UNIVERSITÁ DEGLI STUDI DI MILANO-BICOCCA

Department of Psychology

Master of Science in Applied Experimental Psychological Sciences

ENVISIONING CORALS:

Evaluation of a Virtual Reality Immersive Application Aimed at Raising Awareness about Climate Change and Coral Bleaching Phenomena

Supervisor: Prof. GALLACE Alberto

Master Thesis by: COPPOLA Lilia

(Matr. 819611)

Academic Year 2022/2023

"Ours are the most fortunate generations that have ever lived. Ours might also be the most fortunate generations that ever will. We inhabit a brief historical interlude between ecological constraint and ecological catastrophe".

– George Monbiot

CONTENTS

ABSTRACT

Climate change is one of the most pressing concerns the world has to face nowadays since it poses a threat to humanity as well as other living species. There is a growing need to raise awareness about the impacts of the actual climate crisis on our planet's ecosystems, such as the devastating effects on the Great Barrier Reefs (GBRs). Virtual Reality (VR) is a modern communication tool that, thanks to its immersive and interactive properties, can help to reduce the psychological distance between people's mental representation of climate change and its effects; a variety of VR applications have been successfully developed in this regard in the fields of education and environmental protection. Considering the growing body of research on this topic we decided to develop "Envisioning Corals", a virtual simulation that we ideated and implemented, within a multidisciplinary team, to increase awareness about coral bleaching phenomena. "Envisioning Corals" allows the user to impersonate a coral, a hermit crab, or a sea turtle, and explore a GBR while experiencing first-hand the effects of climate change on the underwater environment. The purpose of the present research was to conduct a usability study, by assessing the overall User Experience (UX), the Learning Properties, the Sense of Presence, and the Embodiment elicited by the "Envisioning Corals" application. The results showed an overall good level of UX, considering both pragmatic and hedonic aspects, and users reported a high degree of engagement. Additionally, the results suggest that "Envisioning Corals" has the potential to effectively communicate the environmental message, making it a valuable tool in raising awareness about the importance of protecting our planet's coral reefs.

KEYWORDS:

Virtual Reality, Corals Bleaching, Climate Change, User Experience, Human Factors.

INTRODUCTION:

This master's degree project is the result of a collaboration between the Psychological Department of the University of Milano Bicocca (MIBTEC center of excellence) and the Department of Electronics, Information Technology, and Bioengineering of Politecnico di Milano. The research aims to evaluate the User Experience and the Educational Properties of a Virtual Reality immersive application called "Envisioning Corals", which was designed to raise awareness towards the "coral bleaching" phenomenon, one of the severe consequences of climate change on our planet's ecosystems. During the simulation, users can choose their virtual avatar (a coral, a hermit crab, or a sea turtle) and engage in a short game while listening to informative educational audio.

The dissertation begins with two introductory chapters providing an overview of the topics. Chapter 1 focuses primarily on climate change and global warming, emphasizing their causes and effects. Chapter 2 discusses the features and properties of Virtual Reality, providing an overview of its use in environmental education and sustainability fields. Chapter 3 is dedicated to a detailed description of our Virtual Reality application, including its functioning and contents. The chapter also outlines the methodology adopted in this study, including the development of the self-report questionnaire aimed at assessing the following constructs: User Experience, Sense of Presence, Embodiment, and Learning Motivation. In Chapter 4 we present the main results obtained in the testing phase, and Chapter 5 provides concluding remarks based on the results, discusses the main limitations of the work, and suggests future implementations. In the Appendix, we included the complete questionnaire with the list of blocks and items.

CHAPTER 1:

Climate change and Environmental Education

Climate change is an increasingly recognized phenomenon, and it is highly probable that the readers have come across the terms "coral bleaching" at least once. However, perhaps not everyone clearly understands the theoretical framework in which this unhappy phenomenon arises. In this chapter we will first define what climate change is and which causes led to such a problematic event; then, we'll provide a brief overview of its consequences before narrowing it down to oceans and specifically to Great Barrier Reefs (GBRs). Finally, we're going to stress the importance of raising awareness about this topic among the world's population and we'll also briefly summarize the commonly adopted strategies to do so.

1.1 Definitions of climate change, its causes, and most relevant consequences

To start introducing the topic, we must first ask ourselves a fundamental question: what is climate change? Is it different from global warming? We often use the two terms interchangeably, but do they denote the same concept? Actually, the definitions of climate change and global warming are not perfectly superimposable. The National Aeronautics and Space Administration (NASA) defines global warming as "the long-term heating of Earth's surface observed since the pre-industrial period (between 1850 and 1900) due to human activities, primarily fossil fuel burning, which increases heat-trapping greenhouse gas levels in Earth's atmosphere (NASA)". A different definition is provided for the term climate change; in fact, the Intergovernmental Panel on Climate Change (IPCC) defines it as follows: "A change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings, or to persistent anthropogenic changes in the composition of the atmosphere (IPCC, 2012)". We can infer though that "climate change" represents a broad concept, which includes changes not only in temperature but also in the pattern of precipitations and wind conditions over a long period, manifesting itself through the increment in oceans and surface temperature, rise in sea level, changes in rainfall and weather patterns. Global warming instead refers only to the rising of Earth's temperatures. According to the National Oceanic and Atmospheric Administration (NOAA) in fact, the temperature of our planet has risen by 0.08° Celsius per decade since the Second Industrial Revolution in the second half of the 19^{th} century; a century later, since 1981, the warming has more than doubled reaching the rate of 0.18° Celsius per decade. Data from 2021 showed that the average surface temperature was 1.04° Celsius warmer in comparison to 1880 (NOAA).

Moving beyond definitions, the next fundamental thing is to understand which causes led to the actual climate crisis, then the short and long-term consequences that this phenomenon has and will continue to have for our planet and the living beings that inhabit it. The first thing to be highlighted is the fact that human activity is a central determinant of such alterations: Höök & Tang (2013) specified that, even if changes in climate can also occur for natural reasons over a long period of time, the modifications occurred in our planet's climate since the mid-19th century are undeniably driven by human activity, in particular by the massive use of non-renewable energy sources such as fossil fuels (coal, oil, gas) which constitute the 80% of the total energy used (Hook & Tang, 2013). The rapid growth of industrialization resulted in an exponential growth in energy demand and fossil fuels responded to it, remaining the main contributor to the energy sector still nowadays. (Olabi & Abdelkareem, 2022). As an overview from the Royal Society about climate change (2020) pointed out, studies aimed at measuring carbon dioxide (CO_2) levels in the atmosphere found an anomalous increment of more than 40% from the 19th century to nowadays, and this is an enormous problem considering that CO_2 is one of the most important greenhouse gases to Earth's energy balance (Royal Society, 2020). Natural dispersion of greenhouse gasses in the atmosphere is what makes life on Earth possible, but human activity broke this natural equilibrium by disproportionately increasing atmospheric carbon dioxide concentrations: for this reason, scientists talk about the anthropogenic greenhouse effect as a major cause of the climate crisis. Dramatic aftermaths of climate change are hard to summarize because they happen at different levels and influence living beings, both humans and animals, in different ways. We will report only some examples, to give a glimpse of the seriousness of the problem; we will classify the consequences into 4 categories: health and survival, food, weather, and oceans.

Analyzing the consequences from a human perspective, climate alterations can affect human beings by making the climate conditions of the regions where they live inhospitable, leaving those people homeless and ultimately forcing them to migrate somewhere else (Black et al., 2011); plus, climate crisis negatively impacts global agriculture with cascading repercussions for food availability (Wheeler & Von Braun, 2013) and for the income and livelihoods of those countries that economically rely on primary sectors, such as sub-Saharan Africa (Connolly-Boutin & Smit, 2016). As outlined by Wu et al. (2016), climate changes (such as modifications in temperatures and precipitations) may dramatically affect humans health by altering the environmental conditions in which diseases pathogens are born and reproduce, ultimately facilitating their transmission and survival: the effects of such alterations can be seen as modifications in the outbreak frequency and severity of human infectious diseases (Wu, Lu, Zhou, Chen & Xu., 2016). Also, climate change results in extreme weather events, occurring globally with increased frequency and intensity. Considering the animal perspective, Lacetera (2019) highlighted that climate changes may have direct effects on animals' health as well: according to the author, direct effects are those caused by global warming and manifest themselves through metabolic disorders, oxidative stress, and immune suppression, ultimately leading to death (Lacetera, 2019). Finally, also biodiversity is affected by the phenomenon of interest since plants and animals are moving from their natural habitats due to climatic upheavals (Pecl et al., 2017).

