usability of the Augmented Environment. Yet, we are confident that even with such limitation, we can still profitably use the feedback coming from our groups of users. Indeed, the Usability Evaluation Questionnaire has been already used by the same 4 participants involved in the pilot test with the HoloLens. And despite the small number of participants, and the fact that none of the participants had specific knowledge on how to evaluate usability, the feedback we obtained through the answers to the Questionnaire allowed us to detect a couple of usability problems that we have solved before carrying out the real test with the group of older adults.

The 4 participants involved in the pilot test filled out the Usability Evaluation Questionnaire soon after they completed their experience with the HoloLens.

Table 11 shows their feedbacks. We believe it useful to recall that each statement in the Usability Evaluation Questionnaire is created in such a way as to verify the presence of a certain functionality, or feature, of particular components or areas of the Augmented Environment which favors the usability of the Augmented Environment; the user can agree (*completely agree* - *agree*), or can have an uncertain opinion (*maybe*), or disagree (*disagree* - *completely disagree*) with what is asserted in the statement. In Table 11, we assigned 1 point to each *strongly agree* answer, and 5 points to each *strongly disagree* answer. For each statement in the Questionnaire, the column “Total Score” contains the sum of all the points assigned by the 4 participants to the statement. The column “Description of problem” shows, for each section, the free answers participants wrote to comments on possible usability problems they identified and that were not described in the section.

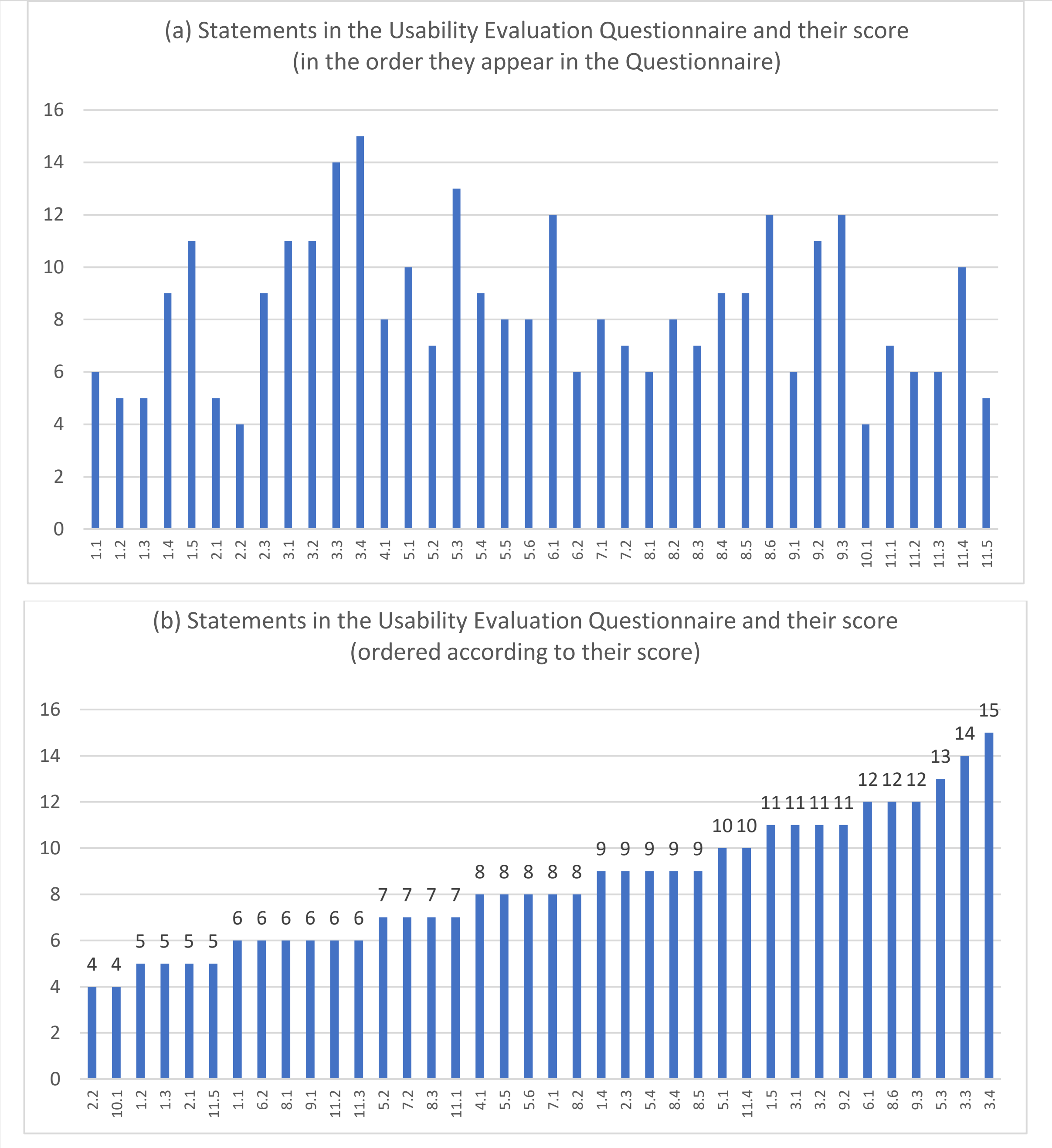
Table 11: Results from the Usability Evaluation Questionnaire - 4 users

Strongly agree=1 - Agree=2 - Maybe=3 - Disagree=4 - Strongly disagree=5

Criterion	User 1	User 2	User 3	User 4	Total score	Description of problem
1						
1.1	2	1	1	2	6	quando scompare un ologramma ci sono effetti speciali piacevoli e sorprendenti. Però gli effetti sono sempre gli stessi. Se fossero diversi per ogni esercizio, l'effetto sorpresa sarebbe migliore.
1.2	1	2	1	1	5	
1.3	2	1	1	1	5	
1.4	2	2	3	2	9	
1.5	4	2	3	2	11	
1.6						
2						
2.1	1	1	2	1	5	
2.2	1	1	1	1	4	
2.3	2	3	2	2	9	
2.4						
3					51	
3.1	3	2	3	3	11	strumenti non sono ben visibili non ci si sente particolarmente liberi
3.2	3	2	3	3	11	
3.3	3	3	4	4	14	
3.4	4	3	4	4	15	
3.5						
4						
4.1	1	2	3	2	8	
4.2						
5						
5.1	3	2	2	3	10	dovrebbe essere più chiaro che bisogna ruotare la testa per cercare gli ologrammi
5.2	2	2	1	2	7	
5.3	3	3	3	4	13	
5.4	2	2	3	2	9	
5.5	2	2	2	2	8	
5.6	3	1	2	2	8	
5.7						
6						
6.1	4	2	3	3	12	
6.2	2	1	2	1	6	
6.3						dovrebbe esserci una sezione in cui si può fare prova del gesto più volte prima di fare l'esercizio
7						
7.1	2	2	2	2	8	
7.2	2	2	1	2	7	
7.3						
8						
8.1	2	1	1	2	6	help panel è troppo grande
8.2	2	2	2	2	8	
8.3	1	1	3	2	7	
8.4	2	2	3	2	9	
8.5	3	2	2	2	9	
8.6	3	2	3	4	12	
8.7						
9						
9.1	1	1	2	2	6	sono impacciato con i gesti puntare con la testa è difficile
9.2	2	3	3	3	11	
9.3	2	3	4	3	12	
9.4						
10						
10.1	1	1	2		4	
10.2						
11						
11.1	2	1	2	2	7	
11.2	2	1	1	2	6	
11.3	2	1	1	2	6	
11.4	2	2	3	3	10	
11.5	1	1	1	2	5	
11.6						

Table 12 shows graphical representations of the data in Table 11: (a) shows all the statements in the Usability Evaluation Questionnaire, in the same order they appear in the Questionnaire, and their total score; (b) shows the statements of the Questionnaire ordered according to their score, from the lowest (left) to the highest (right).

Table 12: Statements in the Usability Evaluation Questionnaire and their scores



Statements with high scores, like the ones we can see in the right-area of the Chart (b) in Table 12, or in any case with scores above 8, signal some usability issue, and clearly demand for further investigation.

If needed, a more precise Severity Ranking Scale can be created [166], [170], by assigning relative severities to individual usability problems, so that problems with higher severity ranking can be treated first. In many cases, however, the analysis of usability issues can be effectively carried out by simply referring to the information shown in Chart (b) in Table 12.

Indeed, Chart (b) provided us with valuable indications on where to start our investigation looking for usability issues. After a close exam of the statements with higher score, and their feedbacks, we were able to identify a few usability issues. Consequently, we were also able to modify some features of the Augmented Environment, so to improve its overall usability.

For example, by analyzing the statement 3.3 (*The tools for leaving the Augmented Environment or for moving on to the next exercise are clearly visible*) and its feedbacks, we realized that despite the fact that these navigational tools *are* visible in the Augmented Environment, they are not so *clearly* visible, after all. So, we decided to change shape, size and position of the tools within the Augmented Environment, so to make them *clearly* visible.

Moreover, the analysis of the statement with the highest score, statement 3.4 (*The system allows me to move freely in all areas of the Augmented Environment*), made us realize that, in this case, there was not a usability issue, but rather an issue with the statement itself. In fact, we intentionally designed the Testing Area of the Augmented Environment in such a way that the user cannot not freely move around in the different immersive modules. So, we realized that statement 3.4 did not really make sense (at least, if referred to the Testing Area), since it asked the user of the Testing Area to agree or disagree on the presence of a feature that we did not want for the Testing Area. As a consequence of our analysis, we decided to remove the statement 3.4 from the version of the Questionnaire that we will use during the test with our target users.

We will conduct deeper and more careful analyses of all the Questionnaire statements and the relative feedbacks once we will have the data from the target users participating to the actual test. However, from the data collected through the Questionnaire during the pilot test, we can already get positive indications on the efficaciousness of the Questionnaire in identifying usability issues. Indeed, the questionnaire proved effective in detecting usability problems of our Augmented Environment despite the small number of participants in the pilot test, and despite the fact that the participants did not really match the ideal target users. Moreover, the Questionnaire also proved to be a useful tool for detecting possible inconsistencies or errors in the formulation of the Questionnaire statements.

7.5.2 Are Older Adults Capable of Using Immersive Augmented Reality?

As we said, in order to be able to answer this question, we should have our disposal the data captured by the HoloLens during the immersive experiences of several older adults selected to participate in the actual test. However, we only have a few data from the participants in the pilot test. So, for the moment, we cannot answer the question. On the other hand, we can at least use the data we have to explain how we intend to work out the answer.

There is a simple answer to the question: *if a user –an older adult– can complete all the exercises in the Testing Area, that user is able to use Immersive Augmented Reality.*

Indeed, we must remember that the Exercises we designed for the Testing Area (see

Table 5-A÷G) are meant to train and test the users on all the gestures necessary to interact with holograms during an immersive experience in a whatsoever augmented environment. Moreover, we must consider that all the tasks required to complete the Exercises can be thought of as sequences of gestures organized in certain ways to accomplish certain purposes. And this idea applies to the tasks in the Exercises we designed, as well as to the tasks – simple or complex – that we can find in any scene of any augmented environment. We think, for example, about *Fragments*, a crime thriller game in Augmented Reality created by Microsoft for the HoloLens [181]. In *Fragments*, the user, by interacting with the holograms, must solve some riddles in order to come up with the solution to a crime. *Fragments* is the most complex augmented environment we had the chance to explore so far. Yet, even the most difficult riddles in *Fragment* can be solved by simply performing sequences of the same gestures that users can learn in the Testing Area of our Augmented Environment. So, if the users of our Augmented Environment are capable of completing the Exercises in the Testing Area, we can assert that those users are *able to use* Augmented Reality.

On the other hand, we must also wonder: what if a user cannot complete one or more of the Exercises? What are the reasons for not being able to complete the Exercises? Is it a problem the user has in performing some of the gestures? Or is it a problem due the user's inability to organize the gestures in the right sequence necessary to complete a task? Or is it rather a problem due to the way one exercise has been created?

Moreover, we should consider that to state that a user is able to use augmented reality, does not say much about the *efficiency* of the user's performance. If a user takes 5 minutes to complete a task that the average user takes 30 seconds to complete, can we still say that the user *is able* to use augmented reality? Up to what extent can we say that the user is able to use augmented reality?

These are the reasons why we cannot be satisfied with the simple answer we provided above. We need to use the data captured by the HoloLens to have a better understanding of the *features* and the *quality* of the users' performance.

If we go back to the charts in Table 10-A through Table 10-G (see 7.5.1.1), showing the performances of 4 different users working on the different Exercises in the Testing Area, we see that, for each user who participated in the immersive experience with the HoloLens, we can get a quite good amount of information. Particularly, by looking at the charts, we know, for each user and for each Exercise:

- whether the user has completed the Exercise, and the time he needed to complete it;
- whether the user has completed all the tasks that make up an Exercise, and the time he needed to complete each task;
- whether the user has been able to perform all the simple gestures (select, click) required to complete a task (see Table 10-A-B-C_D);
- whether the user has been able to perform all the complex gestures required to complete a task (i.e., the sequence of gestures necessary to activate one “primary gesture” [*select* + *click* + *hold* with 1 or 2 hands] + “primary gesture” [*move/rotate/resize* a hologram – see Table 10-E-F-G]. In this case, it is possible to distinguish the time the user needed to complete the primary gesture from the time he needed to 'activate' the primary gesture.

Moreover, in case a user has not been able to complete an exercise, we can also analyze the data to identify the cause(s) of the user's failure (e.g. incorrect execution of a simple gesture, incorrect execution of a complex gesture).

As an example, we can consider the data shown in Table 10-A. By looking at the left-chart, we see that all users completed Exercise 1. So, we can conclude that they all learned the gesture introduced in Exercise 1 (*select* a hologram = move the user’s head in all directions until the yellow dot at the center of their field-of-view is over a hologram). Considering that each task in Exercise 1 has the same level of difficulty, the descending curve in the right-top chart, showing the mean time of execution of the tasks in Exercise 1, further confirms that the tasks (and the gesture required to complete the tasks) have been learned. Moreover, we can see that the values accounting for the time users needed to complete each task are quite similar (from 2 to 6 seconds, with an average value of 3.75 seconds for all the tasks), and reasonably short, which means that all users found the gesture easy to perform, and/or users have similar profiles (in terms of competences) and perform the gesture in similar way. And so on…

After conducting similar analyses on all charts, we are able to come up with a clear and motivated answer to the question: *are participants in the pilot test who experienced the Testing Area of our Immersive Augmented Environment able to use Immersive Augmented*

Reality? According to the data we analyzed, we can assert that all participants in the pilot test are able to use immersive Augmented Reality.

Once we will have at our disposal the data captured by the HoloLens during the immersive experience older adults will have with our Augmented Environment, we will be able to analyze those data in similar ways, and we will therefore be able to answer the question that titles this section: *are older adults able to use immersive augmented reality?*

The above analyses leave yet unsolved one problem that we pointed out a few pages ago: the fact that a user is able to use augmented reality, does not say much about the *efficiency* of the user's performance. In this case, however, we cannot even use the data we obtained during the pilot test to show how we intend to proceed. Indeed, it is only by comparing the two sets of data coming from the group of older adults and the group of students that will we able to work out a definition of the concept of *efficient use* of Augmented Reality.

7.6 Conclusions

The pilot test allowed us to explore the efficacy (and the weakness) of some of the analytical tools that we intend to use during the real test with older adults and students. Because of the pilot test, we had the opportunity to make changes and corrections to the tools we intend to use.

At the beginning of this Chapter, we said that this test has several goals. Of course, we want to use the test to get indications on how to improve the overall usability of our Augmented Environment. But we are also interested in understanding, through the test, whether it is possible and reasonable to use Augmented Reality to create a learning platform for older adults.

It is important to find these answers before we can move on to the design and development of the Learning Area of our Augmented Environment. It would not really be worth continuing to develop a learning tool which, based on the results of the test, turns out to be inadequate for, or even unwelcome to older adults.

NOTE (August, 2020)

As we explained in the Introduction of this Chapter, we were not able to administer the test as we planned, and we will not be able to administer it in the near future. Therefore, we did not change the data in the tables and charts in this Chapter. All the tables and charts contain the data from the pilot test.

As a consequence, we cannot answer the questions we asked at the beginning of this Chapter. We will be able to provide an answer only when it will be possible again to have a safe and direct contact with the people involved in the test. Nevertheless, in the general Conclusions of this Thesis (see Chapter 8) we try to present some hypotheses on the future of our Augmented Environment, and on our future work, based on the possible outcomes from the test.

CHAPTER 8

8. Conclusions

In Section 1.2 we defined the following Research Questions:

- *RQ1*: What are the design principles we need to adopt to design an augmented environment tailored for older adults?
- *RQ2*: What is the relationship older adults have with new technologies and augmented reality?
- *RQ3*: What are the rules defining older adults' interactions in augmented environments?
- *RQ4*: Is it possible to use effectively our augmented environment with older adults to provide them with the necessary knowledge and skills to use computers and digital tools?

These questions have been the main guidelines for this work and have also guided all the stages of the development of the Augmented Learning Environment. Through this thesis we have been able to provide a thorough answer to RQ1, and we also set the conditions for finding clear answers to the remaining Research Questions.

The lockdown of most economic, social and cultural activities, imposed by the Italian Government as a way to fight the pandemic spread of Covid-19, blocked our work as well. From February 2020 on, we were forced to stop any kind of activity related to the administration of the test we defined in Chapter 7. As a result, we have no data from the test with the HoloLens, from the Questionnaire for the Evaluation of Usability of Augmented Environments and from the Focus Groups, and we will not be able to have this data in the near future.

Without the data from the test, we have no way to modify and complete Chapter 7, as we planned before the lockdown. As a consequence, we are not be able, for the moment, to provide the answers to RQ2, RQ3 and RQ4. However, through the work presented in Chapter 7, we have provided an articulated definition of the test, and we have also defined the overall conditions for the administration of the test. This will allow us to find the answers to RQ2-RQ4 as soon as we will be able to administer the test.

8.1 Contributions

In the following sections, we will examine our contributions to the fields of augmented reality, education, usability of augmented environments, and active ageing.

8.1.1 GENERAL KNOWLEDGE ON AUGMENTED REALITY

We believe that the semiotic approach to augmented reality presented in Chapter 4 not only is a significant alternative to the more wide-spread technological approach, but is also an important and innovative contribution to the research on Augmented Reality. Indeed, while the technological approach allows engineers and technicians to develop the technological components of augmented reality, it does not seem very effective for analyzing and designing the forms of communication (the augmented environments) produced with augmented reality. On the contrary, the semiotic approach presented in this work favors the analysis of augmented environments and their components, and helps analysts, designers, humanists, and, in general, non-technical people, to get a good understanding of what augmented reality is.

8.1.2 E-LEARNING AND AUGMENTED REALITY APPLICATIONS

It is already possible to find on the market applications for augmented reality that are considered “educational”. However, most of the times, they refer to a very narrow definition of education. Most of these applications are created to facilitate the acquisition of specific skills within a limited domain of knowledge (e. g., how to assemble, or repair, or use a particular device, or machine), but do not deal with the process of facilitating learning in a more general meaning. We consider these apps as sophisticated "technological translations" of manuals or handbooks.

With our Learning Augmented Environment, we created something new and different, and in so doing we provide a significant contribution to the research on e-learning. Our Learning Augmented Environment is meant to be a system for learning through augmented reality. It is a flexible, virtual container of learning contents. Its contents can be easily modified to satisfy the needs of different target users. Its original contents can be easily replaced with completely new contents, while the general system for delivering those contents does not change. So, we believe that the app we have designed and developed (and, of course, the Augmented Environment generated by the app) is a real educational application.

8.1.3 Evaluation of the usability of the augmented environment for older adults

In Chapter 7, we defined and set up a test which enable us to evaluate the usability of our Learning Augmented Environment. The evaluation of the usability of augmented environments is a research area largely unexplored, so we believe that with the development of the Testing Area (Chapter 5 and Chapter 6), and the design of the test (Chapter 7), we provided an important contribution to the field.
In addition, the test provides contributions also to the research on active ageing, since through the test we can acquire helpful and new information on the ways older adults use Augmented Reality, and on the complex relationship between older adults and technology and, particularly, Augmented Reality.

Overall, we created the test to find answers to the Research Questions. Since we were unable to administer the test, and, therefore, to answer those Questions, in what follows we would like at least to examine the scenarios resulting from the different, possible outcomes of the test. By analyzing these scenarios, we can make hypothesis on the possible directions our work will take.

Scenario 1: Older adults are not able to use Augmented Reality

Let us say that, from the analysis of the data, we make it clear that *older adults are not able to use Augmented Reality*. In this case, we need to reconsider the assumption that gave impetus to this work. We created the Learning Augmented Environment for older adults assuming that it is *easy*, for older adults, to use Augmented Reality. However, if the analysis of the data from the test tells us that our assumption is not correct, we must acknowledge that Augmented Reality is not the right technology to use to develop a learning platform for older adults.
If this will be the outcome from the analysis of the data from the test, then we will have to make a choice.
If we will still be willing to follow our initial goal – create a learning platform for older adults – then we will be forced to look for an alternative technology, very likely, something more conventional, such as the Web. Although we must admit that we do not think of this change of technology as particularly interesting and challenging. Indeed, if we were to follow this new direction, we would need to completely dismiss the work we have done so far on the Augmented Environment, and to focus on the development of a Web platform for older adults. And this would be nothing but a regular Web platform very similar to the many existing online platforms dealing with e-learning (such as those we examined in Section 5.3.2.1).
However, we will also have another possibility. Rather than dismissing the Learning Augmented Environment, we can think of using it with a different target, and with different

learning contents. Or, we can even think of using it for different purposes, in contexts not related to education. After all, this could be a reasonable alternative, especially if we consider the recent changes and improvements we introduced in the Learning Augmented Environment (and discussed in Chapter 5).
We believe that such a possibility has great potential, and we will further explore it in Section 8.1.4.

Scenario 2: Older adults are able to use augmented reality

The analyses of the data from the test might also provide us with a different answer. We might be able to find out that *older adults are able to use augmented reality*. This would be a confirmation of our assumption: *it is easy*, after all, to use Augmented Reality, even for older adults. And it would also provide us with a valid reason to continue with the development of the Learning Area of our Learning Augmented Environment.
However, before continuing with the development of the Learning Area, we will need to examine again the data from the test, this time to investigate about the *efficiency* of older adults' performances during their immersive experience in our Augmented Environment.
To this purpose, we will need to consider the amount of *time* older adults need to fulfill the many tasks required to complete the exercises in the Testing Area. And we will also need to understand how *easily and comfortably* they perform the gestures necessary to manipulate the holograms. Indeed, very slow, or clumsy performances could seriously degrade older adults' ability to access the learning contents offered by the Augmented Environment.
Once we will have more information on the efficiency of older adults' performances during their immersive experience, we will also be able to make a decision on how to continue our work on the Learning Augmented Environment.
Only *reasonable performances* from the Group of older adults (that is, performances that are not too different from the performances of the Control Group) could convince us that it is worth continuing the development of the Learning Area of the Learning Augmented Environment.
On the contrary, if we will realize that, even though older adults are able to use Augmented Reality, they are very slow or clumsy in using it, we will not have many reasons to keep thinking that Augmented Reality is the right technology for a learning platform for older adults.
In this case, there are different options at stake on how to continue; indeed, the same options we considered in the previous scenario.

Beyond scenario 1 and scenario 2: the contribution of the Focus Group

The analysis of the data coming from the immersive experience with the HoloLens will help us to find out whether older adults know how to use Augmented Reality, and know how to use it efficiently. However, without the Focus Group, we will not yet have the answers to all the Research Questions.