1.2 The coral bleaching phenomenon

So far, we have provided a general overview of the negative repercussions of the climate crisis and global warming for our planet, and we have brought some examples concerning food availability, weather phenomena, and humans and other living beings' health. But how does climate change affect oceans? It is difficult to make a complete and exhaustive treatment of this issue; therefore, we decided to focus our work on the negative consequences of climate change on corals, specifically on the phenomenon known as "coral bleaching". The ocean is an essential source of life: it controls the climate and the oxygen needed to survive and is home to countless living species. Due to climate changes, the oceans' waters are increasingly warming up; this constitutes an enormous danger for the ecosystems that depend on it: comparing the temperature on oceans' surface from 1880 to 2020 it is possible to comprehend this enhancement fully.

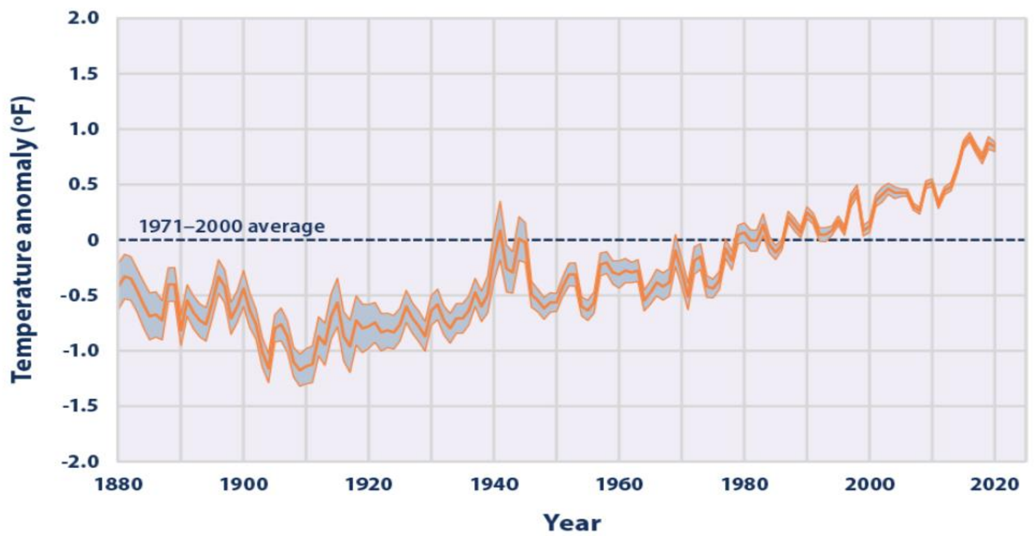


Figure 1.1: Average Global Sea Surface Temperature, 1880–2020.

Data source: NOAA, 2021.

To make the reader fully aware of the concept of coral bleaching, we first need to introduce the Great Barrier Reefs (GBRs): these represent the largest constructions of living organisms on our planet, formed by corals which are the most biodiverse marine ecosystem, groups of species which cooperate to survive. Each coral animal is made up of millions of polyps aggregating together around the skeleton. These polyps are fundamental since the microscopic plants inside them are responsible for photosynthesis, the primary food source for corals. The increasing warming up of oceans' surfaces happens because oceans absorb approximately 25% of the CO_2 emitted each year by anthropogenic activities, and this results in an increment in oceans' temperature but also ocean's acidification, due to the chemical reaction which transforms CO_2 in carbonic acid when it encounters water (Hoegh-Guldberg et al., 2007).

The rising in oceans' temperature has been demonstrated to be one of the main causes of coral bleaching events: the causal relationship between climate change, warmer waters, and coral bleaching have been scientifically demonstrated via experimental studies (Glynn & D'Croz, 1990) and in correlative field studies (Winter, Appeldoorn, Bruckner & Goenaga., 1998). In addition, it is possible to predict where this phenomenon will occur by analyzing surface temperature anomalies through satellites with a high degree of accuracy (Toscano et al., 2002). This constitutes another proof of the existing causal link between rising temperatures and coral reef bleaching.

According to Baker (2001), when corals are exposed to environmental stresses (such as an increase in water temperature beyond the corals' thermal tolerance), these animals react by bleaching. They expel the symbiotic dinoflagellates algae called "zooxanthellae", which are no longer functional, remaining with a transparent issue around the calcified skeleton; since the symbiotic algae constitute the primary source of sustenance, corals begin to starve after bleaching (Baker, 2001).

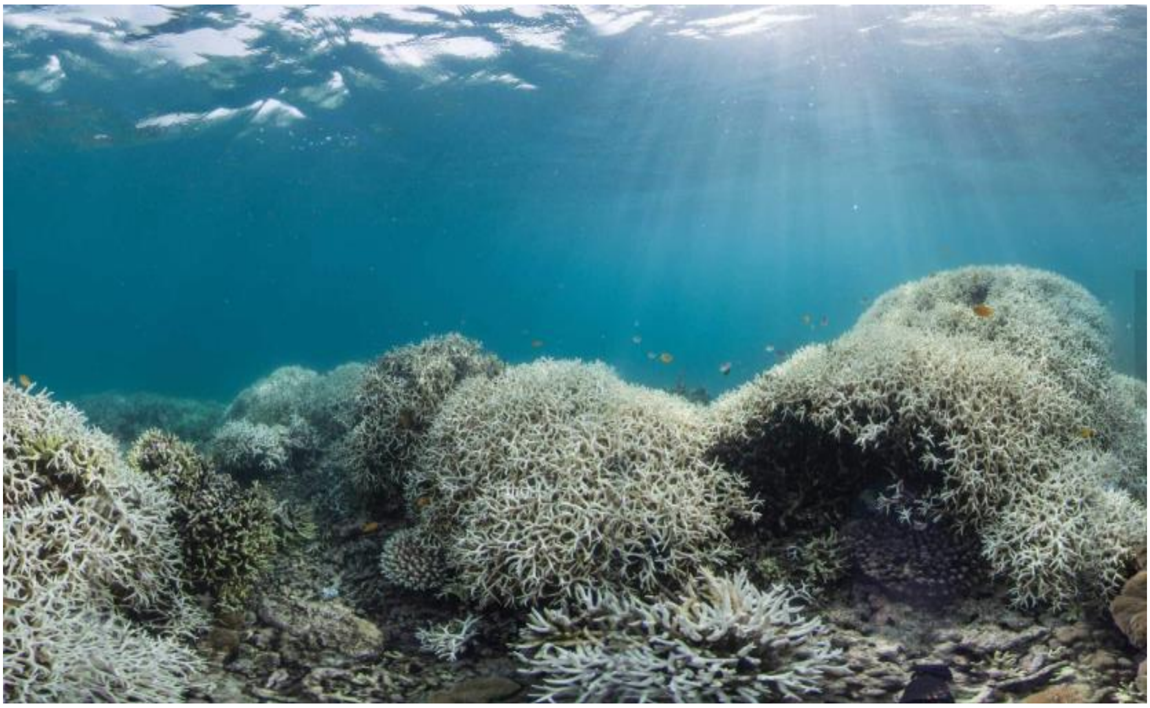


Figure 1.2: Coral Bleaching at Lizard Island, GBR

Source: Underwater Earth XLCatlin Seaview Survey - Christophe Bailhache

Figure 1.3: Bleaching event, anemone.

Source: Underwater Earth XLCatlin Seaview Survey - Christophe Bailhache

This phenomenon began to be observed in 1980; since then, the presence of GBRs has declined by as much as 50% and is continuing to decline at an alarming rate (Hoegh-Guldberg, 2011). If the environmental conditions do not return to an optimal range after bleaching corals encounter death within a few months. Nevertheless, coral bleaching does not necessarily lead to their death: indeed, if the unfavorable environmental conditions do not last long, corals are capable of recovering (Hoegh-Guldberg, 2011). Great barrier reefs are not just marvelous: they serve fundamental functions as they are home to countless GBR inhabitants, provide food and sustenance, and constitute physical protection for coasts against oceanic waves (Hoegh-Guldberg, 2011).

1.3 The importance of raising awareness:

From what we have explained previously, it can be easily understood that climate change and coral bleaching events are the biggest threat to coral reefs, and that is why it becomes essential to raise awareness among as many citizens as possible to inform them about the risks and to teach them which sustainable pro-environmental behaviors (PEBs) can be implemented. Being a research group in psychology, our main target is people: in fact, we are prone to understanding how to effectively communicate climate change's threats and coral bleaching to others, to make them better understand the implications and how to act in everyday life to try to revert this process.

It is not common to be able to witness a phenomenon such as coral bleaching in a direct way, because corals and coral reefs are present only in specific areas of the world. Thus, educating the population about what happens under the ocean's surface becomes important. In the last decades, the huge topic of climate change has grown in popularity, especially among the youngest generations, becoming a point around which public opinion debates and politics try to deal with. Even so, Stoutenborough and colleagues (2014) highlighted that people's concern about environmental issues and PEBs reached the maximum peak in 2007 and significantly declined after that year (Stoutenborough, Liu & Vedlitz., 2014). Fortunately, more and more scientific studies are conducted to tackle this specific issue; however, awareness is unevenly distributed among the population, because individual differences are at stake when it comes to processing information. Hornsey et al. (2016) in their meta-analysis about the determinants of belief in climate change reported that demographic variables such as lower age, higher income, higher education, and higher political affiliation positively correlated with the higher endorsement of climate change beliefs. Also, the authors identified some antecedent variables such as trust in scientists, perceived scientific consensus, new ecological paradigm, green identity, the experience of local weather change, and objective and subjective knowledge which positively correlated with climate change beliefs (Hornsey et al., 2016).

To reach a significant improvement in people's climate change awareness and risk perception and to promote PEBs, effective environmental education is needed. In 1977 took place at Tbilisi the first intergovernmental meeting about environmental issues: the United Nations Conference on Environment and Development (UNCED). It established the five objectives of environmental education: promoting awareness and sensitivity toward environmental hazards, helping to develop attitudes of concern as well as to motivate to act for protecting the environment, helping in acquiring skills for identifying and acting against environmental problems, and lastly promoting active participation among individuals and social groups (Fauville, Lantz-Andersson & Säljö., 2014). Different communication tools have been adopted to promote awareness and sustainable behaviors concerning climate change consequences and coral bleaching events. Media have certainly been and will continue to be, a great resource for reducing the gap between scientific knowledge and public awareness. Indeed, typical examples of communication tools for spreading awareness are constituted by newspapers and magazines, radio, television, social networks, newsletters, and the internet in general. Each of these tools can potentially reach different audiences, from a broader audience to a more restricted one. Traditional strategies involve disseminating information using a variety of media: for instance, journalists interested in this topic can inform the public by writing articles in newspapers, or they can publish in online journals. Internet users can also contribute to spreading environmental messages via social networks by re-sharing articles on their profiles or by sending them to friends, relatives, or acquaintances. The radio has proven to be another effective tool for communicating important messages: in fact, even in the poorest countries, many people possess a radio so that information delivered through this medium can potentially reach a large public and the costs are low compared to other types of media (Talero, 2004).

Global movements such as Fridays for Future and governmental and non-governmental organizations (NGOs) such as Greenpeace, WWF, and many other associations involved in promoting environmental sustainability themes, usually place advertisements on newspapers' pages or in physical places (such as public transportation) as well as on social networks, to make themselves more visible. NGOs also use websites and social accounts to find other members or donors and to organize information campaigns, by posting videos, sharing stories, and also contacting web influencers to support the environmental cause; as correctly highlighted by Pace "These organizations sought to inform the general public about the environment by organizing activities such as campaigns, seminars, meetings and publishing numerous information leaflets, magazines, and articles in newspapers. They sought to raise public awareness and to mobilize public pressure against action that deteriorated the quality of the environment" (Pace, 1997). Television and other free or to-be-paid platforms that allow enjoying audio-visual content have been used effectively for this purpose: TV programs or documentaries that explain scientifically and emotionally the dramatic consequences of climate change can be easily found. “Chasing corals” is an example of that, it is a documentary that deals with coral bleaching issues by interviewing experts and using images and videos taken directly from coral reefs around the world to document the phenomenon. YouTube is another example of such a platform, which makes it possible for scientists and activists to raise awareness and educate people through the creation of informative videos. Another traditional medium that scientists and science communicators use to raise awareness is by writing books that can be both complex and highly detailed, difficult to understand for the general public, or more general ones aimed at reaching a larger and non-expert audience. Also, public conferences with expert figures can be organized to raise awareness and communicate sustainability’s importance; these meetings can also be held in universities and schools in general.

The advent of social media, such as Instagram, Facebook, TikTok, and Twitter, has undoubtedly provided new ways to communicate with people around the world. Different studies have been conducted in order to understand the potentialities and the effectiveness of this tool in promoting PEBs: social media and specifically social networks can be used for different purposes, ranging from passive entertainment (i.e., merely watching others’ content) to active participation such as chatting, posting photos, sharing videos, meeting new people, or creating virtual communities. This kind of media can be also used to spread information on the most diverse topics including environmental problems; indeed, Kaur & Chahal (2018) highlighted that social media serve as potential tools for reaching a huge catchment area and for motivating individuals to act first-hand in an environmentally friendly manner. Kaur and colleagues in their study conducted an Exploratory Factor Analysis to understand which factors pertaining to social networks could allow engaging users on climate change and sustainability: the authors found the following six factors “Competitive Persuasive Power”, “Persuasive Power”, “Perceived Reliability”, “Ease of Accessibility”, “ Perceived Trust” and “Promptness of Activism” (Kaur & Chahal, 2018).

An alternative way to communicate sustainability regarding climate change is represented by games, either board games or computer-based games, which can be useful for raising awareness in a way that is entertaining and that involves active learning: in the words of Wu and colleagues, climate change games are “ games and simulations that have climate change as a central theme and focus on the processes, the role of human systems and potential impacts regarding climate change. (Wu & Lee, 2015)”. Many examples can be found: for instance, “Keep Cool” is a board game that allows players to identify themselves with people in charge of different countries, that have to do negotiations in order to mitigate climate change’s aftermaths. Another case of a board climate change game is “EcoChains: Arctic Crisis”, which focuses specifically on the effects of the climate crisis on the arctic sea. Examples of computer-based games are the "Climate Kids" developed by the National Aeronautics and Space Administration (NASA) and the "Earth Day Canada's Eco-Kids", which imply simple engaging activities such as puzzles or trivia (28). Other resources can be found online, such as the "Climate Interactive" game, a simulation in which players can manipulate many different variables to see the resulting consequences for Earth's climate and environment (28). Games structured in this way can be extremely effective because of their educational properties: in fact, they elicit engagement and first-person experience, which enhance learning processing and allow players to develop empathic responses (Wu & Lee, 2015).

Lastly, new technologies can be an extremely useful resource in this field: they can help us to progress in communicating environmental sustainability themes by providing us with advanced methodologies. Based on previous scientific literature, which highlighted its enormous potential and advantages, we thought of using Virtual Reality for this purpose, because, among other properties, it allows a high degree of immersion and interaction (Fauville, Queiroz & Bailenson., 2020). In the next chapter, we will explain what "Virtual Reality" means, its properties, and the contributions this advanced technology could make to effectively raise awareness and communicate environmental sustainability.