Only the Focus Group can provide us with such answers. Only through the Focus Group will we have the opportunity to further explore the complex relationship between older adults and new technologies and, particularly, Augmented Reality: are older adults so willing to accept a technology that mixes the real world with a fictional and virtual world? How do older adults feel about having a somehow awkward device on their head, which, in addition, alters their perceptions? What is their reaction to dealing with holograms?

Overall, only through the Focus Group will we be able to tell whether the older adults who will take part in the test with the HoloLens will find the experience enjoyable, exciting, or involving, up to the point of considering Augmented Reality to be a new and interesting tool, worth to be used a second time, or maybe even for a whole learning experience.

8.1.4 One Augmented Environment for many purposes

The consequences of the lockdown due to the presence of the Covid-19 pandemic have been immense. Not only for industrial and commercial activities, but also for all activities related to the world of culture, in general. Not to mention the world of education, which, at the time of this writing, is still unable to find clear rules to follow to allow all students - whether they are in elementary school, or in university - to start again learning activities.

On the other hand, not all the consequences of the lockdown are negative. If we consider education, for example, we see that the lockdown has fostered an acceleration in the production of digital tools capable of supporting, if not replacing, the more traditional forms of frontal teaching. In a short time, this new digital wave focused on education has provided, and is providing, new forms of teaching, new communicative strategies between teachers and students, new learning materials.

Even though we started working on the Learning Augmented Environment well before the lockdown, it is quite natural for us to think our work within this digital wave that proposes rapid changes in the ways of teaching and learning.

At the moment, due to the Covid-19 pandemic, most of the teaching activities have moved onto the Internet. Using the Internet was probably the simplest, fastest, and most immediate way to move from face-to-face lessons to virtual lessons. However, we would like to make this clear, the Internet is not the only tool capable of producing and offering e-learning. After all, the Augmented Environment that we have developed has been a *Learning* Augmented Environment right from the beginning, that is, an environment that, starting from the name, clearly shows its purpose.

Certainly, we initially conceived it with a vaguely *ad hoc* purpose (offering a course with particular contents to a particular target). On the other hand, as its development progressed, we realized that the augmented environment we had created was much more flexible, modular, and powerful than the environment we originally had in mind. As its development progressed, we realized that our Learning Augmented Environment for older adults could easily become a more general Learning Environment, capable of offering learning contents to a more general target.

To better understand this claim, let us go back, for a moment, to the *virtual room* described in Chapter 5. The virtual room is a complex virtual object: it is a 3D environment, it is immersive, it is modular and flexible. It displays all the most important features of augmented environments. By connecting different virtual rooms together, we can build complex structures (indeed, entire augmented environments) which are fully working, immersive and navigable. Furthermore, these complex organizations of perfectly working virtual rooms can be *empty*. This means that virtual rooms can exist independent from any particular content. Moreover - and more importantly - they can be filled with any whatsoever content, *at any time*.

These features are fundamental. It is thanks to these features that the Augmented Environment, originally capable of providing only particular contents to a particular target, can easily be changed into a larger and more complex Augmented Environment capable of offering any kind of learning content to any type of user.

And now, we want to try to venture an even more challenging claim. Thanks to those fundamental features, it seems reasonable to think that *our Augmented Environment could be used for different purposes, in domains of knowledge not related to education, and could therefore address the needs of different types of users*[5].

Two examples can help us to clarify the meaning of this claim.

Example 1: The Photo Gallery. To test some of our ideas on Augmented Reality, we have developed a *Photo Gallery* within the Learning Augmented Environment. It is a virtual room connected to the Augmented Environment through the navigation interface. As the user accesses this virtual room, he can see several photos hanging on the four walls of the room, as it would happen in a real gallery. Moreover, like in a real gallery, the user can

[5] Here, we address a comment by Professor Bartolini, charged with interesting and stimulating implications. He writes about the Learning Augmented Environment: "Wouldn't we want [to use the Augmented Environment] to do something with art (museums) or something where AR is more applicable?". Indeed, in recent months, we explored several cultural and artistic contexts which are not related to education. Particularly, we tried to understand how our Augmented Environment could be used in such contexts. If the results from the test will suggest that Augmented Reality is not the right technology to use with older adults, those are, very likely, the contexts within which we would like to work with our Augmented Environment.

freely move around, get closer to the photos, or move away from them. Contrarily to what happens in a real gallery, however, after a certain amount of time, the photos on the walls disappear, and are replaced by new photos, randomly loaded from a folder that can contain many sets of photos on many different topics. And the size and position of all photos on the walls change at random, as well. Overall, these changes give the user the feeling of visiting a large photographic exhibition spread across many different rooms.

Example 2: Presentation of the ICTDays 2019 event. The ICTDays 2019 is an event organized by the University of Trento to promote technology innovation, and to help students to connect to technological companies. We were asked to use our Augmented Environment to create a presentation of the event. We decided to use Elektra (the second version of her avatar) to conduct the entire presentation. After explaining what augmented reality is, also through some concrete examples, Elektra introduces the ICTDays 2019 event, and also shows some videos on the event. The presentation ends with one of the virtual tricks that only augmented reality is capable of: while talking to the user, Elektra walks through one of the walls and enters into a (completely virtual) library existing behind the real room the user is in. Although Elektra is behind the wall, she is still visible through a virtual window which, by "making a hole" in the wall, connects two worlds, so that real and virtual coexist, in real time, in a single augmented world[6].

These examples help us to reaffirm an important idea: in order to create The *Photo Gallery* and the *Presentation of the ICTDays 2019 event,* we did not make any change to the Augmented Environment. We only created two new virtual rooms, and linked them to the Augmented Environment via the navigation menu.

Of course, we also had to deal with the contents: the photos, their organization, the criteria by which the photos are presented to the user; and then, Elektra, the videos on the ICTDays 2019 event, the virtual library, and so on. However, what we want to emphasize here is that we managed to deal with the contents when the development of the general Augmented Environment was already concluded.

The *Photo Gallery* and the *Presentation of the ICTDays 2019 event* are augmented environments *unrelated* to the Learning Augmented Environment. Yet, we have been able to incorporate them into it in a short time, and with ease. This strengthens our claim. This, more than anything else, shows that it is possible to easily extend the use of our Augmented Environment towards contexts other than education, absolutely unforeseen by the original design.

[6] A video of the event can be found here.

Even the Testing Area seems to reaffirm the same claim stated above. Originally, we designed the Testing Area with a particular purpose: to have an augmented environment where older adults could complete some exercises, so that we could evaluate their performances. However, little by little, we changed it into an *augmented sandbox*[7] where we could try out many of the features of Augmented Reality that we presented in Chapter 4, and that could not have much room within the more canonical Learning Environment described in this thesis. For example, we are talking about virtual rooms created behind the real room where the user is in, and that are visible through virtual holes on the real wall (see previous paragraph, and also the video on Exercise 6 - Section 6.3.2). We are talking about virtual objects such as a light beam, or a disc on the floor, or a swarm of butterflies capable of detecting the proximity of the user's body, and reacting to it by activating new virtual elements in the scene (see video of Exercise 4 - Section 6.3.2). We are talking about other virtual objects entering the scene through the walls, or filling up not only the 360 degrees stage space, but also the entire virtual volume above and below the augmented stage (again, see video of the Exercise 6).

As we explained in Chapter 4, there are many similarities between the augmented stage of an augmented environment and the stage of a more traditional theater. Then, we like to think that our Augmented Environment can be considered as the stage of an augmented theater, within which many things are possible.

As we saw in Section 8.1.3, by analyzing the results from the test with older adults, we might find out that Augmented Reality is not the right technology to use for developing a learning platform for older adults. However, even in that case, we would not have worked in vain. By now, the Augmented Environment we created is something bigger than whatever we initially planned and expected. And it can continue to exist independent from its original purpose.

We consider the Augmented Environment as our major contribution to the field of design of augmented environments, and to the research on Augmented Reality. Particularly, we believe that with the creation of the Virtual Room we set a first step toward the creation of a Content Management System (CMS) for Augmented Reality similar to the CMSs, very popular nowadays, used for the creation of websites.

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[7] We use the term "augmented sandbox" to indicate a space similar to the programming sandbox used in computer science to indicate "an especially crafted software environment for running, testing and debugging software programs, which detects and restrains the side effects of the program being tested" [184]. In our case, the augmented sandbox is an area of an augmented space where it is possible to freely experiment and safely test all those ideas that have not yet been included into the Augmented Environment. Our augmented sandbox is very similar to the virtual area used by *SecondLife*, a popular virtual online world, which defines the sandbox as "a place to experiment and create for both new and advanced Second Life residents alike" [185].]

8.2 LIMITATIONS

In the beginning of this work, we wrote that our research is interdisciplinary, and that, through the different Chapters of this thesis, we would have explored different contexts and domains of knowledge. Now that this work is concluded, we can confirm the interdisciplinary character of our work.

On the other hand, we must also admit that, in trying to keep an interdisciplinary perspective, we have somehow struggled to manage the amount of knowledge, technological and non-technological, that we had to acquire in order to complete the development of the Augmented Environment.

The interdisciplinary approach has allowed us to propose new, and interesting connections among different, and sometimes distant fields of knowledge. However, in some occasions, it has also prevented us from going deeper into some important topics described in this work, which might have deserved more attention.

- We are aware that a deeper research on some social issues emerging from the studies on Active Aging, would have helped us to provide, in Chapter 3, a better definition of the problem of social exclusion. With a more solid formulation of the problem, we would have also been able to provide a more solid formulation of the reasons that led us to propose the Learning Augmented Environment as a possible solution of that problem.

- The purpose of this work is to use Augmented Reality to create a course for older adults on the use of computer and digital tools. We are aware that the reasons we provided for supporting such idea might not be as solid as they should be. Indeed, the lack of data from the test with the HoloLens prevented us from providing the answer to the most important question we asked in this work: are older adults able to use Augmented Reality? Without this answer, we are unable to fully justify the use of Augmented Reality as the right technology for a learning platform for older adults.

- We are also aware that the lack of a team to work with, and a not completely structured approach to the design and development of the Augmented Environment has not helped us to find quicker, simpler and more efficient solutions to the many problems we encountered.

  This has had consequences on the overall quality of the prototype of the Augmented Environment. We were not able to solve all the problems we found, especially during the production stage, while working in Unity on the prototype, so that some components in the prototype do not show all the features and behaviors described in the design. In addition, we were not able to completely optimize the project in Unity, so that we cannot consider the development process of the prototype as concluded.

- We must acknowledge that, overall, this work does not completely follow the path we outlined in the introductory Chapter. The lockdown due to the pandemic spread of Covid-19 has forced us to reconsider our work, and to look for a different way to continue and conclude it. This change of direction is clearly visible in the structure of this work. Some chapters have acquired more importance, some other chapters have become more marginal.

  We decided to keep anyway all the Chapters as a documentation of our work, even though we are aware that this choice might reduce the overall coherence of this thesis.

8.3 FUTURE WORK:

The test with the prototype of the Learning Augmented Environment

We will resume our work on the test as soon as it will become possible. First, however, we intend to improve some sections of this work, so to take into account some comments we recently received[8].

Once we will have completed the revision of the above sections, we will be able to resume all those activities necessary to organize the administration of the test with the HoloLens.

Shortly before the lockdown, we contacted the director of the *Centro Socio Ricreativo per Anziani - Associazione Sammartini* (a Recreation Center for Older Adults located in Milan), and he agreed about making the space of the Center available for the test with the HoloLens. Moreover, he also agreed on helping us to contact the older adults who regularly attend the Center, so to facilitate the selection of the people who will participate in the test.

As soon as the *Centro Socio Ricreativo* will open again, and it will be possible to administer the test in safe conditions, we will reactivate that contact.

We also contacted Marta Mondelli, a psychologist with previous experience on administering tests in virtual environments. She will help us with all the activities related to the test: from the selection of the older adults who will participate in the test with the HoloLens, to the moderation of the focus group, and the analysis and interpretation of the results.

At a later time, when a direct contact with the students of the University of Trento will again be possible, we will repeat the administration of the test with them.

[8] We refer to professor Barbabella's useful comments on some problematic issues he identified in this work. Particularly, we will need to reconsider the social problem presented in Chapter 3, looking for a more rigorous formulation of the concept of *social exclusion*. Also, we will need to deepen and refine the definition of the target – older adults – of our Learning Augmented Environment. Based on the changes and improvements we will introduce in Chapter 3, we will eventually be able to refine the design of the test presented in Chapter 7.

In collaboration with Marta Mondelli, and professor Maurizio Marchese, we also plan to work on at least two papers, to be proposed for publication.

Here below, we provide the tentative titles of such papers:

- S. Cicconi, M. Mondellini, M. Marchese, *When Older Adults Wear the HoloLens: A Test in Immersive Augmented Reality to Teach Older Adults How to Interact with Holograms*.
- S. Cicconi, M. Mondellini, M. Marchese, *Evaluating Usability in Immersive Augmented Reality*.

The Augmented Environment and the Internet

We cannot keep pretending to ignore that the HoloLens, through a Wi-Fi connection, has access to the Internet and therefore to everything that the Internet makes available to users: access to the Web, to Social Media, to the Internet of Things, and so on.

We have deliberately excluded the Internet from this work. Opening our Augmented Environment to the Internet, and considering even just a few of the possible implications of such an opening, would have steered our project toward directions we could not, and did not want to go to.

Now, if we talk about our future work, we can no longer ignore the Internet. Very likely, our future work will focus on the exploration of one big question: what does it mean to connect our Augmented Environment to the Internet?

Thinking about our Augmented Environment connected to the Internet means thinking about it from a very different perspective. We can no longer simply talk about a real room that is augmented by a virtual room with a limited amount of virtual content. The moment that augmented room connects to the Internet, a dramatic change occurs. Suddenly, the user of that room finds himself interacting with avatars much smarter than Elektra, controlled by chat-bots and remote Artificial Intelligences. Suddenly, the user of that room finds all the knowledge available on the Web at his disposal. Moreover, he can interact with other users through Social Media, and has the opportunity to meet other users' avatars within an environment that is augmented, and, at the same time, shared.

How is the immersive experience transformed when the Internet comes into play? What changes do we need to introduce to our Learning Augmented Environment to make it connected? And, above all, what are the consequences of these changes on our Learning Augmented Environment?

This is not the place to further address these problems and answer these questions. Here we only want to stimulate the reflection on a few of topics that we believe will become the focus of our future research and future work.

Appendices

Appendix A: Screening Questionnaire

SCREENING QUESTIONNARIE

Project: "Augmented learning: an e-learning environment in augmented reality for older adults"

Augmented learning is a research project developed in the Department of Engineering and Information Sciences of the University of Trento.

The answers to this questionnaire will help us to implement a virtual learning environment capable to introduce the elderly to the use of new technologies (computers, internet, etc.) and encourage their social integration.

For this reason, we trust in your participation and we thank you in advance.

The questionnaire consists of about 50 questions and the compilation is very simple and will take about 25-30 minutes.

I thank you in advance for your precious availability.

Sergio Cicconi

INSTRUCTIONS TO COMPLETE THE QUESTIONNAIRE

The questions in this questionnaire include 3 types of answers:

1) SHORT FREE RESPONSE:

After the question, you will find an empty space (as in question n.1).

In this case, you can freely write your answer in the empty space.

- *EXAMPLE*:

  What is your name? ______John Doe ____________________________

2) ONLY ONE ANSWER:

After the question, you will find several possible answers, but you have to choose only one answer (as in question 2). In this case, you can write an "X" next to your chosen answer.

- *EXAMPLE*:

2	Are you a man or a woman? *(only one answer - write an "X" to indicate your chosen answer)*	
	Male	X
	Female	

3) MULTIPLE RESPONSE:

After the question, you will find several possible answers and you can choose more than one answer (as in question 20). You can write an "X" next to each answer you choose.

- EXAMPLE:

20	Do you normally use glasses? *(multiple answers - write an "X" for each answer)*	
	To read	*X*
	To see at a distance	*X*
	I don't use glasses	

Please, answer all the questions; this is not a test, so there are no right or wrong answers.

DEMOGRAPHY

1	What's your name? ____

2	Are you a man or a woman? *(only one answer - use an X to indicate the chosen answer)*	
	Man	
	Woman	

3	How old are you? ______________

4	Which degree do you hold? (*only one answer - use an x to indicate your answer*)	
	No degree/Primary School degree	
	Middle School degree	
	High school degree	
	Other (University degree, Master, Specialization, etc.)	

5	If you have selected "High School degree" or "Other" in the previous answer, can you please specify the major of your degree: ____

6	What was your job? ____

HEALTH

7	In general, having to judge your health on a scale of 1 (*which means not good*) to 5 (*which means excellent*) what number would you choose? *(only one answer - use an x to indicate the answer)*				
	Not good				Excellent
	1	2	3	4	5

8	Do you have health problems that make it difficult for you to move around and do things yourself? (*only one answer - use an x to indicate the answer*)				
	I have many health problems that cause me trouble moving				I don't have this kind of health problems
	1	2	3	4	5

9	Could you grab light objects (e.g. a jar, the sink faucet)? (*only one answer - use an x to indicate the answer)*				
	I’m not able				Yes, I can grab light objects
	1	2	3	4	5

10	Could you hold light objects with one hand (e.g. a book, a TV remote control, a cup)? *(only one answer - use an x to indicate the answer)*				
	I am very limited/ disabled				I'm not limited / disabled at all
	1	2	3	4	5

11	Could you twist your hands (e.g. to open a can, turn a handle or look at the clock)? *(only one answer - use an x to indicate the answer)*				
	I am very limited/ disabled				I'm not limited / disabled at all
	1	2	3	4	5

12	Could you tighten / take / grab small light objects (e.g. a playing card, a sheet of paper, a pen, a coin, shoe laces)? (*only one answer - use an x to indicate the answer*)				
	I struggle a lot				I don't struggle at all
	1	2	3	4	5

	Could you do simple actions like squeezing an orange or pushing a button on the remote control? (*only one answer - use an x to indicate the answer*)				
	I am very limited/ disabled				I'm not limited / disabled at all
	1	2	3	4	5

	Could you move everyday objects like a plate, a chair, clothes, without difficulty? (*only one answer - use an x to indicate the answer)*				
	I am very limited/ disabled				I'm not limited / disabled at all
	1	2	3	4	5

	Could you coordinate simple finger movements, such as holding cutlery or writing with a pen? (*only one answer - use an x to indicate the answer*)				
	I am very limited/ disabled				I'm not limited / disabled at all
	1	2	3	4	5

	Could you raise your arms like for example to wash your face, use on your glasses or a hat or drink from a glass? (*only one answer - use an x to indicate the answer*)				
	I am very limited/ disabled				I'm not limited / disabled at all
	1	2	3	4	5

	Could you turn your head (without moving your shoulders) on the left / right side? (*only one answer - use an x to indicate the answer*)				
	I am very limited/ disabled				I'm not limited / disabled at all
	1	2	3	4	5

	Could you move your head up or down (as if looking at the sky or your feet)? (*only one answer - use an x to indicate the answer*)				
	I am very limited/ disabled				I'm not limited / disabled at all
	1	2	3	4	5

	Could you tell me if you have head or hand tremors that make it more difficult to do tasks like reading or writing or grabbing small objects? (*only one answer - use an x to indicate the answer)*				
	Yes, I have many problems				No, I have no problems at all
	1	2	3	4	5

	Do you normally use glasses? *(multiple answer - use an x for each answer)*		
	To read		*Go to question 22*
	To see at a distance		*Go to question 22*
	I don't use glasses		*Go to question 23*

	What is your eyesight [with glasses]? (*only one answer - use an x to indicate the answer*)				
	Not good				Excellent
	1	2	3	4	5

	Do you currently use a hearing aid? (*only one answer - use an x to indicate the answer*)		
	Yes		*Go to question 24*
	No		*Go to question 25*

	How is your hearing [with hearing aid]? (*only one answer - use an x to indicate the answer)*				
	Not good				Excellent
	1	2	3	4	5

	How is your hearing [without hearing aid]? (*only one answer - use an x to indicate the answer)*				
	Not good				Excellent
	1	2	3	4	5

DIGITAL LIFE

	Do you use a computer (desktop or laptop)? (*only one answer - use an x to indicate the answer*)				
	Never				Very often
	1	2	3	4	5

	Do you use Tablet / iPad? (*only one answer - use an x to indicate the answer*)				
	Never				Very often
	1	2	3	4	5

	Do you use a mobile phone or a smartphone? (*only one answer - use an x to indicate the answer*)				
	Never				Very often
	1	2	3	4	5

	Do you use an "e-book player" (as Amazon Kindle, Kobo, ecc.)? (*only one answer - use an x to indicate the answer*)				
	Never				Very often
	1	2	3	4	5

	If you use one or more of the devices listed above (computer / tablet / mobile phone / e-book reader), can you please explain how you acquired the knowledge needed to use them? (*multiple answer - use an x to indicate each answer*)	
	I do not use any of the devices listed above	
	I'm self-taught	
	I took courses	
	I used computers in my work	
	I was helped by my children / grandchildren / friends	
	Other	

	If you use one or more of the devices listed above (computer / tablet / mobile phone), for what type of activity do you use them? (multiple answer - use an x to indicate each answer)				
	I do not use any of the devices listed above				
	To read (newspapers, magazines, novels, etc.)				
	To write (email, diary, social media, etc.)				
	To organize photos (take pictures, organize them in albums, etc.)				
	To listen to music				
	To watch videos / movies				
	Other				
	Do you use the Internet or have you used it in the past? (*only one answer - use an x to indicate the answer)*				
	Never				Very often
	1	2	3	4	5

	Which of the following devices do you use to access the Internet? (*multiple answer - use an x to indicate each answer*)	
	I do not use the Internet	
	Computer (desktop or laptop)	
	Tablet / iPad	
	Mobile phone, smartphone	
	Other	

	For which of the following purposes do you use the Internet? (*multiple answer - use an x to indicate each answer)*	
	I do not use the Internet	
	To contact family and friends via instant messaging programs (Skype, WhatsApp, Messenger, Line ...)	
	To send and receive e-mails	
	To listen to music	
	To watch videos and movies	
	To create digital content (such as text, images, photo albums, presentations, etc.) and upload them to the Web and in cloud services (such as Google Drive, Dropbox, etc.)	
	To read newspapers, magazines, novels, etc.	
	To search for information related to my interests	
	To access public services (health, administration, tax office, insurance, others)	

	To make online purchases (buy books, food, clothes, electronics, etc.)	
	Other:	

	Do you use one of the following social media? (*multiple answer - use an x to indicate each answer*)	
	I do not use the Internet	
	I use the Internet, but I don't use social media	
	Facebook	
	Twitter	
	LinkedIn	
	Instagram	
	WhatsApp	
	Blog, forum	
	Other:	

If you use social media, could you tell me what kind of interaction you have with other users (*for example, collaboration on a project, exchange of opinions, search for new friends, discussion on a topic, advice on music or films, etc.*)?