CHAPTER 2:

Virtual Reality

In the following chapter, we will provide a general overview of the historical background and fundamental properties of Virtual Reality, to clarify the framework within which this research is intended; we will also mention the fields of application of this technology, focusing on environmental sustainability and providing examples from the scientific literature on the topic. Finally, we will outline the fundamental aspects to be taken into consideration when carrying out research using virtual reality as a tool.

2.1 Virtual Reality's definition, background, and features.

Imagine putting on a headset and being immediately teleported to another world, a new reality that may appear very similar or completely different from ours, without physical constraints: a world where it is feasible to explore the depths of the oceans or take the form of other animals. Virtual Reality allows humans to do that within a computer-generated world. Virtual reality (VR) can be conceived in a continuum ranging from real environments to virtual ones (Milgram et al., 1994). (Figure 2.1).

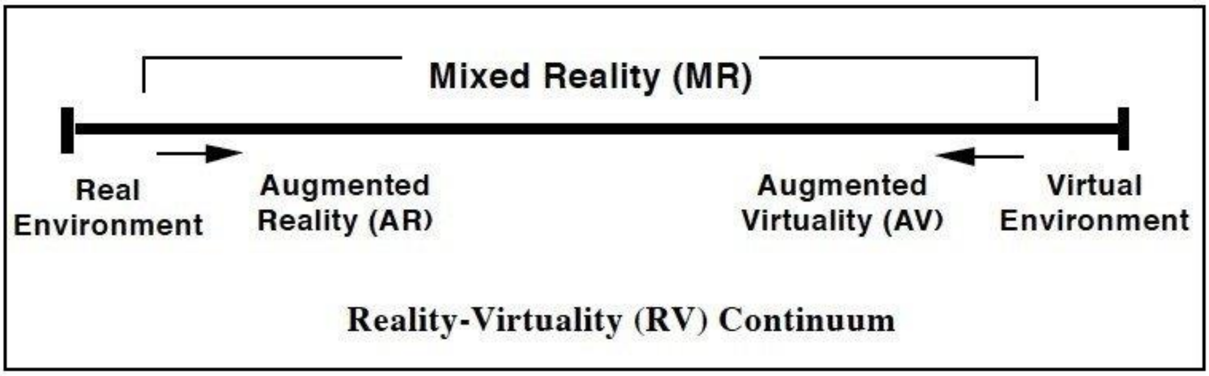


Figure 2.1: Reality-Virtuality Continuum (Milgram et al., 1994)

Giving an unambiguous definition of Virtual Reality is as complex as it is to define the limits of its use. Since it was born during the 60s, VR has experienced a huge development and there are more and more fields in which it is used. The term "Virtual Reality" is more of an umbrella term rather than a term with just one unambiguous meaning: Virtual Reality Environments (VREs) can be entered using different devices and they can provide visual as well as multisensorial stimuli. VR can provide a variety of experiences, ranging from pure immersive experiences to non-immersive ones: non-immersive

VREs are created by computer-generated images and they can be visualized using two-dimensional visual devices such as PC screens, personal smartphones, and tablets; on the contrary, immersive-VREs can be explored through immersive visual devices such as Head-Mounted Displays (HMDs), CAVE systems, virtual reality glasses and other types of interfaces (Slater and Sanchez-Vives, 2016).

It is impossible to talk about VR without mentioning the person who first invented the term: Jaron Lanier, philosopher, computer scientist, and founder of VPL Research Corporation coined the term “Virtual Reality” in 1986 to refer to different wearable technologies able to provide the illusion of physical presence in a virtual world; indeed, Lanier’s conception of Virtual Reality is multi-sensorial, he thought that VR technologies should stimulate as many senses as possible (Ambrosio & Fidalgo, 2020). Many other authors over time have provided different definitions of VR, taking into consideration different aspects and points of view. For instance, McCloy & Stone (2001) defined VR as a group of technologies enabling people to interact in real-time in three-dimensional worlds through their senses and abilities. According to Riva & Gaggioli (2019), Virtual Reality technologies allow users to enter a computer-generated scene, within which an individual can move and interact as in a real place. The various definitions found in the literature differ in their focus, which can be either concentrated on technical aspects (such as the hardware components), the psychological aspects involved in VR, or on the philosophical debate around this topic (Ambrosio & Fidalgo, 2020). Taking these differences into account, we can still draw the core features that characterize VR: indeed, according to all authors, VR technologies should be able to elicit immersion sensations, a sense of presence, and interactivity (Ambrosio & Fidalgo, 2020).

To understand the historical background that led to the rising of VR as we conceive it today we have to go back to the 60s of the last century when Morton Heilig developed the so-called “*Sensorama*” system: it consisted of an on-screen simulation of a motorcycle ride around New York which stimulated four out of five senses (namely sight, touch, smell, hearing) through devices that reproduced wind, temperatures’ changes and different smells which increased the feeling of immersion and three-dimensionality (Riva & Gaggioli, 2019). In 1968 Ivan Sutherland conceived the “*Damocles’ Sword*”, the first prototype of a Head-Mounted Display (HMD) for visualizing a three-dimensional virtual environment, which worked through a cathode ray tube: this system was revolutionary because Sutherland added the head-tracking to implement the stationarity principle, meaning that the images were not fixed but they were adjusted dynamically based on the user’s movements contributing to the sensation of immersion in the virtual world (Riva & Gaggioli, 2019).

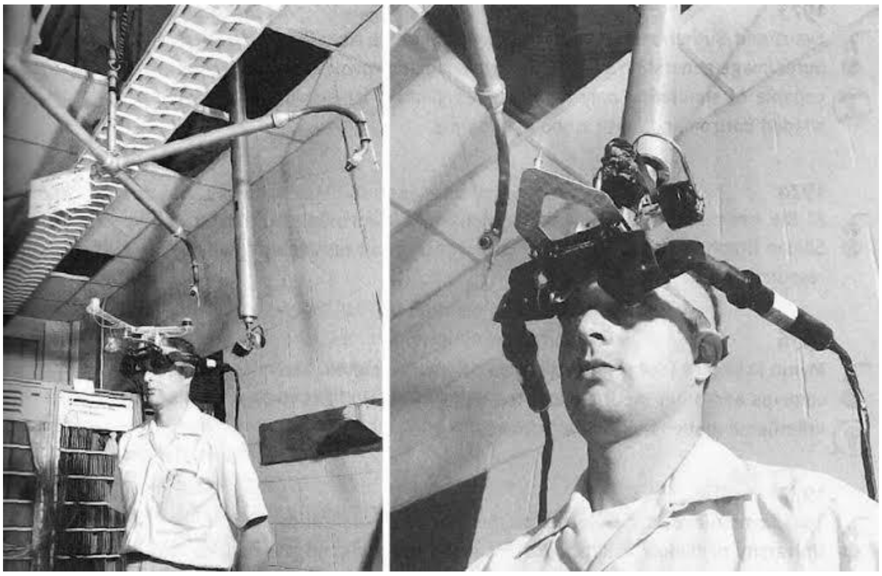


Figure 2.2: Sutherland's "Damocles' Sword" device

In subsequent years significant developments of VR were obtained in the field of air force pilots' training: in fact, progress in this field contributed to creating HMDs for virtual reality that was lighter and easier to handle, without the need for a cathode ray tube. After that, during the 80s of the last century, Tom Zimmerman invented the first virtual haptic glove, with which it was possible to interact in the virtual environment by manipulating virtual objects, albeit in a rudimentary way; soon after, Jaron Lanier's VPL Research developed the first model of a suit equipped with sensors that allowed to interact within virtual reality via the whole body (Riva & Gaggioli, 2019).

Figure 2.3: VPL DataSuit (left) and DataGlove (right) interface devices.