____
____
____
____

	Have you ever heard of AUGMENTED REALITY? (*only one answer - use an x to indicate the answer)*		
	Yes		*Go to the question 38*
	No		*Go to the question 39*

If you answered YES to the previous question, could you give a brief definition of AUGMENTED REALITY? (you can use any word / expression to describe without worrying about using technical terms)

____
____
____
____

ATTITUDES AND MOTIVATIONS

	What are your interests or hobbies? (*multiple answer - use an x to indicate each answer*)	
	Reading	
	Excursions or walks	
	Go to the gym	
	Dancing	
	Go cycling	
	Writing (stories, diaries, poems, etc.)	
	Watching television	
	Listening or playing music	
	Cooking	
	Knitting, crocheting, embroidering	
	Travelling	
	Watching sports (football, cycling, volleyball, basketball, formula 1, etc.)	
	Other:	

	Technologies are changing our world. Do you think this is positive or negative? (*only one answer - use an x to indicate the answer)*				
	Very negative				Very positive
	1	2	3	4	5

Could you briefly explain your previous answer?

____

____

____

____

	Are you interested in technologies in general (such as technological trends, new technological discoveries, the history of technology, electronic equipment, etc.)? (*only one answer - use an x to indicate the answer)*				
	I'm not interested in anything				I'm very interested
	1	2	3	4	5

	Would you like to know how to use computers, portable devices and the Internet? (*only one answer - use an x to indicate the answer)*				
	I wouldn't like it at all				I would like very much
	1	2	3	4	5

	Do you think learning to use computers, portable devices and the Internet can change your daily life? (*only one answer - use an x to indicate the answer*)				
	No, my daily life would be the same				Yes, my daily life would change a lot
	1	2	3	4	5

Could you briefly explain your previous answer (why would there be no changes in your life? Or how would your daily life change?)?

____
____
____
____

	Would you like to take a course to learn how to use the computer, portable devices and the Internet? (*only one answer - use an x to indicate the answer*)		
	No		*Go to question 47*
	Yes		*Go to question 48*

	If you answered "No" to question 46, what are the reasons for not taking a course on how to use the computer and the Internet? (*multiple answer - use an x to indicate each answer*)	
	I don't like computers and technology in general	
	I think computers are dangerous	

	I think the Internet is dangerous	
	I don't care about computers and technology	
	Computers make me feel anxious	
	I'm afraid of computers	
	I think computers are too difficult to use	
	I know I can't learn new things	
	I know I can't learn to use the computer	
	Other:	

	If you answered "YES" to question 46 what are the reasons for not taking a course on how to use the computer and the Internet? (*multiple answer - use an x to indicate each answer*)	
	To keep me busy	
	To get involved in something new	
	To keep my mind active	
	Because I'm interested in learning new things	
	Because I want to keep up to date and adapt to new times	
	Because I'm interested in technology and computers	
	Because I have one more tool to stay in touch with my family and friends	
	Because I have the chance to make new acquaintances	
	Because I can find music and movies that I like	
	Other:	

	If you were asked to wear ski goggles like the ones you see in the picture for a few minutes and in a safe environment, what would you say? (*only one answer - use an x to indicate the answer)*				
	I would wear them without problems				I wouldn't wear them
	1	2	3	4	5


Could you explain your answer?

____

____

____

____

	If asked to wear, for a few minutes and in a safe environment, a new technological device that looks a bit like ski goggles (see figure) and allows you to enrich the normal reality perceived by our senses with sounds and virtual images built from a computer, what would you say? (*only one answer - use an x to indicate the answer*)				
	I would wear them without problems				I wouldn't wear them
	1	2	3	4	5


Please, could you explain your answer?

____
____
____
____
____

CONCLUSIONS

You have finished your questionnaire!

Thank you so much for your patience and your help!

Appendix B1: Call for Participation (Older Adults)

E-LEARNING IN REALTÀ AUMENTATA

AUGMENTED LEARNING FOR OLDER ADULTS

CERCHIAMO

Donne e uomini

Di età compresa tra i 65 e gli 80 anni

Curiosi di provare una nuova e divertente tecnologia

chiamata **REALTÀ AUMENTATA** che permette di arricchire la normale realtà percepita dai nostri sensi con suoni e immagini virtuali costruite da un computer.

Augmented Leaning for Older Adults è un progetto di ricerca che nasce nel Dipartimento di Ingegneria e scienze dell'Informazione dell'Università degli Studi di Trento con lo scopo di realizzare un innovativo strumento di apprendimento capace di far conoscere le nuove tecnologie (computer, internet, ecc.) agli anziani e favorire così la loro integrazione sociale nel mondo digitale.

L'esperienza in realtà aumentata è anonima*, semplice e divertente; non richiede alcuna conoscenza o competenza particolare e non comporta alcun rischio per la salute.

Per partecipare all'esperienza immersiva o avere ulteriori informazioni potete contattare il nostro ricercatore: Sergio Cicconi - email: sergio.cicconi@unitn.it - tel: 334 6024393).

* tutti i dati acquisiti durante l'esperienza con la realtà aumentata saranno tutelati nel pieno rispetto della privacy secondo le linee guida del RGPD (Regolamento UE 2016/679)

Appendix B2: Call for Participation (Students)

E-LEARNING IN REALTÀ AUMENTATA
AUGMENTED LEARNING FOR OLDER ADULTS

CERCHIAMO

studenti del DISI

iscritti ai programmi di Master o Dottorato,
interessati a **provare l'HoloLens** di Microsoft
per immergersi in un
AMBIENTE DI E-LEARNING in **REALTÀ AUMENTATA**

Augmented Leaning for Older Adults è un progetto di ricerca che nasce nel Dipartimento di Ingegneria e scienze dell'Informazione dell'Università degli Studi di Trento con lo scopo di realizzare un ambiente di e-learning in realtà aumentata capace di far conoscere le nuove tecnologie (computer, internet, ecc.) agli anziani e favorire così la loro integrazione sociale nel mondo digitale.

Cerchiamo studenti per raccogliere dati sull'uso di ambienti immersivi in realtà aumentata e sull'utilizzo dell'HoloLens. L'esperienza immersiva in realtà aumentata è anonima*, semplice e divertente e non richiede alcuna conoscenza o competenza particolare.

Per partecipare all'esperienza immersiva o avere ulteriori informazioni scrivete a: sergio.cicconi@unitn.it

* tutti i dati acquisiti durante l'uso dell'HoloLens saranno tutelati nel pieno rispetto della privacy secondo le linee guida del RGPD (Regolamento UE 2016/679)

Appendix C1: Modulo per la richiesta di approvazione di un protocollo di ricerca

UNIVERSITÀ DEGLI STUDI DI TRENTO

Dipartimento di Ingegneria e Scienza dell'Informazione - DISI

Modulo per la richiesta di approvazione di un protocollo di ricerca

SEZIONE 1 - PRESENTAZIONE DEL PROGETTO

1.1 Titolo del progetto:
Augmented Learning: an E-Learning Environment in Augmented Reality for Older Adults.

Fase 1: Progettazione e realizzazione di un Ambiente di Learning in realtà aumentata per anziani
Fase 2: test di usabilità e di user experience per adeguare l'ambiente di learning alle esigenze di utenti anziani

1.2 Responsabile del progetto:

Nome e Cognome	Maurizio Marchese
Ruolo/posizione in UniTrento	Professore Associato
Struttura di afferenza	UNITN
Indirizzo e-mail	maurizio.marchese@unitn.it
Recapito telefonico	-2083

- **Allegato A:** Curriculum Vitae
- **Allegato B**: Dichiarazione di disponibilità di tempo, risorse e personale per condurre la ricerca da parte del responsabile del progetto

1.3 Altri ricercatori coinvolti

Nome e Cognome	Sergio Cicconi
Ente di appartenenza	DISI UNITN
Ruolo/posizione in UniTrento	PhD student in Social Informatics
Ruolo/funzione nel progetto	ricercatore

- **Allegato A:** Curriculum Vitae

1.4 Sede/i della ricerca (dove viene condotta la sperimentazione).

Università di Trento - DISI
Il workshop, le esperienze individuali immersive in realtà aumentata e i focus group (si veda il punto 2.4.6 per ulteriori chiarimenti sulle diverse tipologie di incontri previsti con i partecipanti alla ricerca) si terranno in aule opportunamente attrezzate e prenotabili presso le strutture del DISI.

Maurizio Marchese pagina 1 di 61

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1.5 Sono necessari il parere di altri comitati etici e/o l'autorizzazione di altri Enti (ad es., ospedali, scuole, carceri) per l'accesso a dati o il coinvolgimento di partecipanti? Se sì, allegare copia della richiesta di parere/autorizzazione.

Non è necessario il parere di altri comitati etici.
L'unica sede della ricerca, ove viene condotta tutta la sperimentazione, è l'Università di Trento – DISI.
Va però considerato il fatto che la ricerca coinvolgerà due diversi gruppi di partecipanti: studenti del DISI e anziani (65+). Date le diverse caratteristiche dei partecipanti appartenenti ai due gruppi, si dovranno differenziare le modalità di coinvolgimento nella ricerca dei potenziali partecipanti.
Nel caso degli **studenti**, il reclutamento avverrà tramite l'esposizione di un *Invito alla partecipazione al Progetto* (v. **Allegato D1**) negli appositi spazi pubblici (bacheche, ecc.) del DISI. Di conseguenza, nessun altro Ente o Associazione verrà coinvolta.
Nel caso degli **anziani**, il coinvolgimento dei partecipanti dovrà essere avviato in sedi diverse dal DISI. Il reclutamento avverrà tramite l'esposizione (autorizzata – si veda a tal proposito la NOTA in questa pagina) di un *Invito alla partecipazione al Progetto* (v. **Allegato D2**) negli appositi spazi pubblici (bacheche, ecc.) di alcune Associazioni o Centri Servizi per anziani con sede a Trento o in zone limitrofe.
La lista che segue mostra alcune di tali Associazioni o Centri Servizi per anziani che sono stati finora identificati e che si ritiene siano ideali per la diffusione dell'Invito di Partecipazione al progetto tra potenziali partecipanti (anziani) con caratteristiche adeguate per il test che intendiamo condurre:

- Centro diurno e centro servizi anziani "Contrada Larga" – via Belenzani 49, Trento
- Università della terza età e del tempo disponibile (UTETD) – Sede di Trento
- Centro diurno e centro servizi anziani "APSP Margherita Grazioli" - Via della Resistenza, 63, Povo
- Centro diurno e centro servizi anziani "Il Girasole" - Via A. Gramsci 36, Clarina
- Centro diurno e centro servizi anziani "Filo Filò" – via Belvedere 4, Ravina
- Centro diurno e centro servizi anziani "Sempreverde" - Via Don Dario Trentini, 6 – Mattarello
- Centro diurno e centro servizi anziani Gardolo - Via S. Anna, 5 – Gardolo

NOTA: le sedi sopra identificate non collaboreranno in alcun modo al progetto: ciò significa che non avranno accesso alle procedure sperimentali previste nel test o ad alcun dato dei partecipanti, né forniranno spazi per la sperimentazione, o personale con alcun tipo di competenze, ma si limiteranno solamente ad esporre (dopo aver autorizzato l'esposizione) un *Invito alla partecipazione al Progetto* (v. **Allegato D2**) nei loro spazi preposti. L'**Allegato L** mostra la richiesta di Autorizzazione all'esposizione dell'*Invito* che verrà consegnata di volta in volta al personale dell'Associazione identificata e che andrà firmato da un responsabile dell'Associazione.
Una di queste associazioni ("APSP Margherita Grazioli") è già state contattata e siamo in attesa di ottenere l'Autorizzazione all'esposizione dell'*Invito alla partecipazione al Progetto* mentre le altre saranno contattate in seguito. Considerando la possibile assenza del personale in grado di fornire l'autorizzazione durante il periodo estivo (come è avvenuto nel caso dell'"APSP Margherita Grazioli"), e tenendo anche conto dell'assenza, nel periodo estivo, di potenziali partecipanti, abbiamo ritenuto ragionevole rinviare a Settembre 2019, ovvero in un periodo più vicino all'inizio della sperimentazione, i contatti con il personale delle sedi sopra indicate al fine di ottenere l'Autorizzazione all'esposizione dell'*Invito*.

Allegato L: Autorizzazione alla esposizione di un *Invito di Partecipazione al Progetto* da parte dell'Associazione identificata

1.6 Indicare eventuali Enti finanziatori/Sponsor, l'entità dei relativi contributi e accordi particolari intercorsi.

1.7 Il responsabile e i componenti del gruppo di ricerca nonché i rispettivi familiari hanno potenziali conflitti di interesse in rapporto alla conduzione e all'esito dello studio? Se sì, specificare.

NO. Si veda **Allegato C**: Dichiarazione di assenza di conflitti di interesse

1.8 Sono previsti interventi che richiedono specifiche professionalità (ad es. medico, psicologo, infermiere, ecc.) ai sensi della normativa vigente? Se sì, specificare.

No. La somministrazione del questionario di selezione e quello di usabilità e user experience, il workshop di presentazione del progetto, la somministrazione dell'esperienza immersiva con il dispositivo per la produzione di realtà aumentata denominato HoloLens e la gestione del focus group sono attività che non richiedono specifiche professionalità quali quelle sopra indicate e saranno gestite dal ricercatore (Sergio Cicconi) coinvolto nel progetto, in possesso di un adeguato background in scienze umane e sociali.

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SEZIONE 2 - DETTAGLI RELATIVI AL PROGETTO

2.1 Data prevista di inizio della ricerca: Ottobre 2019

2.2 Durata prevista della ricerca (in mesi) **8**

2.3 Sintesi del programma di ricerca (con rappresentazione schematica del protocollo) ***[obbligatoriamente in italiano]***

Oggigiorno, le nuove tecnologie garantiscono agli anziani (65+) una vita più lunga e più sana, ma non facilitano gli aspetti più sociali della loro vita. In un mondo in cui le relazioni sociali, le attività pubbliche e private o l'intrattenimento si basano sull'uso della tecnologia, le persone anziane prive di conoscenze tecnologiche rischiano l'isolamento sociale. In particolare, troveranno progressivamente più difficile utilizzare tutti i servizi elettronici pubblici e privati necessari per mantenere una vita attiva e socialmente integrata. Quindi, l'obiettivo del nostro progetto di ricerca è aiutare gli anziani a far fronte al loro analfabetismo tecnologico.
Con il nostro progetto di ricerca intendiamo progettare e sviluppare una forma innovativa di e-learning, specificatamente progettata per gli anziani e facilmente accessibile agli anziani senza alcuna precedente conoscenza della tecnologia, che potrebbe fornire un contributo per risolvere il problema precedentemente descritto dell'isolamento sociale. A tal scopo, utilizzeremo la tecnologia disponibile nel campo della realtà aumentata, in modo che l'ambiente di apprendimento sia un ambiente immersivo, tridimensionale e completamente interattivo, in grado di fornire agli anziani conoscenze su alcune tecnologie di base e su alcuni strumenti digitali che potranno utilizzare per mantenersi cittadini attivi e integrati nella società tecnologica.

Le attività necessarie al completamento del progetto sono organizzate secondo la seguente struttura:

A. DESIGN DELL' AUGMENTED LEARNING ENVIRONMENT
   1. l'ambiente aumentato
   2. Ottimizzazione del design in funzione degli utenti target

B. SVILUPPO DEL PROTOTIPO DELL'AUGMENTED LEARNING ENVIRONMENT

C. TEST CON IL PROTOTIPO DELL'AUGMENTED LEARNING ENVIRONMENT
   1. Selezione degli utenti
   2. Workshop introduttivo sulla realtà aumentata
   3. Esperienza immersiva in realtà aumentata con dispositivo HoloLens
   4. Questionario di usability e user experience
   5. Focus group

A. IL DESIGN DELL' AUGMENTED LEARNING ENVIRONMENT

Abbiamo lavorato alla progettazione e allo sviluppo di un Learning Environment utilizzando tecnologie di Realtà Aumentata e siamo stati anche in grado di creare un prototipo funzionante del Learning Environment che mostra tutte le caratteristiche tipiche degli ambienti aumentati. Il prototipo effettivo è un'applicazione in Realtà Aumentata in esecuzione su un dispositivo denominato Microsoft HoloLens, da indossare in testa (al pari di un paio di occhialoni da sci) e in grado di generare un ambiente immersivo, tridimensionale e interattivo. Una volta completato, il Learning Environment sarà in grado di fornire moduli di apprendimento (Learning Modules - LM) su una varietà di argomenti riguardanti le Information and Communication Technologies e i correlati strumenti per l'utilizzo di tali tecnologie, e in particolare i servizi elettronici.
Durante la progettazione del Learning Environment, abbiamo cercato di mantenere il più separato possibile la progettazione dell'ambiente aumentato (Augmented Environment) dal disegno dei Moduli di Apprendimento (Learning Modules). Questo ci ha permesso, durante la progettazione del Learning Environment, di esplorare liberamente tutte le caratteristiche e le possibilità offerte dalla Realtà Aumentata senza alcuna costrizione o limitazione imposta al design dai contenuti da utilizzare nei Learning Modules, o dalle caratteristiche degli utenti reali del Learning Environment.

Solo dopo il completamento di una prima bozza del design dell'Augmented Environment e lo sviluppo di un prototipo funzionante, inizieremo a occuparci della progettazione dei Learning Modules. Infine, una volta completato il progetto dei Learning Modules, ci occuperemo della messa a punto del design complessivo del Learning Environment: terremo conto delle caratteristiche degli utenti ideali del Learning Environment e adatteremo le interfacce e le caratteristiche del Learning Environment per massimizzare l'usabilità del Learning Environment per gli anziani e rendere la loro esperienza di apprendimento quanto più utile e piacevole possibile.

A1. L'AMBIENTE AUMENTATO

Come abbiamo detto, durante la progettazione dell'Augmented Environment, volevamo sfruttare appieno le caratteristiche degli ambienti di Realtà Aumentata per creare un Augmented Environment in grado di esprimere tutto il suo potenziale solo come un'applicazione in Realtà Aumentata per dispositivi indossabili (Head Mounted Displays – HMD) [29], [30], [33]. In particolare, abbiamo ritenuto che il nostro Augmented Environment dovesse avere le seguenti caratteristiche fondamentali: (a) deve essere in grado di mescolare perfettamente il mondo reale e il mondo virtuale; (b) deve essere interattivo in tempo reale; (c) deve essere completamente 3-D; (d) deve essere immersivo.
Tenendo presente quanto sopra, abbiamo definito:

- Le caratteristiche generali dell'Augmented Environment (definizione di un ambiente generale, possibile suddivisione dell'ambiente generale in sub-spazi, definizione di moduli di apprendimento, definizione delle interfacce che consentono all'utente di navigare attraverso l'Augmented Environment);
- le regole su come gli oggetti virtuali interagiscono (con altri oggetti, con l'utente, con il mondo reale);
- le caratteristiche di un assistente virtuale, capace di aiutare l'utente nei diversi momenti della sua esperienza di apprendimento;

In generale, volevamo anche che il Learning Environment avesse alcune caratteristiche extra. Sebbene queste non siano essenziali per definire gli ambienti aumentati, esse dovrebbero contribuire ad aumentare il comfort dell'utente e il senso di familiarità con il mondo aumentato, e rendere l'esperienza di apprendimento più facile e più divertente:

- l'Augmented Environment dovrebbe essere progettato in modo tale da non richiedere agli utenti alcuna conoscenza della tecnologia coinvolta nella creazione dell'Augmented Environment;
- l'Augmented Environment dovrebbe consentire un facile accesso ai suoi oggetti e contenuti (le interfacce che consentono l'orientamento e la navigazione dell'ambiente virtuale dovrebbero essere di facile comprensione e utilizzo);
- l'Augmented Environment dovrebbe essere facilmente adattabile alle esigenze specifiche di utenti diversi (ad esempio, se necessario, i gesti che controllano l'interazione possono essere sostituiti da comandi vocali), in modo da consentire l'uso dell'Augmented Environment anche agli utenti con possibili problemi motori agli arti superiori;

Nel complesso, l'Augmented Environment dovrebbe essere concepito per: (a) facilitare l'apprendimento dei contenuti visivi; (b) incoraggiare il processo di "fare per imparare"; (c) aumentare il coinvolgimento e il divertimento dell'utente; (d) collegare l'esperienza personale dell'utente ai contenuti da apprendere.

A.2. OTTIMIZZAZIONE DEL DESIGN IN FUNZIONE DEGLI UTENTI TARGET

Una volta completata la prima bozza del disegno generale di Augmented Environment e Learning Modules, apporteremo ulteriori modifiche a questo disegno in modo da adattare il Learning Environment agli anziani. Ciò significa identificare i bisogni, gli interessi e le capacità degli anziani, in modo da poter adattare il disegno di conseguenza. Tuttavia, non abbiamo bisogno di una definizione troppo complessa di "anziani"; abbiamo solo bisogno di identificare quei tratti psico-fisici o comportamentali tipici dell'età avanzata che impongono un cambiamento formale o strutturale nel design. In particolare, esamineremo la letteratura in cerca di informazioni su:

- Tratti psico-fisici: gli anziani potrebbero soffrire di alcune forme di decadimento psico-fisico; dobbiamo tenere conto di tali problematicità, e veicolare il contenuto in modo tale da renderne sempre possibile la fruizione. Ad esempio, se sappiamo dalla letteratura che in età avanzata è inevitabile una perdita progressiva della vista o dell'udito, dobbiamo fornire al Learning Environment sistemi di navigazione alternativi (ad esempio, menu testuali e comandi vocali) o diversi modi di veicolare i contenuti (ad esempio, tramite immagini e tramite narrazione orale), in modo che una modalità di fruizione dei contenuti possa sostituire l'altra quando necessario.

- Livello di istruzione e conoscenza digitale: è necessario disporre di informazioni sul livello generale di istruzione degli anziani e sulle loro conoscenze sull'uso del computer, o sulle Information and Communication Technologies e sugli strumenti necessari all'uso di tali tecnologie. Ciò è importante, per esempio, per identificare il linguaggio più adeguato da utilizzare durante l'esperienza di apprendimento, o per decidere il livello di approfondimento dei contenuti o gli argomenti che possono soddisfare i bisogni e gli interessi degli anziani.

B. SVILUPPO DEL PROTOTIPO DELL'AUGMENTED LEARNING ENVIRONMENT

Abbiamo utilizzato una prima versione del design dell'Augmented Environment per sviluppare un prototipo funzionante di Augmented Environment che, tuttavia, non include ancora gli Learning Modules. Il prototipo è un'applicazione in Realtà Aumentata, in esecuzione sul dispositivo denominato Microsoft HoloLens, ed è stata sviluppata utilizzando il *game engine* Unity 2018 [68] e il linguaggio di programmazione C #. Il prototipo necessita di ulteriore sviluppo, ma mostra già tutte le caratteristiche principali degli ambienti di Realtà Aumentata:

- Le caratteristiche generali di un ambiente in Realtà Aumentata funzionante: scansione e comprensione dell'ambiente reale che circonda l'utente; identificazione di superfici reali da utilizzare con contenuto aumentato (ologrammi);
- Diversi sub-ambienti aumentati: area di accesso, sala principale, training area, un modulo di apprendimento (la sua struttura generale e le sue funzionalità, ma senza contenuti):
- le interfacce principali che consentono assistenza e navigazione (pannelli di help, barre degli strumenti);
- un'assistente virtuale (Elektra) con voce sintetica, gesti, sincronizzazione labiale ed espressioni facciali e in grado di interagire parzialmente con l'utente e guidarlo durante l'intera esperienza di apprendimento;

Ognuna delle aree sopra definite è completa e include un pannello di help, interfacce per la navigazione e l'interazione con gli ologrammi già esistenti.

C. TEST CON IL PROTOTIPO DELL'AUGMENTED LEARNING ENVIRONMENT

Al fine di verificare la funzionalità, l'adeguatezza e l'efficacia del prototipo per i target user, e per procedere, eventualmente, con l'ottimizzazione del design dell'augmented learning environment per i target user, così come indicato in 1.3., è necessario testare il prototipo.

Intendiamo condurre dei test di usabilità e di user experience con gruppi selezionati di anziani e di studenti del DISI (12-14 partecipanti per ogni categoria di utenti, uomini e donne).

- I potenziali partecipanti saranno selezionati sulla base di un Questionario di Selezione (partecipanti anziani) o di un breve colloquio (studenti DISI).
- i partecipanti selezionati, divisi in due gruppi (anziani, studenti) prenderanno parte a un breve incontro/workshop durante il quale saranno introdotti ai concetti di realtà aumentata e ologrammi.
- Dopo il workshop, i partecipanti avranno la possibilità di fare (individualmente) un'esperienza immersiva in realtà aumentata indossando (in testa) un dispositivo per la produzione di realtà aumentata denominato Microsoft HoloLens. Durante l'esperienza immersiva avranno la possibilità di completare semplici esercizi e manipolare ologrammi.
- Al termine della loro esperienza immersiva, ai partecipanti sarà chiesto di completare un breve questionario con domande sull'usabilità dell'HoloLens e dell'ambiente immersivo e sull'esperienza che hanno avuto con l'HoloLens e la realtà aumentata.
- Quando tutti i partecipanti di un gruppo avranno terminato la loro esperienza immersiva verrà organizzato un Focus Group finalizzato ad avviare una discussione guidata sull'esperienza con l'HoloLens.

Per ulteriori dettagli si vedano le sezioni 2.4.4. – 2.4.6. di questo documento.

2.4 descrizione del progetto:
Older adults must deal with many problems due to ageing: their physical and mental conditions tend to deteriorate and they find it difficult to cope with many situations that in younger age they could easily control. Nowadays, Information and Communication Technologies can help older adults in many ways to slow down the effects of ageing and preserve their psycho-physical conditions for a longer time. However, Information and Communication Technologies also contribute to create new social problems in older adults, especially social isolation and loneliness. In a world more and more shaped by technology and digital communication, social relationships, public and private activities and services, entertainment and, overall, any form of exchange of information, will increasingly be based on the use of technology. So, older adults without Information and Communication Technologies literacy will find it progressively more difficult to maintain their social relations and activities, and feel that they are active citizens of the technological society. So, in order to avoid this new form of social isolation, the research has to find ways to provide older adults with knowledge on the use of computer and, more in general, on Information and Communication Technologies and tools.
In this project, we present our research on the design and development of an innovative form of e-learning, specifically designed for older adults that could provide a contribution in solving the outlined problem of social isolation. Particularly, we have designed and developed a learning environment using augmented reality. The learning environment is an immersive, 3-D and fully interactive environment, capable of easily introducing older adults to the knowledge on Information and Communication Technologies and tools they need to be integrated and active in e-society.

2.4.1 BASE DI PARTENZA E GIUSTIFICAZIONE TEORICA

Older Adults and Active Ageing

Researches and Governmental Institutions agree on the fact that, all over the world, there is a significant increase in lifespan, and the number of people who are 65 or older is constantly growing. This phenomenon is becoming so evident, and has so many economic and social consequences, that can no longer be neglect [1]. With age, many physical, and mental problems arise. According to the World Health Organization (WHO) [2], health problems in old age may be a consequence of factors such as poor nutrition, physical inactivity and bad habits, which may lead to several chronic diseases. However, these bad health conditions might also be caused by social problems [3], especially loneliness and social isolation [4].
Social isolation is not uncommon among older adults, and is often caused by impaired physical functioning, which might limit the older adults' ability to move and prevent them from having social interactions. So, older adults must rely on their social networks (family, friends) [5]. Such networks provide assistance and, at the same time, prevent from social isolation. However, nowadays, older adults' social networks tend to shrink and lose their supportive role. Furthermore, social services - such as residential care - provide no practical support, if compared with the one that peers and relatives provide [6]. As a consequence, older adults easily feel lonely and socially isolated. And this feeling of loneliness is dangerous, as it might trigger many severe physiological and mental issues [7]. The existence of so many health problems in older population will have an important impact on the societies of the near future. The increasing longevity, without an adequate increment of older adults health conditions, will lead to a greater demand in health services, and consequently to higher costs for public institutions. Therefore, researches and policy makers have urged the development of specific strategies for the wellbeing of older adults [5], [8], [9], [10], [11].
The idea behind this view is "Active Ageing", which has been defined the first time in 2002 by the WHO [12]. Active Ageing refers to "the process of optimizing opportunities for health, participation and security, in order to enhance quality of life and wellbeing as people age" [1]. The European Commission has presented an agenda that proposes specific norms for active ageing [1]. At the same time, researchers have tried to identify the needs of older adults, and to find the ways to best help them, so to make their lives healthier, more active, enjoyable and independent. Within the active ageing context, there is one topic-area relevant for our research: learning, and particularly, learning of Information and Communication Technologies.

Older Adults and Learning

Despite the common opinion, older adults are still capable to learn [13]. Various studies [14], [15], [16], [17] show that older adults learning can deliver many social, mental and physical benefits: not only can learning decrease older adults sense of isolation and loneliness, and enhance their personal and community wellbeing, but it can also can reduce their dependency on government-funded social services. Certainly, the learning interests of older adults differ from those of younger adults. Older adults are mainly interested in learning solutions to practical problems of real-life contexts [18]. Of course, there are biological changes that lead to memory decreases as people age [19]. Nonetheless, in order to learn new information, older adults usually cope with their memory loss by relating new information to previous knowledge or to their personal experience [20].

E-learning and Augmented Learning

E-learning is a combination of methods, structures and networked electronic tools orchestrated into systems that bring about, or are intended to bring about, learning" [21]. Overall, e-learning studies can be focused on three principal research areas [22]: (1) users, interacting with e-learning systems; (2) technologies, enabling the direct or indirect interaction of the different groups of users; (3) learning theories and pedagogical practices. In the literature, we find four learning theories considered the major and most influential pedagogical approaches on learning: Behaviorism and Cognitivism, both developed during the first half of the 20th century, and Constructivism and the On-line Collaborative Learning theory, developed in more recent years, and perhaps more capable of accounting for the emergence of technology in everyday life [21], [23], [24], [25]. Of course, the above theories on learning are not the only ones available. In recent years, as on-line learning and technology-based teaching have evolved, many new theories of learning are emerging [22], [26]. Given the range of learning and teaching styles, the potential ways technology can be implemented, and the ways in which educational technology itself is constantly changing, no single theory seems capable of accounting for all possible e-learning experiences. So, it is reasonable to think that different theories will continue to co-exist, and they will be used to satisfy the different needs of different people, using different technologies in different learning contexts.
Here, we consider some varieties of e-learning [27]: (a) *standalone courses:* self-paced courses taken by a solo learner; (b) *learning games and simulations:* learning by performing simulated activities that require exploration and lead to discoveries; (c) m*obile learning:* learning from the world while moving about in the world; (d) *social learning:* learning through interaction with a community of experts and fellow learners; (e) *virtual-classroom courses:* on-line classes structured much like a classroom course, with reading assignments, presentations, discussions via forums, synchronous on-line meetings, and other social media, and homework.

Augmented Learning

There is one more form of e-learning: A*ugmented Learning*, a form of standalone learning within Augmented Reality environments which provides users with 3-D, interactive, and, in some cases, immersive learning experiences [28]. Researchers started years ago to investigate the potential of Augmented Reality in educational settings [26]. Many argue that fully working Augmented Learning environments deployed as Augmented Reality applications could really contribute to change, enrich, and improve the learning experience in many ways: by facilitating the learning of visual contents; or by encouraging the process of "learning-by-doing"; or by increasing the user's involvement in the process of learning; or by encouraging collaboration and social interaction; or by connecting the user's personal experience to the contents to be learned [29], [30], [31], [32], [33], [34], [35].The state of current research in Augmented Reality for education can be still considered in its infancy [26] but, finally, Augmented Reality is a mature technology, already available in the market. So, researcher can really start thinking about Augmented Reality applications for education.

Augmented Reality

Augmented reality is an emerging form of experience in which the real world is enhanced (or augmented) by computer-generated content. Augmented Reality allows digital content to be seamlessly overlapped and combined into our perceptions of the real world in real time [30], [36], [37]. The most evolved forms of Augmented Reality create a full-rounded immersive experience involving all senses, and add rich and meaningful extra-worlds to the real world. Some recent Augmented Reality systems, actually leading the Augmented Reality market (such as Microsoft HoloLens, Meta, or Magic Leap [38]) allow even the interaction between users and the virtual objects belonging to the Augmented Environments.
The idea of a device capable of displaying computer-generated objects overlaid and mixed with real objects was first devised during the Fifties [30], [39], but it was only during the Sixties that actual devices capable of displaying simple Augmented Reality environments were created. However, the technologies used to develop these devices were too primitive to be able to produce real experiences of augmented reality. From the Seventies, up to the

end of the Nineties, research on Augmented Reality was mostly focused on the development of new technologies related to Augmented Reality. But, again, technology was not good enough, so the devices created in most cases remained experimental devices with no concrete application in the real world. The only exception to this situation was, perhaps, the development of some very expensive and highly specialized devices for professional applications, such as maintenance and repair of complex equipment and medical visualization [40]. Only the rapid growing in microprocessors performance, and the recent progresses in micro-chips and sensors miniaturization, in display techniques, or in techniques for tracking did allow Augmented Reality researchers to finally open the doors of their labs and make Augmented Reality devices accessible to the masses. Today, Augmented Reality is no longer an "emerging" technology, and even though it cannot yet be considered a flawless technology [40], it's not difficult to think that in a few years will become a powerful and familiar tool in everyday life.

Devices and Application for Augmented Reality

The most common devices [39], [41], [42] used to deliver Augmented Reality content are: *(1) mobile devices:* Augmented Reality mobile applications provide a non-immersive augmented experience by creating the virtual contents and mixing them with the real world captured with the device mobile camera; *(2) wearable devices:* Users mount this type of devices, also called head-mounted displays (HMDs), on their heads, with the device see-through displays in front of their eyes. The Augmented Environments are projected on the displays, so to superimpose virtual content onto some portions of the perceived real world. In this case, the devices also allow full 3D, interactive and immersive experiences.
Many Augmented Reality consumer applications for Android or iOS mobile devices are already available, and the market of mobile applications is constantly growing. However, as more models of HMDs become available and their prices decrease, also applications for HMDs are becoming more affordable and popular. For example, we find many professional apps for Augmented Reality HMDs [30], [40], [43], [44], especially in high-tech fields such as medicine [45], robotics [46], industry automotive [47], architecture [48], advertising and marketing, visual arts [49], entertainment, military air crafting, manufacturing.
As for Augmented Reality applications in the field of education, the research is just in its infancy, so it is difficult to find applications devoted to explore educational settings. However, the field of Augmented Learning shows a great potential. For several years, e-learning seemed mostly focused on the Web and the online courses for distant education. Perhaps, in the near future, augmented learning will be able to take education away from the Web and move it into a new reality which will be enriched by augmented reality.

E-society and E-services

According to a recent report commissioned by eBay [50], in 2014 more than 90% of U.S. small and medium-sized businesses used eBay platform to export goods internationally. In 2009, only 10% were exporting. This means that eBay, by using the Internet, has enabled businesses to become really global traders. And eBay is not the only provider offering such services. Also large e-service providers such as Google, Amazon, Alibaba and others enable small and medium-sized businesses to use their platforms to promote their business. In so doing, these big providers not only become able to sell any sort of product or service to an increasing number of customers everywhere in the world, but also boost the shift of traditional business toward electronic business. So, business companies, even those that do not want to join large service providers, trying to remain competitive, are somehow forced to move their business on-line.
Of course, U.S. is not the only country to move business services on-line. In many developed countries, the trend is the same: business companies, no matter where their base-country is, use the Internet to operate globally. And their services are cheaper, faster, and more reliable than old, regular, off-line services [51]. And non-business and public services undergo the same change as well: public services progressively become e-services. E-services offer national governments the promise of increased convenience, lower transacting costs, increased consumer choices, enhanced efficiency and effectiveness of the services being delivered to all citizens, and greater accessibility by eliminating space and time constraints [51]. So, Governments from the various developed countries are gearing up to transform traditional services into on-line services: government services become e-government services, healthcare services become e-health services, and so on. The progressive conversion of services into e-services marks the transition of our society into e-society. In an e-society, social relationships, public and private activities, entertainment and, overall, any form of exchange of information, will increasingly be based on the use of electronic services.

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Older Adults in E-society

The transformation of society into e-society has many evident economic and social benefits. However, the pervasiveness of e-services in e-society also raises a fundamental issue: e-services, in order to be used, need computer literacy. So, people lacking knowledge on Information and Communication Technologies will find it increasingly more difficult to use all the public and private e-services available to e-society members and will be excluded from any form of e-social interaction. In short, they will be excluded from e-society. Clearly, those most at risk of ending up excluded from e-society are, again, those older adults who did not have many opportunities to learn new technologies during their working life. Once they are retired, they find it even more difficult to acquire technological literacy, and so they find themselves unable to cope with e-society. It is true that the portion of older adults using Information and Communication Technologies is increasing; for example, the Italian Institute of Statistics (ISTAT) [52] states that in Italy, in recent years, the number of older adults using the computer and the Internet tripled. But it is still poorer compared with younger adults [53].
In an earlier section of this paper, we saw that social isolation and loneliness were two major sources of mental and physical problems in older adults. Now, we see that the same society that urges to find technological solutions to the problem of social isolation in older adults, also creates, because of technology, a new possible form of social isolation. Without Information and Communication Technologies literacy, older adults will find it difficult, when not impossible, to use technologies to maintain their mental life active. Moreover, they will find progressively harder to "feel connected with the world" and to maintain their social relations in a world that is more and more permeated by technology. So, as we already said, it becomes important to address this problem within the active aging context; it becomes important to look for new strategies for making knowledge on Information and Communication Technologies more accessible to older adults, so to reconnect them with the world.
We also saw that learning, in general, can provide older adults with many social, mental and physical benefits. If we now take also into account what we just said on older adults and e-society, we can easily see that learning focused on Information and Communication Technologies can have on older adults even more beneficial effects. As some studies suggest [54], [55], knowledge on Information and Communication Technologies makes older adults feel connected again with the world, integrated again in society, and part of the "human race".
So, believing that a learning environment designed for older adults and capable of easily introducing them to Information and Communication Technologies and e-services could provide a contribution in solving the problem of social isolation previously outlined, we started working on the design of an innovative form of Learning Environment.

2.4.2 Finalità generali, obiettivi specifici e risultati attesi

We worked on the design and development of a new Learning Environment for older adults using Augmented Reality technologies, and we were also able to create a working prototype of the Learning Environment displaying the most important features of augment environments.

The prototype
The actual prototype is an Augmented Reality application running on Microsoft HoloLens and capable of generating an immersive, 3-D and interactive environment. Once completed, the Learning Environment will be capable of delivering Learning Modules on a variety of topics dealing with Information and Communication Technologies and tools, and particularly with e-services.

The test of usability and user experience
Now, we intend to test the prototype with groups of students (from DISI-UNITN) and older adults. The results from the test will serve several purposes. First of all, we will use the data we will obtain from the test (particularly the information on the functionality and usability of the learning environment) to fine-tune the overall design of the Learning Environment. That is, we will take into account the features of the target users of the Learning Environment, and, on the basis of the results from the test, we will adapt, or even redesign, the interfaces and features of the Learning Environment in order to maximize the usability of the Learning Environment for older adults and make the learning experience as useful and enjoyable as possible.
In addition, by means of the test, we will also have the opportunity to verify our working hypothesis, according to which it should be easy, even for older adults, to use our Learning Environment and, more in general, augmented

reality technology. If our working hypothesis is correct, our Learning Environment could really become a possible alternative to existing online courses, particularly if we think that these courses are usually not tailored for older adults[13], [69] and that, contrarily to what happens with our Learning Environment, they require at least some basic knowledge on Information and Communication Technologies in order to be used.
Finally, the test will also provide us with the opportunity to further explore the complex relationship between older adults and new technologies and, particularly, Augmented Reality: are older adults so willing to accept a technology that mixes the real world with a fictional and virtual world? How do older adults feel about having a somehow awkward device on their head, which, in addition, alters their perceptions? What is their reaction to dealing with holograms?
[For a more detailed description of the test we intend to carry out with groups of DISI students and older adults, see sections 2.4.4. – 2.4.6 in this document.]

General remarks
During the design of the Learning Environment, we followed the well-known Software Engineering practice of "separation of concerns" [56] and we thrived to keep as separate as possible the design of the augmented environment from the design of the Learning Modules. This has allowed us, during the design of the Learning Environment, to freely explore all the features and possibilities offered by Augmented Reality without any constriction or limitation imposed on the design by the learning contents to be used in the Learning Modules, or by the features of the real users of the Learning Environment.
Such separation carries important consequences: it makes it possible to think of a use of our Learning Environment with a wider and more general scope than the one defined so far for our project. In fact, because of such separation, it become possible to introduce substantial changes to the contents of the Learning Modules without affecting the general augmented environment hosting the Learning Modules. And this opens up the possibility of using the same general Learning Environment in different settings, with different contents and for different types of users.

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2.4.3 La ricerca è condotta con volontari, sani o malati, allo scopo di valutare la sicurezza e/o l'efficacia di tecniche/dispositivi/trattamenti volti al miglioramento dello stato di salute?

NO

2.4.4 Metodi di indagine e di elaborazione dei dati raccolti

Una volta sviluppato un prototipo dell'ambiente di apprendimento in realtà aumentata, intendiamo condurre dei test di usabilità e di user experience con gruppi selezionati di studenti del DISI e di anziani. Questi test, eseguiti utilizzando un dispositivo per la produzione di realtà aumentata, denominato Microsoft HoloLens (da indossare in testa al pari di un paio di occhialoni da sci – si veda **Allegato E**: immagine nella domanda n. 49), saranno utili ad acquisire informazioni e dati sull'usabilità dell'HoloLens e dell'ambiente di apprendimento

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da parte di utenti anziani e giovani e anche sul rapporto che questi utenti hanno con le nuove tecnologie, con particolare riferimento alla realtà aumentata.

ELABORAZIONE DEI DATI RACCOLTI

Come indicato in precedenza, il test sarà somministrato a due diversi gruppi di utenti: studenti del DISI (quindi con un livello medio-alto di conoscenza delle nuove tecnologie) e anziani (con un livello minimo o inesistente di conoscenza delle nuove tecnologie). Saranno registrati e analizzati i dati provenienti dall'HoloLens e dalle riprese video sul comportamento dei partecipanti durante il test con l'HoloLens, i dati ottenuti dal questionario di usabilità, nonché le informazioni ottenute dalle audio-registrazioni dei focus group.
Analizzando i dati acquisiti dall'HoloLens e le risposte al questionario di usabilità sarà possibile ottenere indicazioni sulla funzionalità e l'usabilità del prototipo dell'ambiente aumentato, utili a migliorare il design del prototipo stesso e ad adeguare il prototipo alle caratteristiche ed esigenze degli utenti anziani.
Inoltre, confrontando i dati e le informazioni provenienti dai due gruppi, sarà possibile ottenere nuova conoscenza sulle differenze di percezione e utilizzo della realtà aumentata da parte di due diverse e distanti tipologie di utenti. Infine, sarà anche possibile ottenere indicazioni sulla possibilità concreta di utilizzare la realtà aumentata come effettiva tecnologia di learning per gli anziani.

A) Usabilità: Caratteristiche e problemi

Sulla base dei dati catturati dall'HoloLens durante il test immersivo (v. **Allegato F1**) verranno identificate alcune importanti caratteristiche di usabilità dell'ambiente aumentato, impossibili da definire con esattezza prima della somministrazione del test (per esempi., la dimensione minima dei font, tale da permettere la buona leggibilità di tutti i testi visualizzati nell'ambiente aumentato da parte di utenti anziani; la dimensione minima dei bottoni o di ologrammi che devono essere selezionati tramite movimenti della testa; ecc.).
Tramite l'analisi delle risposte al questionario di usabilità e user experience (v. **Allegato F2**) verranno inoltre identificati eventuali problemi nella funzionalità delle interfacce dell'ambiente aumentato.
Come già indicato, tali informazioni verranno utilizzate per correggere gli eventuali errori e perfezionare il disegno dell'ambiente di apprendimento, al fine di massimizzare l'usabilità dell'applicazione di e-learning che intendiamo sviluppare e aumentare la qualità dell'esperienza che gli utenti anziani avranno quando utilizzeranno l'applicazione.

B) Gli anziani sono in grado di utilizzare la realtà aumentata?

L'analisi dei dati ci fornirà anche utili indicazioni per capire se anziani sono in grado di utilizzare la realtà aumentata. Come si vede nelle Tabelle dell'**Allegato F1**, durante il test con i due gruppi (anziani, studenti):

- vengono identificati i gesti eseguiti (e i tempi di esecuzione, se il gesto va mantenuto, come nel caso del gesto "hold")
- vengono rilevati i tempi di risposta ai task richiesti (eseguire un gesto, portare a termine un compito—es. Manipolare un ologramma, completare un esercizio)

Elaborando i dati acquisiti si ricavano:

a) la capacità di apprendimento dei gesti utilizzati nel test (i gesti sono stati appresi: si/no);
b) i tempi di apprendimento dei gesti: dopo tempo t, o dopo n ripetizioni;
c) la capacità di risoluzione dei task di manipolazione di ologrammi richiesti (selezionare un ologramma, spostarlo, ruotarlo, ecc.): i task sono stati risolti: si/no, quali, con quali tempi;
d) la capacità di risoluzione degli esercizi proposti (nel loro insieme): gli esercizi sono stati completati: si/no, quali, con quali tempi;

Esaminando i risultati ottenuti dal gruppo anziani si riuscirà a capire se gli anziani sono in grado di utilizzare la realtà aumentata. In particolare se: (i) sono riusciti ad apprendere i gesti proposti nel test e (ii) sono stati in grado di utilizzare i gesti al fine di completare sequenze di task di manipolazione di ologrammi.

C) Qual è il rapporto degli anziani con le nuove tecnologie e in particolare con la realtà aumentata?

L'analisi dei dati descritta nel punto precedente ci fornirà indicazioni importanti per capire se gli anziani sono in grado di utilizzare la realtà aumentata. Ma non ci permetterà di investigare più a fondo la natura del rapporto

che gli anziani possono avere con la realtà aumentata: hanno apprezzato l'esperienza immersiva con l'HoloLens? Vorrebbero ripeterla? In che condizioni? Con quali cambiamenti o variazioni? Ritengono la realtà aumentata uno strumento utile? Divertente?
In questo caso, è l'analisi delle informazioni acquisite tramite i focus group (si veda **Allegato G**: "Traccia Focus Group") che ci permetterà una miglior comprensione del rapporto che gli anziani hanno con le nuove tecnologie, e in particolare con la realtà aumentata.

Usare la realtà aumentata è facile; questa è l'ipotesi di lavoro che ha motivato lo sviluppo della piattaforma di learning in realtà aumentata per anziani. Avere risposte articolate alle domande B-C diventa quindi essenziale per verificare la correttezza della nostra ipotesi, e ci permetterà di riflettere in maniera più consapevole e sulla base dei dati empirici, sull'efficacia della realtà aumentata come strumento da utilizzare con gli anziani e quindi anche sull'opportunità di continuare nello sviluppo della piattaforma di learning in realtà aumentata.