The journey above described led to the development of modern VR headsets: the Oculus VR company was founded in 2012 with the specific objective of developing VR and AR software programs and hardware components, and it came up with the release of Oculus VR DK1 and DK2 headsets. Google LLC Company officially released another kind of interface for VRE's visualization in 2014, it is the Google Cardboard device. Soon after Mark Zuckerberg's Meta society acquired "Oculus" company: the company developed and released the known "Oculus Rift" and "Meta Quest" VR headsets. In our study, we used the Meta Quest-2 HMD.

Figure 2.4: Meta-Quest 2

2.2: Fields of application of Virtual Reality:

VR is not just an advanced form of entertainment: in recent years it has become a powerful tool in the most diverse fields because of its enormous application potential. Nowadays this technology is used both for business, entertainment, or research purposes in different sectors, such as in medicine, psychology, aeronautics, design, arts, rehabilitation, videogames, museums, movies industry, education, and many others (Ambrosio & Fidalgo., 2020). Concerning the healthcare medical system, VR has proven effective for several purposes: as reported by Javaid & Haleem (2020) this technology provided new opportunities for the interaction with the human body, for the 3D visualization of tissues; it is used for the training and practice of doctors and surgeons and it provides assistance during medical operations in order to improve surgical skills and reduce human errors' probability (Javaid & Haleem, 2020).

Virtual Reality is a revolutionary tool also for the mental healthcare sector, where it is already adopted with auspicious results: indeed, according to Freeman and colleagues (2017) this technology allows for the creation of interactive three-dimensional environments where individuals can experience an actual sense of presence and such a high degree of control over stimuli that is impossible to achieve in real life; this specific property of virtual environments is what makes them innovative tools for the treatment of mental disorders. In fact, many individuals with mental-related issues experience difficulties when interacting with the outside world: it is the case for anxiety disorders, phobias, panic attacks, post-traumatic stress disorder (PTSD), addiction, persecutory thinking, and many others. Through VR simulations these individuals can be repeatedly exposed to triggering situations they know aren't real, while their bodies and brains will react as if the stimuli were actually present. This allows patients to face difficult situations more easily and to learn how to respond effectively to perceived threats, avoiding dysfunctional responses; this learning can be later transferred to everyday life with a high degree of effectiveness (Freeman et al., 2017). Many examples can be found in literature, such as the study conducted by Garcia-Palacios et al. (2002), in which they used a VR application called "SpiderWorld" aimed at exposing participants who suffered from arachnophobia to virtual spiders, effectively reducing their symptoms (Garcia-Palacios et al., 2002). We exemplified the use of VR in psychology specifically for clinical treatment purposes, but as highlighted by Freeman (2008) the virtual technologies can be used also for diagnosis, for assessing mental disorders-related symptoms, for establishing predictive or causal factors and for investigating toxic features present in the environment.

- 2.2.1. Virtual reality for educational purposes: sustainability and ocean warming.

Virtual reality has proved to be an innovative and helpful resource also for educational purposes in various fields because it provides a fascinating and absorbing way of acquiring knowledge: it often happens that students find it difficult to understand scientific concepts because these are complex and abstract, or it happens that teachers need better teaching strategies to meet the needs of all their pupils, or again it may happen that undergraduates have limited possibilities to practice outside the laboratories what they learn inside them: for these and many other reasons researchers are looking at new technologies as tools for solving these difficulties. VR may serve this purpose: in fact, the interactivity of virtual technologies encourages effective learning processes, because they facilitate active learning. (Kaminska et al., 2019). Allcoat & Von Mühlenen (2018) tested participants' learning in three different conditions: traditional textbooks, VR, video. The results showed better knowledge acquisition, understanding and memory in the VR group compared to the other two conditions; also, participants in the VR group showed enhanced positive emotions and higher engagement's levels.

VR can be used in the educational field to raise awareness and communicate important issues such as climate change and environmental sustainability. There are many ways in which VR can be exploited for this purpose: trying to address the "psychological distance" is one of them. The concept of psychological distance is fundamental to consider when trying to raise awareness toward these topics because it constitutes a key barrier toward public engagement with PEBs. According to Jones et al., (2017) people often think of climate change aftermaths as a psychologically distant problem, which means that those people see climate change as a set of ambiguous events distant in place and time that will affect other individuals (Jones, Hine & Marks., 2017). Bar-Anan and colleagues (2007) conceptualized the “Construal Level Theory (CLT)”, a model to try and explain how people will engage in future events and phenomena: according to the authors the distance from events that an individual may perceive depends upon its mental representation. As soon as the perceived gap increases those events will be represented in a more abstract and generalized way, while on the contrary as the distance decreases phenomena will be represented as closer and concrete. Bar-Anan and co-authors listed four dimensions of psychological distance, namely geographical distance, temporal distance, social distance and the fourth factor was uncertainty intended as the perceived likelihood of the occurring of an event (Bar-Anan, Liberman & Trope., 2006). Spence et al. (2012) investigated the four dimensions theorized by Bar-Anan in relation to the topic of climate change and sustainability using a British sample and they found out that lower perceived psychological distance was associated with higher concern toward this issue (Spence, Poortinga & Pidgeon., 2012).

Virtual environment’s experiences can be focused on the psychological distance, trying to reduce it by making people feel closer to environmental issues through perspective-taking process: according to Batson et al. (1997) this process works by simulating situations in which individuals have to put themselves in someone else’s shoes (Batson et al., 1997), and it can result in greater helping and altruistic behaviors (Ahn et al., 2013). The process of perspective-taking can also be referred to with the term “embodiment”, which literally means placing and seeing oneself in another body and feeling as if that body was our own (Wiederhold., 2020). Ahn et al. (2016) applied the concept of perspective-taking to the relationship between humans and nature, trying to promote pro-environmental attitudes and behaviors using an interactive IVE. The authors hypothesized that taking animals or nature’s perspective would induce feelings of concern and caring for nature, consequently promoting greater empathy and involvement toward environmental issues. To test this hypothesis, Ahn and colleagues conducted three experiments in which they compared embodiment conditions in IVEs with a condition involving passively watching a video of the same experience on a computer screen. The VR embodiment conditions implied either taking the perspective of a cow in a pasture (the task required to go around the field feeding the embodied avatar and being later transported on a truck) or a coral in an acidifying ocean (in which participants observed their coral body being corroded) while haptic and audio feedbacks were provided. The results showed greater embodiment’s sensations, feeling of physical presence and interconnection between the nature and the self in the IVE conditions compared to the control passive condition. The enhanced feelings of involvement with nature elicited higher risk perceptions, awareness and caring toward the natural environment which lasted for 1 week.

Another example of a study involving the use of embodiment processes to raise awareness of climate change related issues and to promote PEBs is the one conducted by Markowitz et al. (2018): in this study the experimenters explored the effectiveness of VR simulations in educating high school students, university students and adults about climate change and ocean acidification. The authors implemented an immersive VRE allowing the subjects to embody either a coral avatar or a scuba diver, where they could experience the harmful effects of acidity on coral reefs and underwater life in general. The results revealed that the participants' knowledge about the topic increased after the VR simulation's experience for both coral and scuba diver conditions, and those who were more prone to explore the virtual environment and those who reported greater sense of presence tended to acquire more knowledge and greater concern about environmental issues: these results suggest that the interactive properties of VR were effective in achieving the goal (Markowitz et al., 2018). Another fundamental aspect is that people may not have a clear idea of cause-effect relationships regarding climate change; in fact, as explained by Ahn and colleagues (2016) relations among anthropogenic causes and their consequences over Earth's climate are characterized by temporal distance, and this leads people to underestimate the negative consequences: indeed, as we explained above, temporal distance is one of the causes for psychological distance. An effective solution to this problem is to make people personally experience climate change related issues, because it is a way to reduce this perceived distance in time (Rajecki, 1982) and VR can serve this purpose. Furthermore, the public may hold personal environmental values but may lack sufficient knowledge, reducing the engagement in PEBs (Scurati et al 2021). Different studies exploited the potential of VR for this purpose, since virtual reality offers to designers, developers, and engineers a great number of opportunities to use creativity and imagination for ideating new experiences. One example of a VR application facing this issue is the "Embodied Weather" from Ke et al. (2019), an immersive multi-sensory VR simulation aimed at enhancing people' understanding of extreme weather phenomena in Hong Kong and at promoting PEBs among citizens (specifically household energy consumptions). "Embodied Weather" uses audio, visual, and tactile feedbacks to provide an immersive simulation of typhoons and other extreme weather conditions; the user is also provided with the possibility to enter a domestic environment, where they are able to control energy consumptions of several electrical appliances: the authors finally implemented an algorithm to simulate Hong Kong's future climate according to the users' energy expenditure (Ke et al., 2019).