Allegato E: Questionario di selezione (anziani)
Allegato F1: Description of the immersive experience with the Microsoft HoloLens
Allegato F2: USE Questionnaire: Usefulness, Satisfaction, and Ease of use
Allegato G: Traccia Focus Group

2.4.5 Numerosità ed eventuale stratificazione del campione

La ricerca coinvolgerà due diversi gruppi di partecipanti: studenti dei programmi di Master o di Dottorato del DISI e anziani (65-80). Date le diverse caratteristiche dei partecipanti appartenenti ai due gruppi, si dovranno differenziare le modalità di coinvolgimento nella ricerca dei potenziali partecipanti.

Nel caso degli **studenti**, il reclutamento avverrà tramite l'esposizione di un *Invito alla partecipazione al Progetto* (v. **Allegato D1**) negli appositi spazi pubblici (bacheche, ecc.) del DISI. Tra gli studenti che si offriranno volontariamente di partecipare, ne verranno selezionati 12/14 (uomini e donne) tramite breve colloquio finalizzato a verificare che sussistano le condizioni minime per la partecipazione, così come definite al punto 3.3: *Caratteristiche dei partecipanti allo studio*.

Nel caso degli **anziani**, il coinvolgimento dei partecipanti dovrà essere avviato in sedi diverse dal DISI, ovvero tramite l'esposizione (autorizzata – si veda l'**Allegato L**) di un *Invito alla partecipazione al Progetto* (v. **Allegato D2**) negli appositi spazi pubblici (bacheche, ecc.) di alcune Associazioni/Centri per anziani (già identificate – si veda il punto 1.5) che si ritiene siano ideali per la diffusione dell'Invito di Partecipazione al progetto tra potenziali partecipanti anziani con caratteristiche adeguate per il test che intendiamo condurre, così come definite al punto 3.3: *Caratteristiche dei partecipanti allo studio*. Tra gli anziani che si offriranno volontariamente di partecipare al progetto, verranno selezionati 12/14 partecipanti (uomini e donne), utilizzando un questionario di selezione (v. **Allegato E**: Questionario di Selezione).

Allegato D1-D2: Invito alla partecipazione al progetto (studenti, anziani)
Allegato E: Questionario di selezione (anziani)
Allegato L: Autorizzazione alla partecipazione al progetto da parte dell'Associazione coinvolta

2.4.6 Descrizione della procedura sperimentale [allegare eventuale esemplificazione del materiale e degli stimoli utilizzati]

Workshop

Prima di utilizzare l'HoloLens, che produce un'esperienza individuale, tutti i partecipanti selezionati prenderanno parte ad un breve incontro/workshop (circa 15 minuti) da tenersi in una delle aule del DISI appositamente attrezzate per ospitare seminari e incontri.
Durante il workshop i partecipanti saranno introdotti (attraverso un linguaggio adeguato e con l'aiuto di immagini e 1 video) ai concetti di realtà aumentata e ologrammi, in modo che possano capire meglio i compiti

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che saranno chiamati a svolgere durante l'esperienza con l'HoloLens. Durante l'incontro, i partecipanti potranno anche vedere e toccare il dispositivo e capire come indossarlo, così da avere la possibilità di familiarizzare con l'HoloLens e, più in generale, con l'idea di utilizzare una nuova tecnologia immersiva. Ai partecipanti verranno anche fornite istruzioni scritte e visive (immagini) sui pochi (3-4) gesti che saranno richiesti per portare a termine la loro esperienza con l'HoloLens.

RACCOLTA DEI DATI

Esperienza immersiva con l'HoloLens

L'esperienza immersiva è individuale, quindi sarà possibile organizzare una serie di appuntamenti con i partecipanti al fine di evitare ai partecipanti inutili attese. L'intero test con l'HoloLens può essere somministrato in una stanza di medie dimensioni senza particolari attrezzature. La maggior parte dei dati saranno acquisiti dall'HoloLens, e le attrezzature per la registrazione del comportamento dei partecipanti (un semplice dispositivo di registrazione video, i.e. un cellulare, montato su cavalletto) saranno gestite dal ricercatore (Sergio Cicconi) che si occuperà di somministrare il test. Anche in questo caso, come nel caso del workshop, si potrà utilizzare uno spazio prenotabile al DISI (un'aula o una sala da seminario).

Prima di iniziare l'esperienza immersiva ogni partecipante sarà aiutato a indossare l'HoloLens. Sarà inoltre ricordato ad ogni partecipante che l'esperienza con l'HoloLens potrà essere interrotta in qualsiasi momento e per qualsiasi motivo, senza necessità di fornire alcuna spiegazione. Durante l'intera esperienza in realtà aumentata, ogni partecipante sarà guidato e assistito al fine di facilitare l'esperienza stessa e renderla quanto più gradevole possibile.

L'esperienza con l'HoloLens durerà circa 25 minuti (per ulteriori dettagli si veda l'**Allegato F1**: "Description of the Immersive Experience with the Microsoft HoloLens"). A ogni partecipante verrà chiesto di completare alcuni esercizi di selezione o manipolazione di ologrammi, eseguendo semplici movimenti con la testa (cioè, leggere rotazioni della testa a destra o sinistra, in alto o in basso, per identificare i particolari ologrammi che di volta in volta verranno utilizzati nell'ambiente immersivo), o con le mani (semplici gesti con le dita di una o due mani per "afferrare" gli ologrammi e spostarli, ridimensionarli e ruotarli nello spazio).

Sembra qui utile ricordare che i monitor trasparenti dell'HoloLens, posizionati davanti agli occhi dell'utilizzatore, non sono mai in contatto con gli occhi stessi (infatti, anche chi indossa occhiali può utilizzare il dispositivo senza problemi mantenendo gli occhiali) e non espongono mai gli occhi a luci di intensità tale da potersi considerare in alcun modo pericolose. Inoltre, i dispositivi audio (mini-altoparlanti) posizionati all'altezza delle orecchie dell'utilizzatore non emettono mai suoni a un volume di intensità tale da potersi considerare in alcun modo pericolosi. Infine, la realtà aumentata non induce negli utilizzatori quelle sensazioni di nausea o vertigine che si possono manifestare invece con la realtà virtuale. L'esperienza con l'HoloLens è da considerarsi quindi sicura, cioè non espone in alcun modo gli utilizzatori a situazioni potenzialmente pericolose dal punto di vista fisico, psicologico, sociale.

Usabilità e User Experience

Alla fine dell'esperienza con l'HoloLens, a ciascun partecipante verrà chiesto di compilare un breve questionario (simile a quello in **Allegato F2: "**USE Questionnaire: Usefulness, Satisfaction, and Ease of use") con domande sull'usabilità dell'HoloLens e dell'ambiente immersivo e sull'esperienza che ha avuto con l'HoloLens e la realtà aumentata.

Focus group

Successivamente al completamento del test immersivo da parte di tutti i partecipanti, verrà organizzato un Focus Group finalizzato ad avviare una discussione guidata sull'esperienza con l'HoloLens (v. Traccia della discussione nell'**Allegato G).**

I focus group sono particolarmente utili all'esplorazione dei giudizi e dei vissuti: sfruttando la dinamica di discussione e confronto, ed avvantaggiandosi dell'accumulo di conoscenze, i gruppi consentono la costruzione di un quadro ricco e articolato delle esperienze e dei vissuti in termini razionali e simbolici.

I focus group si terranno in una delle aule del DISI appositamente attrezzate per ospitare seminari e incontri. I gruppi di 6-7 partecipanti e della durata di circa 1 ora, saranno condotti dal ricercatore coinvolto nel progetto (Sergio Cicconi). Ogni focus group sarà audio-registrato (previo consenso dei partecipanti all' Informativa Trattamento Dati – v. **Allegato J**).

Allegato D1-D2: Invito alla partecipazione al progetto (studenti, anziani)
Allegato E: Questionario di selezione (anziani)
Allegato F1: Description of the immersive experience with the Microsoft HoloLens
Allegato F2: USE Questionnaire: Usefulness, Satisfaction, and Ease of use
Allegato G: Traccia Focus Group
Allegato J: Informativa Trattamento Dati

SEZIONE 3 - DETTAGLI RELATIVI AI PARTECIPANTI

3.1 Quali tipologie di persone prenderanno parte allo studio?

X ☐ Studenti dell'Università degli Studi di Trento
X ☐ Adulti in grado di esprimere il loro consenso

☐ Minori di età compresa fra i .... e i .... anni/mesi
☐ Persone con deficit cognitivo/mentale, NON in grado di esprimere il proprio consenso
☐ Altre persone la cui capacità di esprimere consenso possa essere compromessa (indicare per quale motivo)
☐ Persone con disabilità fisica (specificare di quale tipo)
☐ Persone istituzionalizzate (ad es. pazienti ospedalizzati, carcerati, ecc.)
☐ Pazienti e/o clienti segnalati da medici, psicologi o altre categorie di professionisti
☐ Persone di madrelingua non italiana (specificare)
☐ Persone per le quali non è possibile predeterminare una specifica tipologia (ad es., somministrazione questionari via internet)
☐ Altri ....

3.2 È possibile che alcuni dei potenziali partecipanti si trovino in una relazione con lo sperimentatore tale per cui il consenso alla partecipazione potrebbe non essere del tutto libera da ogni tipo di pressione (ad es., studente/professore, paziente/medico)?
Se sì, indicare come si intende provvedere per minimizzare la possibilità che la persona si senta obbligata a prendere parte alla ricerca.

No. I partecipanti saranno messi nella condizione di poter aderire al progetto in modo libero e autonomo. I soggetti coinvolti saranno preventivamente informati riguardo alle finalità e alle tecniche di indagine utilizzate durante il progetto. Inoltre, ai soggetti coinvolti, verrà garantita la possibilità di ritirarsi dal progetto in qualsiasi momento e senza dover fornire alcun tipo di motivazione.

3.3 Caratteristiche dei partecipanti allo studio.

3.3.1 Criteri di inclusione

Studenti UNITN, uomini e donne, nei programmi di Master o Dottorato, in buona salute e senza particolari difficoltà motorie degli arti superiori e della testa, cioè capaci di compiere alcuni semplici movimenti con la testa (ruotare leggermente la testa a destra o sinistra, in alto o in basso), o con le mani (semplici gesti con due dita di una o due mani) o le braccia.

Anziani (65-80), uomini e donne, in buona salute (autonomi) e senza particolari difficoltà motorie degli arti superiori e della testa (vedi sopra). I partecipanti non devono avere familiarità con le nuove tecnologie e in particolare con la realtà aumentata.

3.3.2 Criteri di esclusione

Studenti UNITN: con difficoltà di movimento degli arti superiori e della testa. Familiarità con la realtà aumentata.

Anziani: Tremore in testa, braccia e mani. Difficoltà di movimento degli arti superiori e della testa. Difficoltà, o non volontà, a indossare in testa il dispositivo Microsoft HoloLens. Dichiarato fastidio o mancanza di interesse nei confronti delle nuove tecnologie. Familiarità con nuove tecnologie e in particolare con la realtà aumentata.

3.4 Come verranno reclutati i partecipanti?

La ricerca coinvolgerà due diversi gruppi di partecipanti: studenti dei programmi di Master o di Dottorato del DISI e anziani (65-80). Date le diverse caratteristiche dei partecipanti appartenenti ai due gruppi, si dovranno differenziare le modalità di coinvolgimento nella ricerca dei potenziali partecipanti.

Studenti: il reclutamento avverrà tramite l'esposizione di un *Invito alla partecipazione al Progetto* (v. **Allegato D1**) negli appositi spazi pubblici (bacheche, ecc.) del DISI. Tra gli studenti che si offriranno volontariamente di partecipare, ne verranno selezionati 12/14 (uomini e donne) tramite breve colloquio finalizzato a verificare che sussistano le condizioni minime per la partecipazione, così come definite al punto 3.3: *Caratteristiche dei partecipanti allo studio*. Prima del colloquio, verrà chiesto agli studenti di leggere il Modulo Informativo per la Richiesta di Consenso (v. **Allegato H**) e di compilare e firmare la Dichiarazione di Consenso (v. **Allegato** I). Durante il colloquio verrà chiesto agli studenti di compilare una scheda con semplici dati identificativi (nome, età, titolo di studio, email di contatto). Non verranno chiesti o registrati altri dati identificativi e dati particolari sensibili relativi allo stato di salute.

Anziani: il coinvolgimento dei partecipanti dovrà essere avviato in sedi diverse dal DISI, ovvero tramite l'esposizione (autorizzata – si veda l'**Allegato L**) di un *Invito alla partecipazione al Progetto* (v. **Allegato D2**) negli appositi spazi pubblici (bacheche, ecc.) di alcune Associazioni/Centri per anziani (già identificate – si veda il punto 1.5) che si ritiene siano ideali per la diffusione dell'Invito di Partecipazione al progetto tra potenziali partecipanti anziani con caratteristiche adeguate per il test che intendiamo condurre. Agli individui che si mostreranno interessati a partecipare al progetto verrà chiesto di leggere il Modulo Informativo per la Richiesta di Consenso (v. **Allegato H**) e di compilare e firmare la Dichiarazione di Consenso (v. **Allegato** I). Successivamente, verrà loro chiesto di compilare il Questionario di Selezione (v. **Allegato E**). La compilazione del questionario avverrà in maniera individuale con i tempi e nei luoghi scelti dai singoli candidati e il questionario completato andrà restituito al ricercatore coinvolto nel progetto. Sulla base delle risposte fornite al questionario, e sulla base dei criteri definiti in 3.3.1. e 3.3.2. il ricercatore coinvolto nel progetto selezionerà un gruppo ristretto (12-14) di candidati che parteciperanno effettivamente al progetto.

Allegato D1-D2: Invito alla partecipazione al progetto (studenti, anziani)
Allegato E: Questionario di selezione (anziani)
Allegato H: Modulo Informativo per la richiesta di consenso
Allegato I: Dichiarazione di consenso
Allegato L: Autorizzazione alla esposizione di un *Invito di Partecipazione al Progetto* da parte dell'Associazione identificata

3.5 Si prevede che vi possano essere benefici materiali per chi prende parte alla ricerca? Quali?

No, non sono previsti incentivi o benefici materiali per i partecipanti.

3.6 Oltre all'attestato di partecipazione, è prevista qualche forma di rimborso spese per i partecipanti allo studio?

Come indicato nel punto 2.4.6, il progetto prevede diversi incontri con i partecipanti, sia in gruppo (workshop, focus group) che individualmente (esperienza immersiva con l'HoloLens). Tali incontri avverranno in spazi adeguati messi a disposizione dal DISI. Considerando che tali incontri prevedono la necessità di spostamento dei partecipanti (da una sede di partenza alle strutture del DISI (Povo), e indietro) sarà cura del ricercatore coinvolto nel progetto (Sergio Cicconi) organizzare tali spostamenti (per esempio con autobus) e provvedere al pagamento o al rimborso delle spese di trasporto, utilizzando il budget del gruppo di ricerca *Social Informatics* del DISI.

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SEZIONE 4 - STRUMENTI DI INDAGINE, RISCHIO E GESTIONE DEL RISCHIO

4.1 La ricerca prevede (indicare tutte le voci appropriate)

☐ interviste strutturate o semi-strutturate (allegare copia delle domande che verranno poste; ove questo non sia possibile, indicare gli argomenti che verranno trattati)
☐ interviste in profondità
X ☐ utilizzo di questionari (v. **Allegato E, F2**)
X ☐ focus group (v. **Allegato G**)
☐ narrazioni autobiografiche
☐ raccolta di diari (diary keeping)
☐ somministrazione di test e/o questionari attraverso internet (web, posta elettronica)
☐ utilizzo di test neuropsicologici
☐ osservazione del comportamento dei partecipanti a loro insaputa
☐ osservazione del comportamento dei partecipanti
X ☐ registrazioni audio e/o video dei partecipanti
☐ registrazione di movimenti oculari
☐ registrazione di potenziali evocati
X ☐ somministrazione di stimoli, compiti o procedure e registrazione di risposte comportamentali, opinioni o giudizi (v. **Allegato F1**)
☐ utilizzo di stimoli, compiti o procedure che il partecipante potrebbe trovare *fisicamente* fastidiosi, stressanti, dolorosi (ad es., somministrazione di stimoli dolorosi, esposizione a suoni di forte intensità), sia durante sia successivamente la conduzione dello studio
☐ utilizzo di stimoli, compiti o procedure che il partecipante potrebbe trovare *psicologicamente* fastidiosi, stressanti, dolorosi (ad es., utilizzare come stimoli visivi immagini sessualmente esplicite o disgustose), sia durante sia successivamente la conduzione dello studio
☐ la messa in atto di comportamenti che potrebbero alterare significativamente lo stato emotivo dei partecipanti (es. diminuire l'autostima, aumentare l'aggressività) o indurre imbarazzo, dispiacere, frustrazione
X ☐ immersione in ambienti di realtà virtuale/aumentata (v. **Allegato F1**)
☐ utilizzo di tecniche di stimolazione transcranica (ad es., TMS, tDCS)
☐ tecniche di neuroimmagine (ad es., MRI, fMRI, MEG)
☐ somministrazione di sostanze o agenti (ad es., alcol)
☐ raccolta di campioni di tessuto o fluidi umani
☐ misurazione di parametri fisiologici (ad es. frequenza cardiaca, ecc.)
☐ studio di comportamenti illeciti
☐ altro (specificare):

NOTA: le registrazioni verranno eseguite durante la somministrazione del test con l'HoloLens (video), e durante il focus group (audio), previa autorizzazione dei partecipanti (v. **Allegato H, I**).
Da notare che nel caso delle registrazioni video durante l'esperienza immersiva l'HoloLens copre parte del viso (fronte, occhi, naso) rendendo gli utilizzatori dell'HoloLens non riconoscibili.

- **Allegato E:** Questionario di Selezione;
- **Allegato F1:** Description of the immersive experience with the Microsoft HoloLens;
- **Allegato F2**: USE Questionnaire: Usefulness, Satisfaction, and Ease of use;
- **Allegato G:** Focus Group.
- **Allegato H:** Foglio informativo per la richiesta di consenso
- **Allegato I:** Dichiarazione di Consenso

4.2 La procedura prevista potrebbe esporre i *partecipanti* a rischi di natura psicologica, sociale o fisica? Se sì, descrivere la natura di tali rischi e gli interventi preventivi messi in atto per minimizzarne il verificarsi e le possibili conseguenze.

Non si prevedono rischi in questa fase di ricerca. L'unico dispositivo usato con i partecipanti è l'HoloLens, da indossare in testa come un paio di occhialoni da sci. Il peso dell'HoloLens è tale da poter essere facilmente sopportato per la durata dell'esperienza immersiva. I monitor trasparenti posizionati davanti agli occhi del partecipante non sono mai in contatto con gli occhi stessi (infatti, anche chi indossa occhiali può utilizzare il dispositivo senza problemi mantenendo gli occhiali) e non espongono mai gli occhi a luci di intensità tale da potersi considerare in alcun modo pericolose. I dispositivi audio (mini-altoparlanti) posizionati all'altezza delle orecchie del partecipante non emettono mai suoni a un volume di intensità tale da potersi considerare in alcun modo pericolosi. Il dispositivo per la generazione di realtà aumentata è pensato per permettere all'utente di mantenere sempre un contato visivo con la realtà esterna attraverso i monitor trasparenti; tale costante contatto visivo con la realtà esterna evita l'insorgere negli utenti di quelle sensazioni di nausea o vertigine che si possono manifestare invece con la realtà virtuale.
L'esperienza con l'HoloLens è quindi da considerarsi sicura, cioè non espone in alcun modo i partecipanti a situazioni potenzialmente pericolose dal punto di vista fisico, psicologico, sociale o legale.
Va comunque ricordato che durante l'intera esperienza immersiva gli utenti sono assistiti dal ricercatore coinvolto nel progetto (Sergio Cicconi) e possono interrompere il test in qualsiasi momento senza dover fornire alcuna spiegazione.

4.3 La ricerca prevede che i partecipanti vengano ingannati, ovvero che non vengano fornite loro informazioni rilevanti prima di ottenere il consenso alla partecipazione? Se sì, descrivere quale informazione viene omessa, giustificare per quale motivo e indicare quando e in che modo i partecipanti verranno informati dell'inganno

No. L'intera esperienza immersiva è spiegata ai partecipanti durante il workshop che precede l'esperienza stessa e non sono assolutamente previste durante l'esperienza immersiva pratiche non spiegate o non dichiarate, o che tendano ad ingannare i partecipanti in qualsiasi modo.

4.4 È possibile che lo studio metta i *ricercatori* in situazioni potenzialmente pericolose dal punto di vista psicologico, fisico, legale? Se sì, descrivere la natura del rischio e le misure prese per tutelare la sicurezza degli sperimentatori coinvolti.

No.

4.5 È prevista una specifica polizza di assicurazione per responsabilità civile aggiuntiva a quella di Ateneo? Se sì, allegare il contratto di assicurazione in copia integrale.

No

4.6 C'è il rischio che i risultati dello studio si prestino a un duplice uso?

No, non è previsto che i risultati dello studio vengano utilizzati in modi diversi da quelli esplicitamente indicati.

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SEZIONE 5 - INFORMAZIONE E CONSENSO RELATIVI AL PROGETTO

5.1 Come verranno informati i partecipanti rispetto allo studio e alle procedure a cui verranno sottoposti?

Tramite il Modulo Informativo per la Richiesta di Consenso: (v. **Allegato H).** Tale modulo sarà consegnato ai partecipanti prima del loro coinvolgimento nel progetto. In particolare:

studenti: il modulo informativo verrà consegnato agli studenti che si mostreranno interessati a partecipare al progetto prima del colloquio finalizzato a verificare che sussistano le condizioni minime per la partecipazione al progetto (si veda punto 3.4).

anziani: il modulo informativo verrà consegnato agli anziani che si mostreranno interessati a partecipare al progetto prima del loro coinvolgimento nel progetto, cioè prima che abbiano l'opportunità di compilare il Questionario di Selezione (si veda punto 3.4).

- **Allegato H:** Foglio informativo per la richiesta di consenso

5.2 Come verrà acquisito e documentato il consenso alla partecipazione al Progetto?

Tramite la Dichiarazione di Consenso (v. **Allegato I)** che verrà consegnata ai partecipanti assieme al Modulo Informativo per la Richiesta di Consenso (vedi punto precedente) e dovrà essere debitamente compilata e firmata.

Allegato I: Dichiarazione di consenso

5.3 Tenuto conto che l'informazione va data a tutti i potenziali partecipanti, quali modalità saranno adottate per informare coloro che non possono esprimere il consenso (ad es. minori) e per acquisire il loro "assenso"?

Non sono previsti partecipanti minorenni.

5.4 Come saranno resi pubblici i risultati della ricerca?

I risultati della ricerca saranno resi pubblici attraverso articoli su riviste, presentazioni a congressi, e ogni altra modalità di scambio e divulgazione delle informazioni scientifiche ritenute idonee a giudizio dei ricercatori, garantendo sempre l'anonimato delle persone che hanno partecipato.

5.5 I partecipanti verranno informati sui risultati della ricerca? Se sì, quando e in che modo?

Non si prevede di informare direttamente i partecipanti sui risultati della ricerca. D'altra parte, i risultati della ricerca, disseminati secondo le modalità indicate in 5.4, saranno disponibili pubblicamente, in forma gratuita o a pagamento, e saranno quindi accessibili da parte di chiunque sia interessato.

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SEZIONE 6 - TRATTAMENTO DEI DATI PERSONALI

6.1 Selezionare la tipologia di dati trattati

X ☐ **Dati personali**

O **Dati identificativi**

X ☐ **Categorie particolari di dati (Dati particolari sensibili)**

O **Dati genetici**

O **Dati biometrici**

X O **Dati relativi alla salute (anche se in forma non dettagliata)**

☐ **Dati giudiziari**

☐ **Dati anonimi**

6.2 Modalità di raccolta dei dati personali:

X ☐ **Diretta** (si prega di specificare)

Nel caso di partecipanti anziani:
- tramite il Questionario di Selezione: **Allegato E.**

Per tutti i partecipanti:
- Tramite il dispositivo per la produzione di realtà aumentata denominato HoloLens. Dati sui gesti compiuti dall'utente con testa e mani vengono registrati dall'HoloLens, associati all'utente e inviati a un database. Per ulteriori dettagli sui tipi di dati acquisiti si veda **Allegato F.**
- Tramite registrazioni:
  - Dell'esperienza immersiva con l'HoloLens (video-registrazione)
  - Del focus group (audio-registrazione)

☐ **Indiretta** (si prega di specificare)

6.3 Se il progetto prevede il trattamento di dati particolari sensibili (ad es. dati relativi allo stato di salute), come verrà fornita ai partecipanti l'Informativa relativa al trattamento dei dati, e come verrà raccolto il loro consenso (ex art. 13 Reg. UE 2016/679)?

Tramite l'**Allegato J**, presentato prima del colloquio di selezione per la partecipazione al progetto (per gli studenti del DISI), o prima della somministrazione del Questionario di Selezione ((**Allegato E** - per partecipanti anziani).

Da notare che, nel caso degli studenti del DISI, vengono raccolti dei dati anagrafici (nome, età, titolo di studio, email di contatto), ma non viene raccolto alcun dato sulle loro condizioni psico-fisiche, e in sede di colloquio ci si limita solo ad accertare verbalmente che i candidati siano in possesso di quei requisiti fisici e motori necessari per poter utilizzare l'HoloLens.
Da notare inoltre che, nel caso dei partecipanti anziani, i dati sulle loro condizioni psico-fisiche, prelevati attraverso la somministrazione del Questionario di Selezione (**Allegato E**), hanno il solo scopo di identificare partecipanti che risultino adeguati a compiere i compiti richiesti durante il test previsto dal progetto. Il dispositivo denominato HoloLens utilizzato durante il test è pensato per utilizzatori senza particolari difficoltà motorie degli arti superiori e della testa; di conseguenza, le domande nella sezione *Salute* del Questionario hanno il solo scopo di verificare che i partecipanti siano in possesso di quei requisiti fisici e motori necessari

per poter utilizzare l'HoloLens. Una volta conclusa la selezione dei partecipanti, i dati sulla salute non verranno più utilizzati o elaborati in alcun modo.

- **Allegato J**: Informativa e modulo di consenso relativi al trattamento di dati particolari (art. 13 Reg. UE 679/2016)

6.4 Se il progetto prevede esclusivamente il trattamento di dati personali non particolari, come verrà fornita ai partecipanti l'Informativa relativa al trattamento dei dati (ex art. 13 Reg. UE 2016/679)?

6.5 In che modo saranno informati i partecipanti dell'eventualità che dalla ricerca, indipendentemente dagli obiettivi dello studio, possano emergere dati relativi alle loro condizioni psico-fisiche?

Non è previsto che i dati relativi alle condizioni psico-fisiche dei partecipanti possano essere utilizzati per scopi diversi da quelli definiti per il progetto (si veda punto 6.3). Nel caso risulti comunque necessario fornire ai partecipanti l'informazione richiesta dalla domanda, tale informazione potrà essere fornita prima della somministrazione del Questionario di Selezione (v. **Allegato E**).

6.6 Qualora, per la realizzazione dello studio, non fosse possibile informare i partecipanti prima dell'inizio della sperimentazione sull'obiettivo della stessa, specificare quali saranno le modalità e i tempi della successiva integrazione dell'informativa e della raccolta dell'eventuale consenso al trattamento dei dati personali.

Tutti i partecipanti che iniziano il test con l'HoloLens sono stati precedentemente selezionati e all'atto della selezione sono stati informati sulle finalità del progetto e sulle metodologie di sperimentazione. Di conseguenza, il caso ipotizzato dalla domanda non è contemplabile.

6.7 Qualora i dati siano raccolti presso terzi, oppure il trattamento riguardi dati raccolti per altri scopi, e il fornire l'informativa comporti uno sforzo sproporzionato, selezionare le forme di pubblicità di cui si prevede l'adozione e specificarne i relativi dettagli:

Non applicabile al progetto in questione

- O inserzione su almeno un quotidiano di larga diffusone nazionale o annuncio presso un'emittente radiotelevisiva a diffusione nazionale (per insiemi numerosi di soggetti distribuiti sull'intero territorio nazionale): ....
- O Inserzione su un quotidiano di larga diffusione regionale (o provinciale) o annuncio presso un'emittente radiotelevisiva a diffusione regionale (o provinciale) (per insiemi di soggetti distribuiti su un'area regionale o provinciale): ....
- O Inserzione in strumenti informativi di cui gli interessati sono normalmente destinatari (per insiemi di specifiche categorie di soggetti): ....
- O Altre idonee forme di pubblicità da comunicare preventivamente al Garante Privacy, il quale potrà, in ogni caso, prescrivere eventuali misure ed accorgimenti: ....

6.8 È prevista la diffusione dei dati personali (non in forma anonima e/o aggregata) e secondo quale modalità:

X ☐ No
☐ Sì
Se sì, specificare la modalità (Internet, strumenti multimediali, riviste scientifiche, convegni, banche dati, ecc.)

....

6.9 È prevista la comunicazione dei dati personali (in forma non anonima e/o non aggregata) e secondo quale modalità:

X ☐ No
☐ Sì
Se sì, specificare la modalità (Pubbliche Amministrazioni, partner di progetto, altri soggetti pubblici o privati, ecc.)

………

6.10 È previsto il trasferimento dei dati personali (in forma non anonima e/o non aggregata) extra UE e secondo quale modalità:

X ☐ No
☐ Sì

SEZIONE 7 - VALUTAZIONE E GESTIONE DEL RISCHIO, MISURE DI SICUREZZA E PERIODO DI CONSERVAZIONE DEI DATI

7.1 Il trattamento presenta rischi per i diritti e le libertà degli interessati?

X ☐ No
☐ Sì

Se sì, indicare il rischio specifico e le misure previste per affrontarlo

Il trattamento dei dati sarà limitato a soddisfare esclusivamente gli scopi del progetto. È quindi da escludersi un trattamento dei dati tale da permettere qualsiasi forma di profilatura dei partecipanti che violi o metta a rischio i diritti e le libertà dei partecipanti.

7.2 Indicare le specifiche misure tecniche ed organizzative che verranno adottate nel trattamento e nella conservazione dei dati

L'anonimato verrà garantito associando un codice a ogni partecipante. I dati e i codici identificativi verranno conservati su due dispositivi differenti, in modo da ostacolare il più possibile da parte di terzi l'associazione dei dati ai nominativi dei partecipanti. Inoltre, i dati saranno custoditi presso l'Università degli studi di Trento in un servizio di storage garantito dall'Ateneo. Tutti i dati, incluse le adioregistrazioni e videoregistrazioni, saranno anonimi e trattati in accordanza con lo statuto di protezione dei dati (v. **Allegato J**)

7.3 Per quanto tempo verranno conservati i dati raccolti nell'ambito del Progetto di ricerca (specificare l'eventuale conservazione dei dati oltre la realizzazione del Progetto)

Tutti i dati identificativi dei partecipanti e i codici identificativi associati ai dati verranno conservati solo per la durata del progetto e saranno elaborati e utilizzati solamente per le finalità del progetto. Al termine del progetto (Giugno 2020) tutti i dati identificativi e i codici identificativi associati ai dati saranno definitivamente cancellati.
I dati anonimi e/o anonimizzati saranno conservati per un tempo indeterminato oltre il termine del progetto. Da notare che le videoregistrazioni effettuate durante le esperienze immersive con l'HoloLens non permettono di risalire alle identità dei partecipanti, in quanto la schermatura data dal dispositivo indossato dai partecipanti è sufficiente ad anonimizzarli. Le videoregistrazioni sono quindi da intendersi come dati anonimi e come tali andranno trattati.

Da notare inoltre che anche le audioregistrazioni dei focus group sono da considerarsi come dati anonimi, in quanto tutti gli interventi verbali pronunciati dai partecipanti durante i focus group sono anonimi e non c'è alcun modo di associare quegli interventi verbali con le identità dei partecipanti.

7.4 Chi avrà accesso ai dati raccolti nel corso della ricerca?

Ruolo Privacy	Nominativo
Titolare del trattamento	Università degli Studi di Trento
Autorizzato al trattamento	i componenti del gruppo di ricerca: • Maurizio Marchese • Sergio Cicconi

NB. È necessario compilare la "*Dichiarazione di impegno a conformarsi alle disposizioni del Codice di deontologia e di buona condotta per i trattamenti di dati personali per scopi statistici e scientifici (Allegato 4 Codice Privacy)"* e depositarla firmata presso il Dipartimento/Centro di afferenza del responsabile del progetto.

Si veda **Allegato K**: *Dichiarazione di impegno a conformarsi alle disposizioni del Codice di deontologia…*

UNIVERSITÀ DEGLI STUDI
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Dipartimento di Ingegneria e Scienza dell'Informazione - DISI

DICHIARAZIONE DI RESPONSABILITÀ

Io sottoscritta/o MAURIZIO MARCHESE

responsabile del progetto:

"Augmented Learning: an E-Learning Environment in Augmented Reality for Older Adults"

DICHIARO

che le informazioni contenute nel presente documento sono accurate,

E MI IMPEGNO A

a. comunicare per iscritto la data di inizio e di conclusione della sperimentazione, come pure della sua eventuale sospensione anticipata con l'indicazione dei motivi;
b. condurre la sperimentazione secondo le modalità indicate;
c. non introdurre forme di incentivazione alla partecipazione che potrebbero limitare la libertà o l'autonomia decisionale e l'espressione del consenso;
d. informare per iscritto degli eventi avversi insorti nel corso dello studio e di ogni elemento che potrebbe influire sulla sicurezza dei partecipanti o sul proseguimento dello studio;
e. non introdurre variazioni al protocollo senza che il Comitato Etico per la sperimentazione con l'essere umano abbia espresso parere favorevole;
f. informare il Comitato Etico di qualunque modifica nella composizione del gruppo di ricerca, sia in caso di cessazione della collaborazione di uno o più componenti, sia in caso di inserimento di nuovi componenti;
g. ottemperare alle eventuali raccomandazioni richieste dal Comitato Etico per la sperimentazione con l'essere umano;
h. qualora il progetto implichi il trattamento di dati personali, garantire il rispetto della normativa vigente e depositare copia della presente documentazione (insieme alla *Dichiarazione di Impegno di cui all'Allegato 4 Codice Privacy*) presso la struttura di afferenza;
i. inviare al Comitato Etico per la sperimentazione con l'essere umano, alla fine della ricerca, un rapporto sullo studio completato.

Data 25 giugno 2019

Firma del Responsabile del Progetto

Maurizio Marchese pagina 28 di 61

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Dipartimento di Ingegneria e Scienza dell'Informazione - DISI

ALLEGATI PROGETTO:

"Augmented Learning: an E-Learning Environment in Augmented Reality for Older Adults"

Contenuti

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Dipartimento di Ingegneria e Scienza dell'Informazione - DISI

ALLEGATO A: CURRICULUM VITAE

Responsabile del progetto

Maurizio Marchese (DISI, UNITN, maurizio.marchese@unitn.it)

He is associate professor of Computer Science at the University of Trento in the Department of Information Engineering and Computer Science (DISI). He has been working in the field of web engineering and service-oriented architectures for over ten years. He is author of over 100 publications, and has taken part to FP7 and H2020 projects as coordinator and participant; he has been Director of DISI, Director of Education in the European Institute of Technology EIT Digital initiative for the Trento node. Currently, he is Vice Rector for International Relationships. His main research interests are in social informatics: how information systems can realize social goals, apply social concepts, and become sources of information relevant for social sciences and for analysis of social phenomena.

Ricercatori coinvolti

Sergio Cicconi (DISI, UNITN sergio.cicconi@unitn.it)

Cicconi holds a degree in Philosophy and a Master in English Literature and is currently a Ph.D student in Information and Communication Technology at the Department of Computer Science and Information Engineering at the University of Trento. He works on E-learning and New Technologies and is focusing his research on the social and cultural use of augmented reality. He collaborates with the Interactive Media Design Lab at the Nara Institute of Science and Technology (NAIST), Japan, thanks to the cooperation between NAIST and the University of Trento, and to a TEAM mobility scholarship in the framework of the ErasmusMundus program, "Technologies for information and communication Europe-east Asia Mobilities".

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Dipartimento di Ingegneria e Scienza dell'Informazione - DISI

ALLEGATO B: DICHIARAZIONE RESPONSABILITÀ

Dichiarazione disponibilità di tempo, strutture e personale

Trento, 25 giugno 2019

Il sottoscritto, **Maurizio Marchese** responsabile del progetto di ricerca:

"Augmented Learning: an E-Learning Environment in Augmented Reality for Older Adults"

DICHIARA

Di poter svolgere le proprie ricerche avendo a disposizione attrezzature, strutture e personale idonei, nonché disponibilità di tempo adeguata per condurre la sperimentazione oggetto del progetto di ricerca.

Prof. Maurizio Marchese

responsabile del progetto di ricerca

Direttore del Dipartimento

UNIVERSITÀ DEGLI STUDI
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Dipartimento di Ingegneria e Scienza dell'Informazione - DISI

ALLEGATO C: CONFLITTI DI INTERESSE

Dichiarazione di assenza di conflitti di interesse

Trento, 25 giugno 2019

Il sottoscritto, **Maurizio Marchese** responsabile del progetto di ricerca:

"Augmented Learning: an E-Learning Environment in Augmented Reality for Older Adults"

DICHIARA

che il responsabile del progetto e i componenti del gruppo di ricerca nonché i rispettivi familiari non hanno interessi specifici in rapporto all'esito dello studio al di là di quelli normalmente legati alla buona riuscita scientifica di un progetto di ricerca.

Prof. Maurizio Marchese

responsabile del progetto di ricerca

UNIVERSITÀ DEGLI STUDI
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Dipartimento di Ingegneria e Scienza dell'Informazione - DISI

ALLEGATO D1:
INVITO ALLA PARTECIPAZIONE AL PROGETTO (STUDENTI)

[testo per locandina]

E-LEARNING IN REALTÀ AUMENTATA
AUGMENTED LEARNING FOR OLDER ADULTS

CERCHIAMO

studenti del DISI

iscritti ai programmi di Master o Dottorato,

interessati a **provare l'HoloLens** di Microsoft

per immergersi in un

AMBIENTE DI E-LEARNING in **REALTÀ AUMENTATA**

Augmented Leaning for Older Adults è un progetto di ricerca che nasce nel Dipartimento di Ingegneria e scienze dell'Informazione dell'Università degli Studi di Trento con lo scopo di realizzare un ambiente di e-learning in realtà aumentata capace di far conoscere le nuove tecnologie (computer, internet, ecc.) agli anziani e favorire così la loro integrazione sociale nel mondo digitale.

Cerchiamo studenti per raccogliere dati sull'uso di ambienti immersivi in realtà aumentata e sull'utilizzo dell'HoloLens. L'esperienza immersiva in realtà aumentata è anonima*, semplice e divertente e non richiede alcuna conoscenza o competenza particolare.

Per partecipare all'esperienza immersiva o avere ulteriori informazioni scrivete a: sergio.cicconi@unitn.it

* tutti i dati acquisiti durante l'uso dell'HoloLens saranno tutelati nel pieno rispetto della privacy secondo le linee guida del RGPD (Regolamento UE 2016/679)

Maurizio Marchese pagina 33 di 61

UNIVERSITÀ DEGLI STUDI DI TRENTO

Dipartimento di Ingegneria e Scienza dell'Informazione - DISI

ALLEGATO D2:
INVITO ALLA PARTECIPAZIONE AL PROGETTO (ANZIANI)

[testo per locandina]

E-LEARNING IN REALTÀ AUMENTATA

AUGMENTED LEARNING FOR OLDER ADULTS

CERCHIAMO
Donne e uomini
Di età compresa tra i 65 e gli 80 anni
Curiosi di provare una nuova e divertente tecnologia
chiamata **REALTÀ AUMENTATA** che permette di arricchire la normale realtà percepita dai nostri sensi con suoni e immagini virtuali costruite da un computer.

Augmented Leaning for Older Adults è un progetto di ricerca che nasce nel Dipartimento di Ingegneria e scienze dell'Informazione dell'Università degli Studi di Trento con lo scopo di realizzare un innovativo strumento di apprendimento capace di far conoscere le nuove tecnologie (computer, internet, ecc.) agli anziani e favorire così la loro integrazione sociale nel mondo digitale.

L'esperienza in realtà aumentata è anonima*, semplice e divertente; non richiede alcuna conoscenza o competenza particolare e non comporta alcun rischio per la salute.

Per partecipare all'esperienza immersiva o avere ulteriori informazioni potete contattare il nostro ricercatore: Sergio Cicconi - email: sergio.cicconi@unitn.it - tel: 334 6024393).

* tutti i dati acquisiti durante l'esperienza con la realtà aumentata saranno tutelati nel pieno rispetto della privacy secondo le linee guida del RGPD (Regolamento UE 2016/679)

UNIVERSITÀ DEGLI STUDI
DI TRENTO

Dipartimento di Ingegneria e Scienza dell'Informazione - DISI

ALLEGATO E: QUESTIONARIO DI SELEZIONE

Progetto: "Augmented learning:
an e-learning environment in augmented reality for older adults"

Augmented learning è un progetto di ricerca sviluppato nel Dipartimento di Ingegneria e Scienze dell'Informazione dell'Università degli Studi di Trento.
Le risposte a questo questionario ci aiuteranno a perfezionare un ambiente di apprendimento virtuale capace di introdurre gli anziani all'utilizzo delle nuove tecnologie (computer, internet, ecc.) e favorire la loro integrazione sociale.

Per tale motivo confidiamo nella sua partecipazione e la ringraziamo anticipatamente.

Il questionario è composto da circa 50 domande e la compilazione richiederà circa 25-30 minuti.

La ringrazio anticipatamente per la sua preziosa disponibilità.

Sergio Cicconi

Per qualsiasi dubbio può scrivermi a:
sergio.cicconi@unitn.it

UNIVERSITÀ DEGLI STUDI
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Dipartimento di Ingegneria e Scienza dell'Informazione - DISI

ISTRUZIONI PER COMPLETARE IL QUESTIONARIO

Le domande che troverai in questo questionario sono disponibili in tre diversi formati:

1) RISPOSTA BREVE LIBERA:

dopo la domanda troverai uno **SPAZIO VUOTO** (Come nella domanda n.1):

ESEMPIO: Qual è il tuo nome? ________________________________

In questo caso, scrivi la tua risposta nello spazio vuoto.

2) UNA SOLA RISPOSTA:

dopo la domanda troverai diverse risposte possibili, ognuna preceduta da un **CERCHIO = o** (Come nella domanda n.2):

ESEMPIO: Sei uomo o donna? (una sola risposta)
- o Uomo
- o Donna

In questo caso, contrassegna **SOLO** il **cerchio** che corrisponde alla tua scelta.

3) RISPOSTA MULTIPLA:
dopo la domanda troverai diverse risposte possibili, ognuna preceduta da un **QUADRATO =** □ (Come nella domanda n. 20)

ESEMPIO: Normalmente usi gli occhiali? (risposta multipla)
- □ Per leggere
- □ Per vedere a distanza
- □ Non uso occhiali

In questo caso, puoi contrassegnare **UNO O PIÙ quadrati** che corrispondono alle tue scelte.

Per favore, prova a rispondere a tutte le domande. Questo non è un test, quindi non ci sono risposte giuste o sbagliate.

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DEMOGRAFIA

1. **Come ti chiami?** ____

2. **Sei uomo o donna? (una sola risposta)**
   - ○ Uomo
   - ○ Donna

3. **Quanti anni hai?** ____________

4. **Qual è il tuo livello di istruzione? (risposta multipla)**
   - ☐ Scuola elementare
   - ☐ Scuola media
   - ☐ Istruzione superiore
   - ☐ Altro (laurea, specializzazione, ecc.):____________________________________

5. **Se hai selezionato "Istruzione superiore" nella tua risposta precedente, specifica il tipo di diploma:**

   ____

6. **Qual è stata la tua attività lavorativa principale?**

   ____

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SALUTE

7. In generale, diresti che la tua salute è:
(una sola risposta)
Non buona (1) (2) (3) (4) (5) Eccellente

8. Hai problemi di salute che ti causano difficoltà a muoverti e fare le cose per te?
(una sola risposta)
sì (1) (2) (3) (4) (5) No

9. Puoi afferrare oggetti (un barattolo, il rubinetto del lavandino)?
(una sola risposta)
Sono molto limitato (1) (2) (3) (4) (5) Non sono limitato affatto

10. Riesci a tenere oggetti (un libro, il telecomando del televisore, una tazza)?
(una sola risposta)
Sono molto limitato (1) (2) (3) (4) (5) Non sono limitato affatto

11. Puoi torcere le mani (per aprire un barattolo, girare una maniglia, o guardare l'orologio)
(una sola risposta)
Sono molto limitato (1) (2) (3) (4) (5) Non sono limitato affatto

12. Puoi stringere/ prendere / afferrare piccoli oggetti (una carta di gioco, un foglio di carta, una penna, una moneta, i lacci delle scarpe)?
(una sola risposta)
Sono molto limitato (1) (2) (3) (4) (5) Non sono limitato affatto

13. Puoi spremere un'arancia, o spingere un pulsante del telecomando?
(una sola risposta)
Sono molto limitato (1) (2) (3) (4) (5) Non sono limitato affatto

14. Puoi spostare oggetti (come il tuo piatto, una sedia, i tuoi vestiti)?
(una sola risposta)
Sono molto limitato (1) (2) (3) (4) (5) Non sono limitato affatto

15. Puoi coordinare i movimenti delle dita (come quando si tengono le posate o si scrive con una penna)?
(una sola risposta)
Sono molto limitato (1) (2) (3) (4) (5) Non sono limitato affatto

16. Puoi alzare le braccia (per lavarti la faccia, mettere gli occhiali o un cappello, o bere da un bicchiere)?
(una sola risposta)
Sono molto limitato (1) (2) (3) (4) (5) Non sono limitato affatto

17. Puoi girare la testa (senza muovere le spalle) sul lato sinistro / destro?
(una sola risposta)
Sono molto limitato (1) (2) (3) (4) (5) Non sono limitato affatto

18. Puoi muovere la testa in alto o in basso (come se guardassi il cielo, o i tuoi piedi)?
(una sola risposta)
Sono molto limitato (1) (2) (3) (4) (5) Non sono limitato affatto

19. Hai problemi come tremori (con la testa o le mani) che rendono più difficile svolgere compiti come leggere o scrivere o afferrare piccoli oggetti?
(una sola risposta)
Sono molto limitato (1) (2) (3) (4) (5) Non sono limitato affatto