Apart from temporal distance in cause-effect relationships, there is also physical distance that has to be taken into consideration: in fact, it is not possible for everyone to easily reach places like coral reefs or glaciers; moreover, as Scurati et al. (2021) highlighted, the recent COVID-19 pandemic has emphasized this condition. The distance from natural environments can be reduced using VR interfaces, which also allow fewer polluting consumptions because virtual trips do not require fuel (Scurati et al., 2021). Nim et al. (2016) presented a mixed-reality environment conceived for communicating individual behaviors and their effects on the GBR survival. The set up consisted of an immersive tour of a GBR projected on a tiled display that allowed the visualization of coral bleaching and death phenomena. The authors also collected each user's water and carbon footprint emissions and used the results to provide individualised feedbacks through HMDs, showing different degrees of GBRs' harms (Nim et al., 2016).

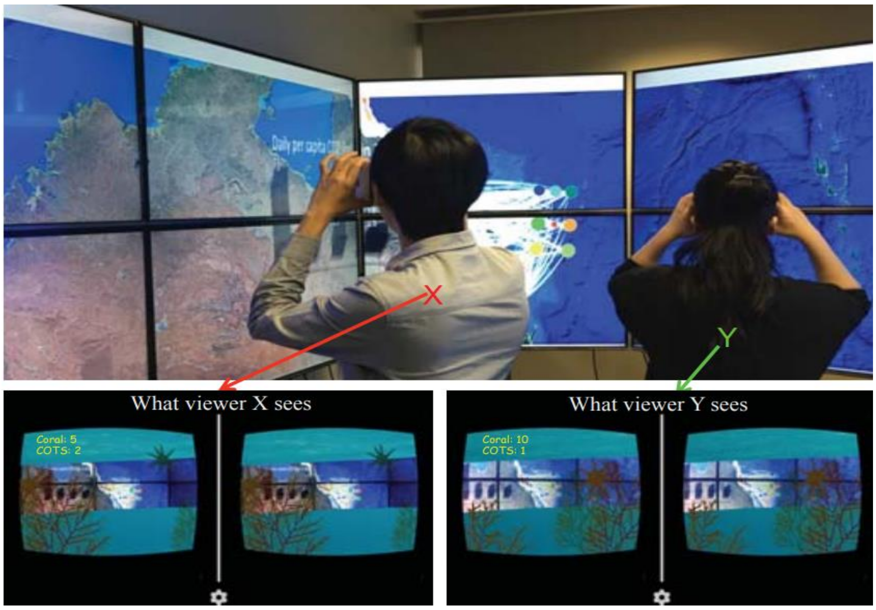


Figure 2.5: mixed-reality application from Nim et al., (2016)

2.3: Immersive VR applications' assessment

When conducting psychological research using Virtual Reality it is necessary to consider certain variables that might influence and shape participants' virtual experience and involvement. This is why there is a debate about the psychological measurements to be collected when evaluating a VR application. We will give a general overview of the topic, providing definitions for the main variables and highlighting the measurement methods that have emerged from the literature.

Let's start considering embodiment and body ownership which, as we defined above, can be considered as the capacity to change one's perspective in a VRE in favor of another point of view: understanding the levels of virtual embodiment's illusion provided by a VR simulation is fundamental because it has concrete implications for research purposes, allowing for psychological proximity with the embodied character (Markowitz 2021) and enhancing the learning power of the application (also called "Embodied Learning") (Lindgren & Glenberg., 2013). The scientific literature lacks a standardized measure for embodiment: as reported by Gonzalez-Franco & Peck (2018), previous studies in the field used qualitative and quantitative assessments such as skin-conductance responses, electroencephalogram (EEG), heart-rate responses (ECG), and various questionnaires. However, questionnaires still remain the most commonly used instrument: studies aimed at comparing quantitative and qualitative embodiment's measures demonstrated existing correlations among the two, therefore self-report questionnaire may reasonably be a reliable measure for assessing embodiment (Gonzalez-Franco & Peck., 2018). Despite these results, Roth & Latoschik (2020) highlighted that ad-hoc standardized self-report questionnaires do not exist: in fact, most of the assessment's measures derived from the famous experimental paradigm called "the rubber hand illusion" (RHI); also, embodiment is also commonly assessed through single-item measures. In order to solve this problem, the authors constructed a data-driven validated questionnaire which they called "Virtual Embodiment Questionnaire (VEQ) (Roth & Latoschik, 2020). We are going to describe it more in details in the next chapter.

Another fundamental variable to be measured to evaluate the effectiveness of a VR application is the so called "Sense of Presence": it has been defined by Witmer & Singer (2005) as the "psychological state of being there, mediated by an environment that engages our senses, captures our attention, and fosters our active involvement". Starting from this moment a debate arose which another author, Mel Slater, also entered providing a different definition: according to him, presence can be considered as the "state of consciousness that may be concomitant with immersion and it is related to a sense of being in a place" (Slater, 1997). As for the embodiment, the scientific literature highlights different ways and tools to measure the sense of presence too: on one hand there are physiological measures such as ECG, EEG, and skin-conductance response, on the other hand there are self-report questionnaires which comprehend the widely used Witmer & Singer's presence questionnaire (PQ), a 32-item validated questionnaire (Witmer & Singer, 1998) and the Slater-Usoh-Steed questionnaire (SUS), a 6-item validated questionnaire (Slater, Usoh, Steed., 1994).

User eXperience (UX) is another essential aspect to be assessed when doing research using VR: it is a very known topic in the Human-Computer Interaction field, and it has been defined as follows: "The user's perceptions and responses resulting from the use of a system or a service" ISO 9241-210, 2009). As it happened for the definition of VR, also in this case different definitions have been provided depending on where the focus is oriented, whether on the user (more psychological focus, hedonic qualities) or on the device (more technical focus, pragmatic qualities). The first author who theorized this distinction was Hassenzahl (2008), who provided a model of UX based on pragmatic (supporting do-goals) as well as hedonic qualities (supporting be-goals). However, there is still no shared standard model in the literature for the evaluation of UX in the field of VR simulations; different authors have hypothesized and tested different comprehensive models for VR UX and its components: for instance, Tcha-Tokey et al. (2018) proposed and validated the "User eXperience in Immersive Virtual Environment (UXIVE)" model, which comprehended variables such as flow, presence and experience's consequences and their subcategories.

Also for the assessment strategies of UX in VR there are no standards; different scales and questionnaires can be adopted in this regard: one example of a questionnaire commonly used is the User Experience Questionnaire (UEQ) from Schrepp and colleagues (2008), which the authors successfully validated in a series of studies; the factors underlying this questionnaire are attractiveness, perspicuity, efficiency, dependability, stimulation and novelty.