20. Normalmente usi gli occhiali?
(risposta multipla)
- ☐ Per leggere
- ☐ Per vedere a distanza
- ☐ Non uso occhiali

21. Com'è la tua vista [con gli occhiali]?
(una sola risposta)
Non buona (1) (2) (3) (4) (5) Eccellente

22. Attualmente usi un apparecchio acustico?
(una sola risposta)
- ○ No
- ○ Si

23. Com'è il tuo udito [con apparecchi acustici]?
(una sola risposta)
Non buona (1) (2) (3) (4) (5) Eccellente

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VITA DIGITALE

24. Usi un computer (desktop o portatile)?
(una sola risposta)
Mai (1) (2) (3) (4) (5) Molto spesso

25. Usi un Tablet / iPad?
(una sola risposta)
Mai (1) (2) (3) (4) (5) Molto spesso

26. Usi un telefono cellulare o uno smartphone?
(una sola risposta)
Mai (1) (2) (3) (4) (5) Molto spesso

27. Usi un "lettore di e-book" (come Amazon Kindle, Kobo, ecc.)?
(una sola risposta)
Mai (1) (2) (3) (4) (5) Molto spesso

28. Se utilizzi uno o più dei dispositivi sopra elencati (computer / tablet / telefono cellulare / lettore di e-book), puoi per favore spiegare in che modo hai acquisito la conoscenza necessaria per usarli
(risposta multipla)
- ☐ Non uso nessuno dei dispositivi sopra elencati
- ☐ Sono autodidatta
- ☐ Ho seguito corsi
- ☐ Ho usato i computer nel mio lavoro
- ☐ Altro: _____________

29. Se utilizzi uno o più dei dispositivi sopra elencati (computer / tablet / telefono cellulare), indica per che tipo di attività li usi
(risposta multipla)
- ☐ Non uso nessuno dei dispositivi sopra elencati
- ☐ per leggere (giornali, riviste, romanzi, ecc.)
- ☐ per scrivere (email, diario, social media, ecc.)
- ☐ per organizzare le foto (scattare foto, organizzarle in album, ecc.)
- ☐ per ascoltare la musica
- ☐ per guardare video / film
- ☐ Altro: _______________

30. Usi Internet o l'hai usato in passato?
(una sola risposta)
Mai (1) (2) (3) (4) (5) Molto spesso

31. Quale dei seguenti dispositivi usi per accedere a Internet?
(risposta multipla)
- ☐ Non uso Internet
- ☐ Computer (desktop o portatile)
- ☐ Tablet / iPad
- ☐ telefono cellulare, smart phone
- ☐ Altro: ______________

32. Per quale dei seguenti scopi usi Internet?
(risposta multipla)
- ☐ Non uso Internet
- ☐ per contattare famiglia e amici tramite programmi di messaggistica istantanea (Skype, Whatsapp, Messenger, Line...)
- ☐ per inviare e ricevere e-mail
- ☐ per ascoltare musica
- ☐ per guardare video e film
- ☐ per creare contenuti digitali (come testi, immagini, album fotografici, presentazioni, ecc.) e caricarli nel Web e nei servizi cloud (come Google Drive, Dropbox, ecc.)
- ☐ per leggere giornali, riviste, romanzi, ecc.
- ☐ per cercare informazioni relative ai miei interessi
- ☐ per accedere ai servizi pubblici (salute, amministrazione, ufficio delle imposte, assicurazioni, altri)
- ☐ per effettuare acquisti on-line (come comprare libri, cibo, vestiti, elettronica, ecc.)
- ☐ Altro: ___________________

33. Usi uno dei seguenti social media?
(risposta multipla)
- ☐ Non uso Internet
- ☐ Uso Internet, ma non utilizzo i social media
- ☐ Facebook
- ☐ Twitter
- ☐ LinkedIn
- ☐ Instagram
- ☐ WhatsApp
- ☐ Altro: ________________

34. **Se utilizzi i social media, puoi spiegare che tipo di interazione hai con altri utenti (ad esempio, collaborazione su un progetto, scambio di opinioni, ricerca di nuove amicizie, discussione su un argomento, consigli su musica o film, ecc.)?**

____

____

35. Hai mai sentito parlare di REALTA' AUMENTATA?
- ○ No
- ○ SI

36. **Se hai risposto SI alla precedente domanda, sapresti dare una breve definizione di REALTA' AUMENTATA?**
(usa qualsiasi parola ti sembri appropriata e non preoccuparti se non conosci termini tecnici)

____

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ATTITUDINI E MOTIVAZIONI

37. Quali sono i tuoi interessi o hobby?
(risposta multipla)
- ☐ lettura
- ☐ escursioni o passeggiate
- ☐ andare in palestra
- ☐ andare a ballare
- ☐ andare al karaoke
- ☐ scrivere (storie, diari, poesie, ecc.)
- ☐ guardare programmi televisivi e film
- ☐ ascoltare o suonare musica
- ☐ cucinare
- ☐ lavorare a maglia
- ☐ viaggiare
- ☐ guardare lo sport (calcio, ciclismo, pallavolo, pallacanestro, formula 1, ecc.)
- ☐ Altro:__________________

38. Le tecnologie stanno cambiando il nostro mondo. Pensi che questo sia positivo o negativo?
(una sola risposta)
Molto negativo (1) (2) (3) (4) (5) Molto positivo

39. Puoi spiegare brevemente la tua risposta precedente?

____

____

40. Ti interessano le tecnologie in generale (come le tendenze tecnologiche, le nuove scoperte tecnologiche, la storia della tecnologia, le apparecchiature elettroniche, ecc.)?
(una sola risposta)
Non mi interessa (1) (2) (3) (4) (5) sono molto interessato

41. Ti interessa saper usare il computer, i dispositivi portatili e Internet?
(una sola risposta)
Non mi interessa (1) (2) (3) (4) (5) sono molto interessato

42. Pensi che imparare a usare il computer, i dispositivi portatili e Internet possa cambiare la tua vita quotidiana?
(una sola risposta)
No, la mia vita quotidiana sarebbe la stessa (1) (2) (3) (4) (5) Sì, la mia vita quotidiana cambierebbe molto

43. Puoi spiegare brevemente la tua risposta precedente (perché non ci sarebbero cambiamenti nella tua vita? O quali sarebbero i cambiamenti?)

____

____

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44. Ti piacerebbe seguire un corso su come utilizzare il computer, i dispositivi portatili e Internet?
(una sola risposta)
- ○ No
- ○ Si

45. Se hai risposto "No" alla domanda 44, quali sono le ragioni per non voler seguire un corso su come utilizzare il computer e Internet?
(risposta multipla)
- □ Non mi piacciono i computer e la tecnologia in generale
- □ Penso che i computer siano pericolosi
- □ Penso che Internet sia pericoloso
- □ Non mi interessa il computer e la tecnologia
- □ i computer mi fanno sentire ansioso
- □ Ho paura dei computer
- □ Penso che i computer siano troppo difficili da usare
- □ So che non posso imparare nuove cose
- □ So che non posso imparare a usare il computer
- □ Altro: _______________

46. Se hai risposto "Sì" alla domanda 44, perché vorresti seguire un corso su come utilizzare un computer e Internet?
(risposta multipla)
- □ Per tenermi occupato
- □ solo per essere coinvolto in qualcosa di nuovo
- □ per mantenere la mia mente attiva
- □ perché sono interessato a imparare cose nuove
- □ perché voglio tenermi aggiornato e adattarmi ai nuovi tempi
- □ perché sono interessato alla tecnologia e ai computer
- □ perché ho uno strumento in più per rimanere in contatto con i miei familiari e i miei amici
- □ perché ho la possibilità di fare nuove conoscenze
- □ perché posso trovare musica e film che mi piacciono
- □ Altro: __________________

47. Se ti venisse chiesto di indossare, per alcuni minuti e in un ambiente sicuro, degli occhiali da sci simili a quelli che vedi in foto...
(una sola risposta)

li indosserei senza problemi (1) (2) (3) (4) (5) non li indosserei

48. Puoi spiegare la tua risposta?

____

____

49. Se ti venisse chiesto di indossare, per pochi minuti e in un ambiente sicuro, un nuovo dispositivo tecnologico che assomiglia un po' agli occhiali da sci (vedi figura) e permette di arricchire la normale realtà percepita dai nostri sensi con suoni e immagini virtuali costruite da un computer (una sola risposta)

li indosserei senza problemi (1) (2) (3) (4) (5) non li indosserei

50. Per favore, spiega la tua risposta.

____

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CONCLUSIONE

Hai completato il questionario. Grazie mille per la tua pazienza e il tuo aiuto!

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ALLEGATO F1:
DESCRIPTION OF THE IMMERSIVE EXPERIENCE WITH THE MICROSOFT HOLOLENS

The different sections of the Learning Environment will be developed according to the following description:

Section	Introduction
Holograms in scene	Elektra, help panel, navigation menu
What is analyzed	
Data acquired	
Description	Elektra introduces the Learning Environment and the tools for help and navigation. Explains what to do during the test.
Purpose	To introduce the user to the Learning Environment

Section	Exercise 1
Holograms in scene	spherical holograms in random position
What is analyzed	head movement: - use of the head-pointer
Data acquired	• user behavior (with video) • total duration of the exercise • type of gesture performed • times between gestures
Description	6 holograms (same size, spherical shape) are presented to the user in random positions (but in an area in front of the user, so as to avoid large rotations of the user's head). The user must move her head to place the pointer/dot onto the hologram. On a positive hit, the hologram disappears and a new hologram appears in a different position
Purpose	• to train the user to use her head to point at holograms • find out average time it takes to perform the "POINT AT HOLOGRAMS" gesture

Section	Exercise 2
Holograms in scene	spherical holograms in random position
What is analyzed	• head movement: - use of the head-pointer • gesture: - 1 hand - click
Data acquired	• user behavior (with video) • total duration of the exercise • type of gesture performed • times between gestures
Description	6 Holograms (same size, spherical shape) are presented to the user in random positions (but in an area in front of the user, so as to avoid large rotations of the user's head). The user must move her head to place the pointer/dot onto the hologram and then use the click gesture to move to the next hologram. On a positive hit, the hologram disappears and a new holograms appears in a different position
Purpose	• to train the user to use her head to point at holograms and then to click on holograms • to find out the average time it takes to perform the "CLICK" gesture

Section	Exercise 3
Holograms in scene	floating panels with squares or circles inside
What is analyzed	• head movement: - use of the head-pointer • gesture: - 1 hand - click
Data acquired	• user behavior (with video) • total duration of the exercise • type of gesture performed • times between gestures
Description	4 Panels are presented to the user at a fixed distance (2 meters). Each panel contains one squared or a circular shape. The user must move her head and place the pointer/dot on the square/circle. Each square/circle has a different size, from big to small.
Purpose	to find out the smallest square/circle that can be pointed at and then clicked. [Squares and circles are used to create BUTTONS and CHECK BOXES, used in quizzes and forms, and are also used to allow the user to have some forms of interaction with holograms, so it is important to identify the smallest square/circle that the user is able to manage]. It is expected that times of response increase as the box/circle size decreases. Also, by analyzing the average times necessary to perform the 2 gestures (head, 1 hand) and other info (from video) on the user's behavior, we can gain further info on training sessions and we might also be able to answer questions such as: Did the user learn the 2 gestures presented in the previous exercises? Was the number of holograms presented in the previous exercises enough to train the user on the gestures?, Does the user need a larger number of examples to learn and manage one gesture? etc.)

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Section	Exercise 4
Holograms in scene	floating panels with textual info
What is analyzed	• head movement: - use of the head-pointer • gesture: - 1 hand - click
Data acquired	• user behavior (with video) • total duration of the exercise • type of gesture performed • times between gestures
Description	3 Panels are presented to the user at a fixed distance (2 meters). Each panel contains 2-3 YES/NO questions. Questions do not require knowledge of any sort, and are based on facts known to the user (i.e. Do you like driving the car? Have you ever been to CITY? Do you prefer meat, fish, or vegetables?). The font size is different for each panel, from big to small. To select one answer, the user must move her head to place the pointer onto one (large) square/circle next to the answer and click on it
Purpose	• to find out the smallest font that can be easily read by the user. [It is expected that times of response increase as the font size decreases and becomes more difficult to read the questions and the answers.] • Info on training (see previous section)

Section	Exercise 5
Holograms in scene	Holograms that can be moved
What is analyzed	• head movement: - use of the head-pointer • gesture: - 1 hand - hold and move
Data acquired	• user behavior (with video) • total duration of the exercise • type of gesture performed • times between gestures • duration of hold/move gesture
Description	2 holograms in different positions and with different sizes (large, small) are presented, one at the time. The user must point at the hologram with her head, click and hold and then move the hologram from the actual position onto a table (an hologram) in front of the user.
Purpose	• to train the user to the CLICK & HOLD + MOVE gesture with 1 hand (necessary to move holograms around). • find out average time it takes to perform the "click and hold" gesture • find out the average time of a "hold" gesture

Section	Exercise 6
Holograms in scene	Holograms that ca be resized
What is analyzed	• head movement: - use of the head-pointer • gesture: - 2 hands - hold and resize
Data acquired	• user behavior (with video) • total duration of the exercise • type of gesture performed • times between gestures • duration of hold/resize gesture
Description	2 holograms in different positions and with different dimensions (large, small) are presented, one at the time. The user must point at the hologram with her head, click and hold with two hands and then resize the hologram (smaller, bigger).
Purpose	• to train the user to the CLICK & HOLD + RESIZE gesture with 2 hands (necessary to resize holograms). • Info on training (see previous section)

Section	Exercise 7
Holograms in scene	Holograms that ca be rotated
What is analyzed	• head movement: - use of the head-pointer • gesture: - 2 hands - hold and rotate
Data acquired	• user behavior (with video) • total duration of the exercise • type of gesture performed • times between gestures • duration of hold/rotate gesture
Description	2 holograms in different positions and with different dimensions (large, small) are presented, one at the time. The user must point at the hologram with her head, click and hold with two hands and then rotate the hologram (left, right).
Purpose	• to train the user to the CLICK & HOLD + ROTATE gesture with 2 hands (necessary to rotate holograms). • Info on training (see previous section)

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ALLEGATO F2:
USE QUESTIONNAIRE: USEFULNESS, SATISFACTION, AND EASE OF USE

Please rate your agreement with these statements.

- Try to respond to all the items.
- For items that are not applicable, use: **NA**
- Add a comment about an item by clicking on its icon, or add comment fields for all items by clicking on **Comment All**.

USEFULNESS		**1**	**2**	**3**	**4**	**5**	**6**	**7**		**NA**
1. It helps me be more effective.	strongly disagree								strongly agree	
2. It helps me be more productive.	strongly disagree								strongly agree	
3. It is useful.	strongly disagree								strongly agree	
4. It gives me more control over the activities in my life.	strongly disagree								strongly agree	
5. It makes the things I want to accomplish easier to get done.	strongly disagree								strongly agree	
6. It saves me time when I use it.	strongly disagree								strongly agree	
7. It meets my needs.	strongly disagree								strongly agree	
8. It does everything I would expect it to do.	strongly disagree								strongly agree	
EASE OF USE		**1**	**2**	**3**	**4**	**5**	**6**	**7**		**NA**
9. It is easy to use.	strongly disagree								strongly agree	
10. It is simple to use.	strongly disagree								strongly agree	
11. It is user friendly.	strongly disagree								strongly agree	
12. It requires the fewest steps possible to accomplish what I want to do with it.	strongly disagree								strongly agree	
13. It is flexible.	strongly disagree								strongly agree	
14. Using it is effortless.	strongly disagree								strongly agree	
15. I can use it without written instructions.	strongly disagree								strongly agree	
16. I don't notice any inconsistencies as I use it.	strongly disagree								strongly agree	
17. Both occasional and regular users would like it.	strongly disagree								strongly agree	
18. I can recover from mistakes quickly and easily.	strongly disagree								strongly agree	
19. I can use it successfully every time.	strongly disagree								strongly agree	
EASE OF LEARNING		**1**	**2**	**3**	**4**	**5**	**6**	**7**		**NA**
20. I learned to use it quickly.	strongly disagree								strongly agree	
21. I easily remember how to use it.	strongly disagree								strongly agree	
22. It is easy to learn to use it.	strongly disagree								strongly agree	
23. I quickly became skillful with it.	strongly disagree								strongly agree	
SATISFACTION		**1**	**2**	**3**	**4**	**5**	**6**	**7**		**NA**
24. I am satisfied with it.	strongly disagree								strongly agree	
25. I would recommend it to a friend.	strongly disagree								strongly agree	
26. It is fun to use.	strongly disagree								strongly agree	
27. It works the way I want it to work.	strongly disagree								strongly agree	
28. It is wonderful.	strongly disagree								strongly agree	
29. I feel I need to have it.	strongly disagree								strongly agree	
30. It is pleasant to use.	strongly disagree								strongly agree	
		1	**2**	**3**	**4**	**5**	**6**	**7**		**NA**

List the most **negative** aspect(s):

1.
2.
3.

List the most **positive** aspect(s):

1.
2.
3.

Based on: Lund, A.M. (2001) *Measuring Usability with the USE Questionnaire.* STC Usability SIG Newsletter, 8.2

Maurizio Marchese

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Dipartimento di Ingegneria e Scienza dell'Informazione - DISI

ALLEGATO G: TRACCIA FOCUS GROUP

INTRODUZIONE AL FOCUS GROUP

Breve presentazione degli obiettivi del focus group (parlare assieme dell'esperienza immersiva in realtà aumentata con il dispositivo HoloLens).
Spiegare la dinamica dell'incontro (ciascun partecipante è libero di esprimere le proprie opinioni, lasciando però anche agli altri la possibilità di parlare; chiarire che non si sta effettuando un test e che non ci sono risposte giuste/sbagliate, ecc.)
Segue breve giro di presentazione dei partecipanti.

INIZIO DELLA DISCUSSIONE

Ricostruzione delle aspettative

1. Prima di fare questa esperienza con l'HoloLens, che cosa vi aspettavate?

Verifica della comprensione

2. Dopo aver fatto questa esperienza, secondo voi che cos'è la realtà aumentata?
3. E gli ologrammi che avete visto? Cosa sono, secondo voi?
4. Se doveste raccontare la vostra esperienza a qualcuno che non sa nulla di realtà aumentata e ologrammi, e non conosce l'HoloLens, che cosa direste?

Restituzione dell'esperienza

5. Potete raccontare l'esperienza che avete avuto con l'HoloLens?
   a. Che cosa avete fatto?
   b. Come avete trovato gli esercizi? (facili, difficili, ecc.)
   c. Che effetto vi ha fatto interagire con gli ologrammi?
   d. Quali sensazioni avete avuto durante l'esperienza?
   e. Come vi siete sentiti dal punto di vista emotivo? (Imbarazzati, incuriositi, a proprio agio, infastiditi, annoiati, spaventati, ecc.)
   f. Potete spiegare le ragioni per queste vostre emozioni?
   g. Che effetto vi ha fatto vedere Elektra e seguire le sue indicazioni?
   h. Durante l'esperienza immersiva, avevate consapevolezza del mondo esterno?

Valutazione dell'esperienza

6. Cosa vi è piaciuto in particolare di questa esperienza? [eventuale ranking: cosa al primo posto?, ecc.]
7. Cosa NON vi è piaciuto [capire la motivazione: perché era difficile, poco chiara, faticosa, noiosa, ecc.]
8. Secondo voi la realtà aumentata è utile? Divertente? Altro?
9. Vi piacerebbe fare una nuova esperienza con la realtà aumentata, però con diversi contenuti? (quali?)

Raccolta dei suggerimenti

10. Quali miglioramenti introdurreste nell'esperienza immersiva per renderla più gradita? (più facilità d'uso, più grafica, più azione, più musica, più video, meno complicata, ecc.)
11. Ci sono altri consigli o indicazioni che vi sentite di dare a chi ha realizzato l'esperienza immersiva che avete fatto?

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ALLEGATO H: MODULO INFORMATIVO PER LA RICHIESTA DI CONSENSO

FOGLIO INFORMATIVO PER LA RICHIESTA DI CONSENSO
Titolo dello studio:
"Augmented learning: an e-learning environment in augmented reality for older adults"

Dipartimento di Ingegneria e Scienze dell'Informazione (DISI)
Via Sommarive, 9 38123 Povo (TN)

Titolo della ricerca: "Augmented learning: an e-learning environment in augmented reality for older adults"

Descrizione degli scopi della ricerca
Questa ricerca ha lo scopo di progettare e sviluppare una forma innovativa di e-learning, specificatamente progettata per gli anziani e facilmente accessibile agli anziani senza alcuna precedente conoscenza della tecnologia, che potrebbe fornire un contributo per ridurre l'analfabetismo tecnologico negli anziani e favorire la loro integrazione nella società digitale. A tal fine, verrà utilizzata la tecnologia disponibile nel campo della realtà aumentata, in modo che l'ambiente di apprendimento sia un ambiente immersivo, tridimensionale e completamente interattivo, e in grado di fornire agli anziani conoscenze su alcune tecnologie di base e su alcuni strumenti digitali.

Descrizione della procedura sperimentale

*In caso di **questionari autosomministrati***
[da sottoporre ai potenziali partecipanti che compilano il Questionario di Selezione (solo se con età = 65+) e a tutti i partecipanti che compilano il questionario di usability e user experience.]
Le verrà presentato un questionario, con semplici domande cui lei dovrà rispondere autonomamente in modo sincero, veloce e senza particolare sforzo. Il questionario non è un test, quindi non ci saranno risposte giuste o sbagliate.

*In caso di **partecipazione al test immersivo con l'HoloLens***
Le verrà chiesto di indossare in testa un dispositivo come quello che può vedere in questa foto:

Il dispositivo che vede nell'immagine, chiamato HoloLens, le permetterà di percepire degli oggetti virtuali, chiamati ologrammi, che sono creati dal dispositivo stesso e vengono mostrati nelle lenti davanti ai suoi occhi. Guardando il mondo attorno a lei attraverso le lenti, lei vedrà gli ologrammi mescolarsi con gli oggetti del mondo reale.
Durante il test, le verrà chiesto di compiere dei semplici movimenti con la testa o con le dita di una o due mani così da interagire con gli ologrammi. Le basterà seguire le indicazioni per procedere con i diversi esercizi che compongono il test.
Ci sembra utile spiegare che i monitor trasparenti dell'HoloLens che, come può vedere nella foto, sono posizionati davanti agli occhi dell'utilizzatore, non sono mai in contatto con gli occhi stessi (infatti, anche chi indossa occhiali può utilizzare il dispositivo senza problemi mantenendo gli occhiali) e non espongono mai gli occhi a luci di intensità tale da potersi considerare in alcun modo pericolose. Inoltre, i dispositivi audio (mini-

altoparlanti) posizionati all'altezza delle orecchie dell'utilizzatore non emettono mai suoni a un volume di intensità tale da potersi considerare in alcun modo pericolosi. Infine, la realtà aumentata non induce negli utilizzatori quelle sensazioni di nausea o vertigine che si possono manifestare invece con un'altra simile tecnologia chiamata realtà virtuale. L'esperienza con l'HoloLens è da considerarsi quindi sicura, cioè non espone in alcun modo gli utilizzatori a situazioni potenzialmente pericolose dal punto di vista fisico, psicologico, sociale.
Le ricordiamo comunque che nel caso lei decida, in qualsiasi momento e per qualsiasi motivo, di interrompere il test con l'HoloLens, potrà avvalersi dell'aiuto della persona che l'assiste per rimuovere l'HoloLens, e sarà libero di terminare immediatamente il test senza che le venga richiesto di fornire alcuna spiegazione o giustificazione.
Con il suo permesso, la sua esperienza con l'HoloLens verrà video-registrata a singolo uso dei ricercatori coinvolti nella ricerca. Da notare comunque che l'HoloLens copre parte del viso (fronte, occhi, naso) rendendo gli utilizzatori dell'HoloLens non riconoscibili.