The last variable important to consider is the so called "Cybersickness" that can be experienced by some individuals in VREs: in fact, immersive VR might cause discomfort and unpleasant sensations, which obviously negatively affect the participants' experience and evaluation of the experience. Cybersickness might depend upon several factors, from individual differences to the duration of the VR experience (Scurati et al., 2021). According to LaViola (2000), cybersickness symptoms are similar to those of classical motion sickness (the type of sickness usually experienced by some individuals when approaching roller coasters); what changes though is the fact that cybersickness does not imply real movements, instead the individual remains stationary while experiencing illusion of motion; in fact, cybersickness is caused by a perception mismatch between visual and vestibular information: the visual system is stimulated by information that suggests that the body is moving, while the vestibular system receives feedbacks from the body suggesting that the person is actually stationary. Common reported symptoms are headache, sweating, dryness of mouth, vertigo, nausea, and disorientation. Unfortunately, there is not a single solution for eliminating the problem: among possible reduction strategies there are motion platforms (VR walking platforms such as the "Virtualizer VR Treadmill"), direct vestibular stimulations or adaptation paradigms (LaViola, 2000).

CHAPTER 3:

Envisioning Corals Project

Introduction:

We will dedicate chapter three to a detailed description of our study. We will start by underlining the different multidisciplinary aspects of our project, then we will proceed to provide an account of the core features of "Envisioning Corals", a VR application that we ideated and designed to raise awareness toward coral bleaching phenomena and communicate environmental sustainability among citizens. We will also focus on the structure of the self-report questionnaire we built, based on previously validated items, and then we will illustrate the experimental design we conceived. Finally, we will provide the reader with a list of the main hypotheses we wanted to test in our research. To give the reader an overall idea, with the present study we aimed at testing the User Experience (UX) and the learning properties of Envisioning Corals', an explorable IVE that reproduces a cartoonish-styled version of a GBR: to do so, we relied on the construction of a self-report questionnaire that we administered to participants after the "Envisioning Corals" immersive experience. Our simulation offers users the opportunity to choose among three different animal characters (coral, hermit crab, sea turtle) with which they can immerse in the GBR while listening to informative audio and engaging in a short game. We aimed at specifically comparing these three embodiment options, which indeed constituted the three experimental conditions in our study, in terms of the Sense of Presence, Embodiment, overall UX, and Learning Motivation elicited. Our research follows the growing body of scientific evidence, analyzed in the previous chapter, demonstrating the effectiveness of using VR technologies for educational purposes, especially in the field of climate change and sustainability (Kaminska et al., 2019; Quieroz et al., 2018; Fauville et al., 2020; Quieroz et al., 2022).

We had the possibility to conduct our study inside the MIBTEC (Mind and Behavior Technological Center) facilities; MIBTEC is a high-level research center from the University of Milano-Bicocca, which is aimed at gathering academics from psychological and technological areas interested in Virtual Reality, Augmented Reality, and Mixed Reality. We believe that the immersive properties of our virtual environment, combined with the ability to embody a virtual animal character, allow users to feel more connected to nature and facilitate greater awareness of climate change and its anthropogenic implications through the educative audio we implemented. However, before delving into the educational aspects of our application, it was necessary to evaluate the User Experience (UX) and consider the aspects related to the Sense of Presence and Embodiment. These data are crucial for developing the most effective version of our simulation in terms of efficacy; this is why our research is configured primarily as a usability study, which also investigates on an exploratory basis the aspects of "Envisioning Corals" related to the ability to raise awareness and to transmit the pro-environmental message.

3.1 The importance of multidisciplinarity in our research:

Envisioning Corals has been developed by a multidisciplinary research team composed of members from MIBTEC, Politecnico di Milano, and Marhe Center. The idea of the project has been born within the MIBTEC facilities and their research group, who involved Doctor Paolo Boffi, a Ph.D. student of computer engineering from Politecnico di Milano (POLIMI), in the developmental phase of the project under the supervision of Professor Pierluca Lanzi. The main elements related to the design of the virtual environment have been implemented by Doctor Marco Muolo, a graduate designer from Politecnico di Milano (POLIMI). The MIBTEC research group took care of the ideation, teamwork management, and UX validation of the Envisioning Corals application.

The VE has been conceived to support the line of research of Professor Alberto Gallace regarding the use of VR applications for educational purposes and for communicating sustainability. The content aspects related to marine biology and marine science were kindly provided by the Marine Research and High Education Center (MaRHE center) of UNIMIB located in the Maldives, a center that carries out research and educational activities in the fields of environmental science and marine biology. We believe that multidisciplinarity is a key element in our work and, as supported by previously mentioned literature, in designing VEs for sustainability education. According to Brewer (1999), multidisciplinarity can be defined as the integration of knowledge and methodologies from different disciplines to address complex scientific problems; modern scientific research can be highly challenging, but the interdisciplinary collaboration among various experts can lead to faster advancement in human understanding of complex scientific questions and it can surely help researchers in solving such challenges (Brewer, 1999). To provide an example, the climate change phenomenon is studied by disciplines reunited under the name of "environmental sciences"; according to Uiterkamp & Vlek (2007), environmental sciences are multidisciplinary by definition, indeed we can effortlessly imagine how many scientists work on it: physicists, computer scientists, biologists, chemists as well as psychologists, engineers, history and geography experts, but also economists, policy and ethics experts, all these professionals and many others must work together to provide a comprehensive understanding of the issue (Uiterkamp & Vlek, 2007).

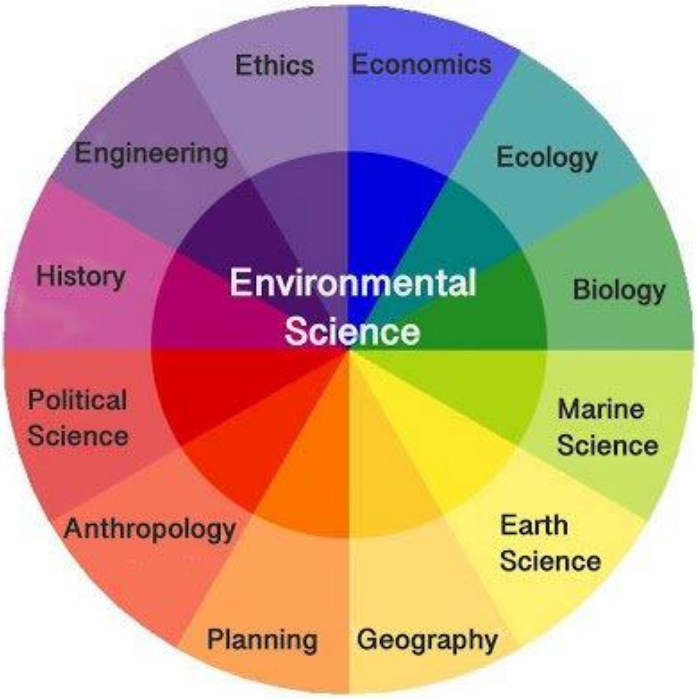


Figure 3.1: Different disciplines under the umbrella term "Environmental Science".

Multidisciplinarity is also a key element in promoting innovation. Thus, being able to bring together a diversity of perspectives and approaches that lead to significant and impactful results in the development of new creative and effective solutions, that otherwise would not have been possible. In fact, multidisciplinarity promotes cross-disciplinary collaboration and communication, which can help break down barriers between diverse fields. Additionally, multidisciplinarity enables the integration of various data and methods which can lead to more accurate and reliable results.

We believe it is important to emphasize the multidisciplinary nature of our work because it has allowed each member to contribute by bringing their unique knowledge, skills, and expertise to the project and it has also allowed us to learn from other fields in a highly stimulating professional environment; in fact, multidisciplinary research provides a more comprehensive and nuanced understanding and it enables researchers to consider different perspectives toward a problem and account for their interrelationships (Gobet, 2018). However, multidisciplinarity is not without its challenges: collaborating across disciplines can be difficult due to different languages, cultures, and approaches to research. Since VR is a rapidly evolving field that has the potential to revolutionize several industries (from entertainment to education and the healthcare system), multidisciplinarity in this realm of research is crucial for driving innovation and addressing the complex challenges posed by this technology.

In conclusion, we think that multidisciplinarity is a vital aspect of scientific research, and that is why we conceived Envisioning Corals' project as a multidisciplinary work, to which experts in computer science and engineering, design, marine biology, and psychology made their contribution.