In caso di focus group

[da condurre con i partecipanti al test immersivo in realtà virtuale dopo che tutti hanno terminato l'esperienza immersiva]
Per circa 60 minuti parteciperà a una discussione all'interno di un gruppo composto da coloro che hanno partecipato all'esperienza immersiva con l'HoloLens. Vi verranno poste alcune domande in merito all'esperienza che avete fatto con la realtà aumentata. In particolare, questo focus group, sarà orientato a comprendere i dettagli della vostra esperienza immersiva e a raccogliere spunti e suggerimenti che potranno aiutare i ricercatori a migliorare l'esperienza stessa.
Con il suo permesso, l'incontro verrà audio-registrato a singolo uso dei ricercatori coinvolti nella ricerca.

Confidenzialità dei dati e loro trattamento: Le informazioni raccolte nel questionario, durante il test immersivo con l'HoloLens e nel focus group saranno trattate in forma anonima e confidenziale solamente dai ricercatori coinvolti nel progetto.
I risultati della ricerca saranno resi pubblici attraverso articoli su riviste, presentazioni a congressi, ed ogni altra modalità di scambio e divulgazione delle informazioni scientifiche ritenute idonee a giudizio dei ricercatori, garantendo sempre l'anonimato delle persone che hanno partecipato.

Per poter partecipare allo studio dovrà firmare un **Modulo di Consenso al Trattamento dei Suoi Dati Personali**. Tutti i dati identificativi verranno cancellati una volta finito lo studio. I soggetti saranno informati del trattamento dei dati prima dello studio.

Volontarietà e libertà di ritirarsi dalla ricerca: La partecipazione alla presente ricerca è completamente volontaria ed il rifiuto a parteciparvi, così come il ritiro dalla ricerca in qualsiasi momento della stessa, non hanno alcuna conseguenza.
Questo studio è stato approvato dal Comitato Etico dell'Università degli Studi Trento e sarà condotto secondo i principi etici definiti dalla dichiarazione di Helsinki sulla ricerca che coinvolge esseri umani. Nel caso avesse dubbi sulla correttezza e coerenza della conduzione della sperimentazione rispetto a quanto indicato in questo foglio informativo, può rivolgersi per segnalazioni al Rettorato dell'Università degli Studi di Trento, via Calepina, 14 38122 Trento.

Per qualunque ulteriore informazione o comunicazione relativa a questo studio saremo a disposizione ai seguenti contatti:

Sergio Cicconi: 334 6024393 – sergio.cicconi@unitn.it

LE SUGGERIAMO DI TENERE UNA COPIA DEL PRESENTE FOGLIO INFORMATIVO PER POTERLO EVENTUALMENTE CONSULTARE IN FUTURO.

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ALLEGATO I: DICHIARAZIONE DI CONSENSO

Dipartimento di Ingegneria e Scienze dell'Informazione (DISI)
Via Sommarive, 9 38123 Povo (TN)

DICHIARAZIONE DI CONSENSO ALLA PARTECIPAZIONE

Io sottoscritto/a ……………………………………………………………………………………………..................................

nato/a a ………………………………………………………………………….………il ……………………………………......

residente a ………………………...................................... in via..…………………………………………… n. …...

DICHIARO:

- di avere preso visione del **Foglio Informativo per la Richiesta di Consenso** concernente lo studio dal titolo: **"Augmented learning: an e-learning environment in augmented reality for older adults".**
- che le finalità, le modalità di svolgimento dello studio mi sono state illustrate in maniera chiara e dettagliata da ______________________________________;
- che ho avuto modo di esporre le mie considerazioni e di domandare eventuali ulteriori precisazioni,
- che ho avuto il tempo necessario per prendere una decisione spontanea, ponderata e non sollecitata,
- di essere a conoscenza di potermi ritirare dallo studio in ogni momento senza fornire spiegazioni.
- di aver compreso che i dati raccolti in questa sede non hanno alcuna validità clinica, ma sono intesi a puro scopo di ricerca;
- che il consenso da me espresso circa la partecipazione allo studio sopracitato è una libera decisione, non influenzata da promesse di benefici economici o di altra natura, né da obblighi nei confronti del Ricercatore responsabile dello studio.

Pertanto, sono consapevole delle attività previste e delle modalità di una mia adesione.

Ciò premesso:

DO IL MIO CONSENSO A PARTECIPARE ALLO STUDIO PROPOSTO

_____________	_______	_______________________________
Luogo	data	firma leggibile

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ALLEGATO J: INFORMATIVA TRATTAMENTO DATI

INFORMATIVA SUL TRATTAMENTO DEI DATI PERSONALI E PARTICOLARI SENSIBILI PER FINALITA' DI RICERCA SCIENTIFICA (ANCHE IN CAMPO MEDICO, BIOMEDICO O EPIDEMIOLOGICO) E RELATIVO CONSENSO (ART. 13 REG. UE 2016/679)

Titolo del Progetto di ricerca (di seguito "Progetto"):

"Augmented learning: an e-learning environment in augmented reality for older adults"

Gentile Partecipante,

desideriamo informarLa che il Regolamento UE 2016/679 *"Regolamento Generale sulla protezione dei dati personali"* (d'ora in avanti "RGPD"), il D.lgs. n. 196/2003 *"Codice in materia di protezione dei dati personali"* e il relativo Allegato A.4 "*Codice di deontologia e di buona condotta per i trattamenti di dati personali per scopi statistici e scientifici*" *(Provvedimento del Garante n. 2 del 16 giugno 2004)* nonché le Autorizzazioni generali al trattamento dei dati personali effettuato in materia, **sanciscono il diritto di ogni persona alla protezione dei dati di carattere personale che la riguardano**.
Ai sensi della normativa sopra indicata, il trattamento dei Suoi dati personali da parte dei ricercatori coinvolti nell'attività di ricerca sarà improntato al rispetto dei principi di cui all'art. 5 del RGPD - e, in particolare, a quelli di liceità, correttezza, trasparenza, pertinenza, non eccedenza - e svolto in modo da garantire un'adeguata sicurezza dei dati personali.

Il Progetto, che si propone di sviluppare una forma innovativa di e-learning, specificamente disegnata per gli anziani e facilmente accessibile agli anziani senza alcuna precedente conoscenza della tecnologia, è condotto dal prof. Maurizio Marchese nel Dipartimento di Ingegneria e Scienze dell'Informazione (DISI).

Le caratteristiche dello studio e le sue modalità di svolgimento sono descritte di seguito:

Tutti i partecipanti selezionati prenderanno parte ad un breve incontro/workshop durante il quale saranno introdotti ai concetti di realtà aumentata e ologrammi, in modo che possano capire meglio i compiti che saranno chiamati a svolgere durante l'esperienza con un dispositivo per la produzione di esperienze in realtà aumentata denominato *Microsoft HoloLens*. Durante l'incontro, i partecipanti potranno anche vedere e toccare il dispositivo e capire come indossarlo, così da avere la possibilità di familiarizzare con l'HoloLens e, più in generale, con l'idea di utilizzare una nuova tecnologia immersiva.
Ai partecipanti verranno anche fornite istruzioni scritte e visive (immagini) sui pochi (3-4) gesti che saranno richiesti per portare a termine la loro esperienza con l'HoloLens. Ogni partecipante sarà aiutato a indossare l'HoloLens e sarà guidato e assistito durante l'intera esperienza in realtà aumentata, al fine di facilitare l'esperienza stessa.
L'esperienza con l'HoloLens durerà circa 25 minuti. A ogni partecipante verrà chiesto di completare alcuni esercizi di selezione o manipolazione di ologrammi, eseguendo semplici movimenti con la testa (cioè, leggere rotazioni della testa a destra o sinistra, in alto o in basso, per identificare i particolari oggetti virtuali che di volta in volta verranno utilizzati nell'ambiente immersivo), o con le mani (semplici gesti con le dita di una o due mani per "afferrare" gli oggetti virtuali e spostarli, ridimensionarli e ruotarli nello spazio). Alla fine dell'esperienza con l'HoloLens, a ciascun partecipante verrà chiesto di compilare un breve questionario con domande sull'usabilità dell'HoloLens e sull'esperienza che ha avuto con l'HoloLens e la realtà aumentata.
Al fine di poter confrontare i dati e le informazioni fornite dal gruppo di anziani relativamente all'utilizzo dell'HoloLens e, più in generale, all'esperienza con l'ambiente in realtà aumentata, si intende somministrare l'esperienza con l'HoloLens sopra descritta anche a un gruppo selezionato di studenti di UNIT. Tale confronto fornirà nuove informazioni sulle differenze di percezione e utilizzo della realtà aumentata da parte di due

diverse e distanti tipologie di utenti. Inoltre, fornirà anche indicazioni sulla possibilità concreta di utilizzare la realtà aumentata come effettiva tecnologia di learning per gli anziani.

In qualità di Interessato, Le forniamo le seguenti informazioni relative al trattamento dei Suoi dati personali.

Titolare del trattamento e Responsabile della protezione dei dati
Il Titolare del trattamento è l'Università degli Studi di Trento, via Calepina n. 14, 38122 Trento, email: ateneo@unitn.it. Il contatto del Responsabile della protezione dei dati di Ateneo è: rpd@unitn.it.

Finalità del trattamento
Il trattamento dei Suoi dati personali è effettuato per la realizzazione delle finalità scientifiche del Progetto, ovvero verificare la possibilità di utilizzare la realtà aumentata come effettiva tecnologia di learning per gli anziani e sviluppare un ambiente di learning in realtà aumentata per anziani. La natura scientifica di questa ricerca impone la raccolta dei suoi dati personali (nome, cognome, data di nascita), alcuni dati generali sulle sue condizioni fisiche, la registrazione video della sua sessione di test con il dispositivo per la produzione di realtà aumentata denominato Microsoft HoloLens, e la registrazione audio del focus group, successivo al test, al quale parteciperà.

IL PROGETTO NON HA COME FINALITÀ LA TUTELA O IL MIGLIORAMENTO DELLO STATO DI SALUTE DEL PARTECIPANTE.

Il Progetto è stato redatto conformemente agli standard metodologici del settore disciplinare interessato ed è depositato presso il Dipartimento/Centro di Ingegneria e Scienze dell'Informazione (DISI) dell'Università degli Studi di Trento ove verrà conservato per cinque anni dalla conclusione programmata della ricerca stessa.

Base giuridica del trattamento
Il trattamento dei Suoi dati personali viene effettuato dal Titolare nell'ambito di esecuzione dei propri compiti di interesse pubblico ai sensi dell'art. 6, comma 1, lett. e) del RGPD.
Il trattamento delle categorie particolari di dati personali (dati particolari sensibili) viene effettuato per fini di ricerca scientifica ai sensi dell'art. 9, comma 2, lett. j) del RGPD e sulla base di un consenso esplicito da Lei prestato (art. 9, comma 2, lett. a) del RGDP; art. 110 del Codice Privacy; art. 11 dell'Allegato A.4).

Categoria e tipologia di dati personali trattati
La realizzazione del Progetto implica il trattamento dei seguenti dati personali:
dati identificativi, alcuni dati particolari sensibili relativi alla salute, videoregistrazione durante il test con l'HoloLens, adioregistrazione del focus group successivo al test.

Modalità del trattamento
Il trattamento dei Suoi dati verrà effettuato mediante strumenti cartacei e/o automatizzati; la documentazione sarà poi conservata in archivi protetti cartacei ed elettronici presso l'Università degli studi di Trento in un servizio di storage garantito dall'Ateneo.

I Suoi dati personali saranno trattati esclusivamente dal Titolare e/o da soggetti autorizzati nell'ambito della realizzazione del Progetto.

Periodo di conservazione dei dati
I Suoi dati personali saranno conservati fino al raggiungimento delle finalità del Progetto.

Natura del conferimento dei dati
Fornire i Suoi dati per le suddette finalità di ricerca è indispensabile per lo svolgimento del Progetto e non discende da un obbligo normativo e/o contrattuale. La decisione di non fornirli, determina la Sua impossibilità a partecipare al Progetto.

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Destinatari dei dati ed eventuale trasferimento all'estero
I Suoi dati personali potranno essere comunicati in forma anonima e/o aggregata ai seguenti soggetti:

- ai componenti del gruppo di ricerca, ad altri ricercatori autorizzati,
- ai componenti il Comitato Etico dell'Università degli Studi di Trento
- alle Autorità regolatorie competenti in materia (ad es. l'Autorità Garante della privacy)

per fini di ricerca scientifica e per la salvaguardia dei suoi diritti, nel rispetto della Sua riservatezza

Divulgazione dei risultati della ricerca
La divulgazione dei risultati statistici e/o scientifici (ad esempio mediante pubblicazione di articoli scientifici e/o la creazione di banche dati, anche con modalità ad accesso aperto, partecipazione a convegni, ecc.) potrà avvenire soltanto in forma anonima e/o aggregata e comunque secondo modalità che non La rendano identificabile.

Diritti dell'Interessato
In qualità di Interessato ha diritto di chiedere in ogni momento al Titolare l'esercizio di diritti di cui agli artt. 15-22 del RGPD e, in particolare, l'accesso ai propri dati personali, la rettifica, l'integrazione, la cancellazione, la limitazione del trattamento che la riguardi o di opporsi al loro trattamento. L'Interessato ha sempre il diritto di revocare, in qualsiasi momento, il consenso senza pregiudicare la liceità del trattamento basato sul consenso prestato prima della revoca. Ai sensi dell'art. 17, comma 3, lett. d) il diritto alla cancellazione non sussiste per i dati il cui trattamento sia necessario ai fini di ricerca scientifica qualora rischi di rendere impossibile e/o pregiudicare gravemente gli obiettivi della ricerca stessa.

Per l'esercizio dei suddetti diritti può contattare il Titolare (ateneo@unitn.it) e/o il Responsabile della protezione dei dati di Ateneo (rpd@unitn.it).

Resta salvo il diritto di proporre reclamo al Garante per la protezione dei dati personali.

Per informazioni relative al Progetto può rivolgersi al Responsabile scientifico del Progetto al seguente recapito: maurizio.marchese@unitn.it

UNIVERSITÀ DEGLI STUDI
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Dipartimento di Ingegneria e Scienza dell'Informazione - DISI

CONSENSO AL TRATTAMENTO DEI DATI PERSONALI E PARTICOLARI

Il/la sottoscritto/a ....

nato/a a .... il ....

residente a ....

in via .... n. ....

dopo aver preso visione e aver compreso l'informativa che precede, relativa al Progetto dal titolo "**Augmented learning: an e-learning environment in augmented reality for older adults**":

☐ acconsente
☐ non acconsente

al trattamento dei propri dati personali e particolari sensibili raccolti nell'ambito del Progetto sopracitato.

....
(Luogo e data)

Firma ....

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Dipartimento di Ingegneria e Scienza dell'Informazione - DISI

ALLEGATO K:
DICHIARAZIONE DI IMPEGNO A CONFORMARSI ALLE DISPOSIZIONI DEL CODICE DI DEONTOLOGIA...

Dichiarazione di impegno a conformarsi alle disposizioni del Codice di deontologia e di buona condotta per i trattamenti di dati personali per scopi statistici e scientifici (Allegato 4 Codice Privacy)

Nell'ambito del Progetto di ricerca dal titolo

"**Augmented learning: an e-learning environment in augmented reality for older adults**":

vengono effettuati trattamenti di dati:

- **personali**
  - **identificativi**
- categorie particolari di dati (dati particolari sensibili)
  - genetici
  - biometrici
  - **relativi alla salute**
- giudiziari

Nello svolgimento del Progetto sono adottate tutte le misure richieste per il trattamento dei dati al fine di garantire il rispetto della normativa vigente in materia di protezione dei dati personali.

Sottoscrivendo la presente dichiarazione, tutti i soggetti coinvolti nel Progetto si conformano alle disposizioni del Codice di deontologia e di buona condotta per i trattamenti di dati personali per scopi statistici e scientifici.

La dichiarazione dovrà essere fatta sottoscrivere anche ai soggetti – ricercatori, responsabili e autorizzati al trattamento – che fossero coinvolti nel prosieguo della ricerca.

La presente dichiarazione, allegata al Progetto di cui sopra, verrà depositata presso il Dipartimento/Centro di afferenza

DISI – UNITN

il quale ne cura la conservazione, in forma riservata (essendo la consultazione del progetto possibile ai soli fini dell'applicazione della normativa in materia di dati personali), per cinque anni dalla conclusione programmata della ricerca.

Persone coinvolte nel Progetto:

Ruolo Privacy	Nominativo	Firma
Responsabile del Progetto	Maurizio Marchese	

UNIVERSITÀ DEGLI STUDI DI TRENTO

Dipartimento di Ingegneria e Scienza dell'Informazione - DISI

Autorizzato al trattamento	Sergio Cicconi	Sergio Cicconi
.....		

Eventuali modifiche alla composizione del gruppo di ricerca avvenute nel prosieguo del Progetto:

Ruolo Privacy	**Nominativo**	**Data di ingresso**	**Data di cessazione**	**Firma per i nuovi ingressi**
Responsabile del progetto				
Autorizzato al trattamento				
Autorizzato al trattamento				
.....				

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ALLEGATO L:
AUTORIZZAZIONE ALLA ESPOSIZIONE DI UN INVITO DI PARTECIPAZIONE AL PROGETTO DA PARTE DELL'ASSOCIAZIONE COINVOLTA

Il/la sottoscritto/a ______________________________

in qualità di (*ruolo*) ______________________________

di (*nome istituto/centro/associazione*) ______________________________

- dopo aver preso visione del foglio informativo relativo al progetto dal titolo: **"Augmented learning: an e-learning environment in augmented reality for older adults",** (qui di seguito allegato*),
- dopo aver partecipato a un incontro con il ricercatore (Sergio Cicconi) coinvolto nel progetto, durante il quale ho avuto modo di comprendere alcuni dettagli del progetto, soprattutto per ciò che riguarda il test di usabilità previsto nel progetto e che si intende somministrare a un gruppo di anziani che frequentano le nostre strutture,
- e dopo aver compreso che il test e gli incontri previsti dal progetto non esporranno in alcun modo i partecipanti a situazioni potenzialmente pericolose dal punto di vista fisico, psicologico, sociale o legale;

- e considerando che:
    - Il nostro Istituto/Centro/Associazione, come da richiesta del ricercatore (Sergio Cicconi) coinvolto nel progetto, si limiterà esclusivamente ad esporre nei propri spazi previsti una o più copie dell'**Invito alla Partecipazione al Progetto** (qui di seguito allegato – si veda **Allegato D2**) allo scopo di coinvolgere nel progetto anziani che frequentano le nostre strutture,
    - la partecipazione al test e agli incontri previsti nel progetto è su base esclusivamente volontaria; pertanto, tutti i candidati saranno liberi di partecipare, senza alcuna sollecitazione o pressione da parte del personale del nostro Centro/Associazione
    - Il nostro Istituto/Centro/Associazione non avrà nessun ulteriore coinvolgimento nel progetto. Ciò significa che non verrà fornito alcun supporto da parte del personale del nostro Istituto /Centro/Associazione, né verranno forniti spazi (locali, laboratori, ecc.) per le attività previste nel progetto.
    - Il nostro Istituto/Centro/Associazione non si assume alcun tipo di responsabilità nei confronti di coloro che, dopo aver visionato L'Invito alla Partecipazione al Progetto esposto negli spazi previsti, scelgano liberamente di partecipare.

autorizza

l'esposizione dell'**Invito alla Partecipazione al Progetto** negli adeguati spazi pubblici del nostro Istituto/Centro/Associazione per un periodo non superiore a 60 giorni.

Data__________ Firma

UNIVERSITÀ DEGLI STUDI DI TRENTO

Dipartimento di Ingegneria e Scienza dell'Informazione - DISI

(*) AUGMENTED LEARNING FOR OLDER ADULTS

Augmented Learning: an e-learning environment in augmented reality for older adults è un progetto di ricerca condotto nel Dipartimento di Ingegneria e Scienze dell'Informazione dell'Università degli Studi di Trento, con lo scopo di realizzare un ambiente di e-learning in realtà aumentata capace di far conoscere le nuove tecnologie (computer, internet, ecc.) agli anziani e favorire così la loro integrazione sociale nel mondo digitale.
Nelle fasi di messa a punto del prototipo dell'ambiente di e-learning in realtà aumentata, il progetto prevede la somministrazione di un test di usabilità a un gruppo di anziani e a un gruppo di studenti, al fine di verificare la funzionalità e usabilità del prototipo con coloro che saranno gli utilizzatori finali dell'ambiente di e-learning.

Le caratteristiche del test e le sue modalità di svolgimento sono descritte di seguito:

Workshop:
Tutti i partecipanti selezionati presso una o più associazioni culturali e ricreative per la terza età prenderanno parte ad un breve incontro/workshop durante il quale saranno introdotti ai concetti di realtà aumentata e ologrammi, in modo che possano capire meglio i compiti che saranno chiamati a svolgere durante l'esperienza con un dispositivo per la produzione di esperienze in realtà aumentata denominato *Microsoft HoloLens*. Durante l'incontro, i partecipanti potranno anche vedere e toccare il dispositivo e capire come indossarlo, così da avere la possibilità di familiarizzare con l'HoloLens e, più in generale, con l'idea di utilizzare una nuova tecnologia immersiva.

Esperienza immersiva con l'HoloLens
Ai partecipanti verranno anche fornite istruzioni scritte e visive (immagini) sui pochi (3-4) gesti che saranno richiesti per portare a termine la loro esperienza con l'HoloLens. Ogni partecipante sarà aiutato a indossare l'HoloLens e sarà guidato e assistito durante l'intera esperienza in realtà aumentata, al fine di facilitare l'esperienza stessa e renderla quanto più piacevole possibile.
L'esperienza con l'HoloLens durerà circa 25 minuti. A ogni partecipante verrà chiesto di completare alcuni esercizi di selezione o manipolazione di ologrammi, eseguendo semplici movimenti con la testa (cioè, leggere rotazioni della testa a destra o sinistra, in alto o in basso, per identificare i particolari ologrammi che di volta in volta verranno utilizzati nell'ambiente immersivo), o con le mani (semplici gesti con le dita di una o due mani per "afferrare" gli ologrammi e spostarli, ridimensionarli e ruotarli nello spazio). Alla fine dell'esperienza con l'HoloLens, a ciascun partecipante verrà chiesto di compilare un breve questionario con domande sull'usabilità dell'HoloLens e sull'esperienza che ha avuto con l'HoloLens e la realtà aumentata.
Al fine di poter confrontare i dati e le informazioni fornite dal gruppo di anziani relativamente all'utilizzo dell'HoloLens e, più in generale, all'esperienza con l'ambiente in realtà aumentata, si intende somministrare l'esperienza con l'HoloLens sopra descritta anche a un gruppo selezionato di studenti di UNIT. Tale confronto fornirà nuove informazioni sulle differenze di percezione e utilizzo della realtà aumentata da parte di due diverse e distanti tipologie di utenti. Inoltre, fornirà anche indicazioni sulla possibilità concreta di utilizzare la realtà aumentata come effettiva tecnologia di learning per gli anziani.

Usabilità e User Experience
Alla fine dell'esperienza con l'HoloLens, a ciascun partecipante verrà chiesto di compilare un breve questionario con domande sull'usabilità dell'HoloLens e dell'ambiente immersivo e sull'esperienza che ha avuto con l'HoloLens e la realtà aumentata.

Focus group
Successivamente al completamento del test immersivo da parte di tutti i partecipanti, verrà organizzato un Focus Group finalizzato ad avviare una discussione guidata sull'esperienza con l'HoloLens. I gruppi di 6-7 partecipanti e della durata di circa 1 ora, saranno condotti dal ricercatore coinvolto nel progetto.

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