Figure 3.2: Envisioning Corals application

3.2 Description of the Envisioning Corals application

- **3.2.1: The aims**

Since previous studies demonstrated how VR can be an effective and engaging tool for encouraging users' learning and for raising awareness, we decided to develop an application that would fit within this theoretical framework (Sheehan et al., 2020; Ferrer et al., 2020) . Based on the existing scientific literature we ideated and tested an immersive VR application that we emblematically called "Envisioning Corals", aimed at informing and raising awareness about the coral bleaching phenomena and promoting PEBs among the general public. We decided to give our simulation the look and features of a videogame, since Scurati et al. (2021) highlighted the fact that, among all the existing VR experiences in the field of environmental sustainability education, only eight simulations (corresponding to 15% of the total amount of studies reviewed by the author) were actual games. According to Scurati, serious games are functional for the purpose because they raise awareness and provide knowledge through the stimulation of engagement; also, games help simplify complex concepts using more intuitive graphic solutions (Scurati et al., 2021).

Our application allows participants to virtually see themselves in the body of a GBR's inhabitant (a coral, a hermit crab, or a sea turtle) and to experience first-hand the effects of increased water temperatures on GBRs. The aims of Envisioning Corals application can be divided into 4 areas:

1. *Education*: the IVE provided by the simulation would bring a unique and interactive educational experience, allowing participants to learn about coral bleaching's causes and consequences in a highly engaging and interactive way. By immersing participants in a virtual underwater world, the application would aim to increase their understanding of the critical importance of coral reefs and the role they play in the ecosystem.
2. *Awareness*: our VR simulation aims at raising awareness about coral reefs and the threats posed by coral bleaching; it aims at communicating the need for conservation efforts, in order to increase public interest in the issue and to inspire people to take action to protect these valuable ecosystems.
3. *Behavior change*: Envisioning Corals also aims at promoting behavior change by encouraging greater adoption of PEBs, stressing the importance of reducing the impact of climate change on oceans and supporting coral reef conservation through our daily actions.
4. *Research purposes*: our study is primarily focuses on UX research, but we also aimed at contributing to the scientific understanding of the impact of VR immersive educational simulations on public awareness and environmental education. Our study's results are important for improving the experience and the interaction between users and the application, and they could be used to inform future VR educational applications.

- **3.2.2: The application**

We will now discuss the content of the virtual immersive simulation. The Envisioning Corals application consists of two parts: at first, as soon as the users put on the headset, they will find themselves immersed in the virtual reproduction of MIBTEC laboratories (Figure 3.4), where they have the opportunity to settle in and familiarize themselves with the controller's commands. The second phase consists of a gamified version of a GBR, where participants are asked to listen to some informative audio before and after having played a short game.

Going further into detail, the first phase of the simulation could be seen as a training phase, in the sense that it serves to make the subject learn the necessary commands to teleport. Indeed, the application does not require participants to move around; instead, we implemented an intuitive teleport function: whenever the users wish to move within the IVE, they will simply have to press the trigger button (Figure 3.3) on the Oculus controller and direct it to the desired position. As soon as the participants release the trigger button, they will be instantly transported to the chosen location. We decided to use the teleporting modality in the present study as we tested it in our previous study, and we demonstrated the ability of teleportation to minimize cybersickness symptoms in the users (Clerici et al., 2022). In this first part of the simulation, participants do not see their whole virtual body, but they can just see their virtual hands that move by imitating real hand movements (Figure 3.4).

Figure 3.3: Trigger button on the Oculus Quest-2 controller

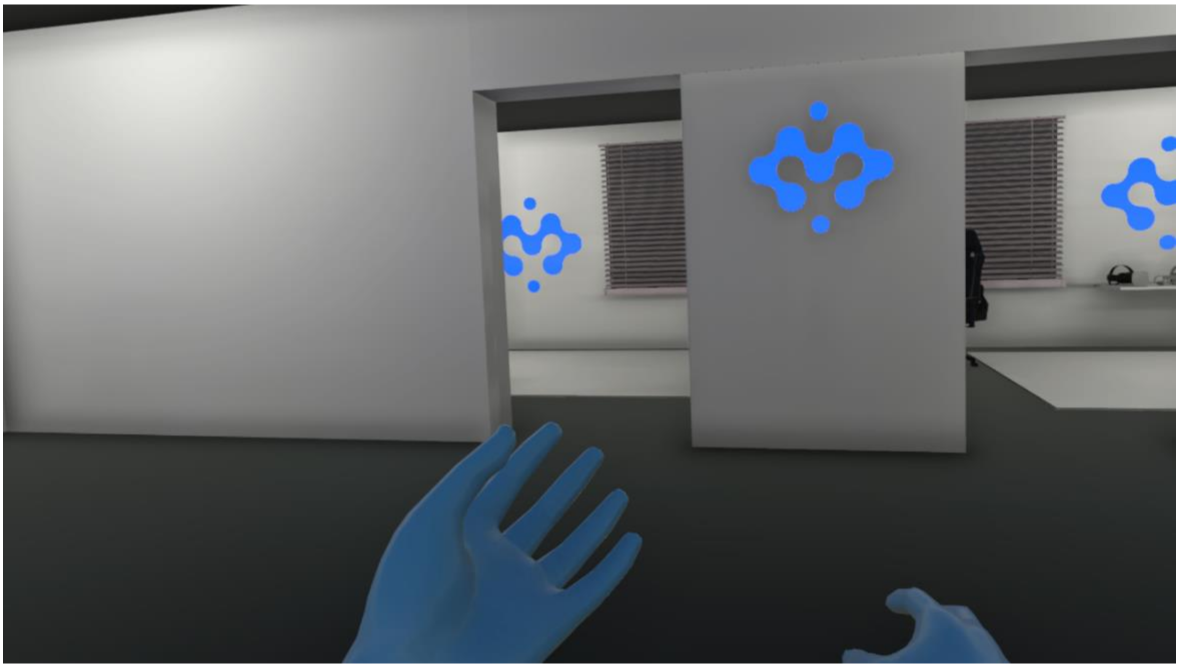


Figure 3.4: First virtual environment that is encountered when playing Envisioning Corals: virtual reproduction of MIBTEC laboratories.

Soon after the participants have familiarized themselves with the environment and have learned how to move inside it, they will be asked to teleport themselves inside a specific room: here, the users will have to choose their avatar among three possibilities: a coral, a sea turtle, and a hermit crab. As soon as participants make their choice, they will be immediately teleported to the underwater environment; here, whatever animal the participants have chosen, the same scenario opens up in front of them: they will find themselves immersed in a cartoonish-styled GBR where they will first listen to a voice explaining where they are now and what they will have to do. On the left of the visual field, users will see a box containing 3 types of information: the year they are in, the average surface water temperature relative to that specific year, and a little counter for the food collected during the game phase. During the whole embodiment experience in the GBR, the passage of time from 1960 to 2020 will be simulated, and significant changes in the environment will occur: water temperatures will rise, food availability will diminish and the wonderful colors of GBR will fade, becoming opaque and desaturated.

As soon as the audio will stop the game will begin: it will require participants to get as much food as possible in the time available (2 and a half minutes) to feed their avatar. This playful part of the simulation differs in the three embodiment conditions for two aspects: the modalities for gathering food and the type of nourishment to procure In fact, in real-life conditions, corals are static animals while the other two can move around. Corals feed on plankton and other organic substances that swim near them, while hermit crabs and sea turtles move or swim in search of food; despite this, a substantial difference exists also between hermit crabs and sea turtles, as the latter swim in mid-water in search of food while hermit crabs move along the seabed. So, taking into account these differences we decided to reproduce them in our simulation: indeed, in the coral's embodiment condition, participants cannot move but they can only try to grab the organic particles that come close to them; instead, in the other two conditions, participants can teleport themselves all around the Envisioning Corals' GBR in order to get the food.

The game will end when the voice starts to speak again: the final audio explains to users the causes of the changes seen during the experience but at the same time it leaves them with a positive message.

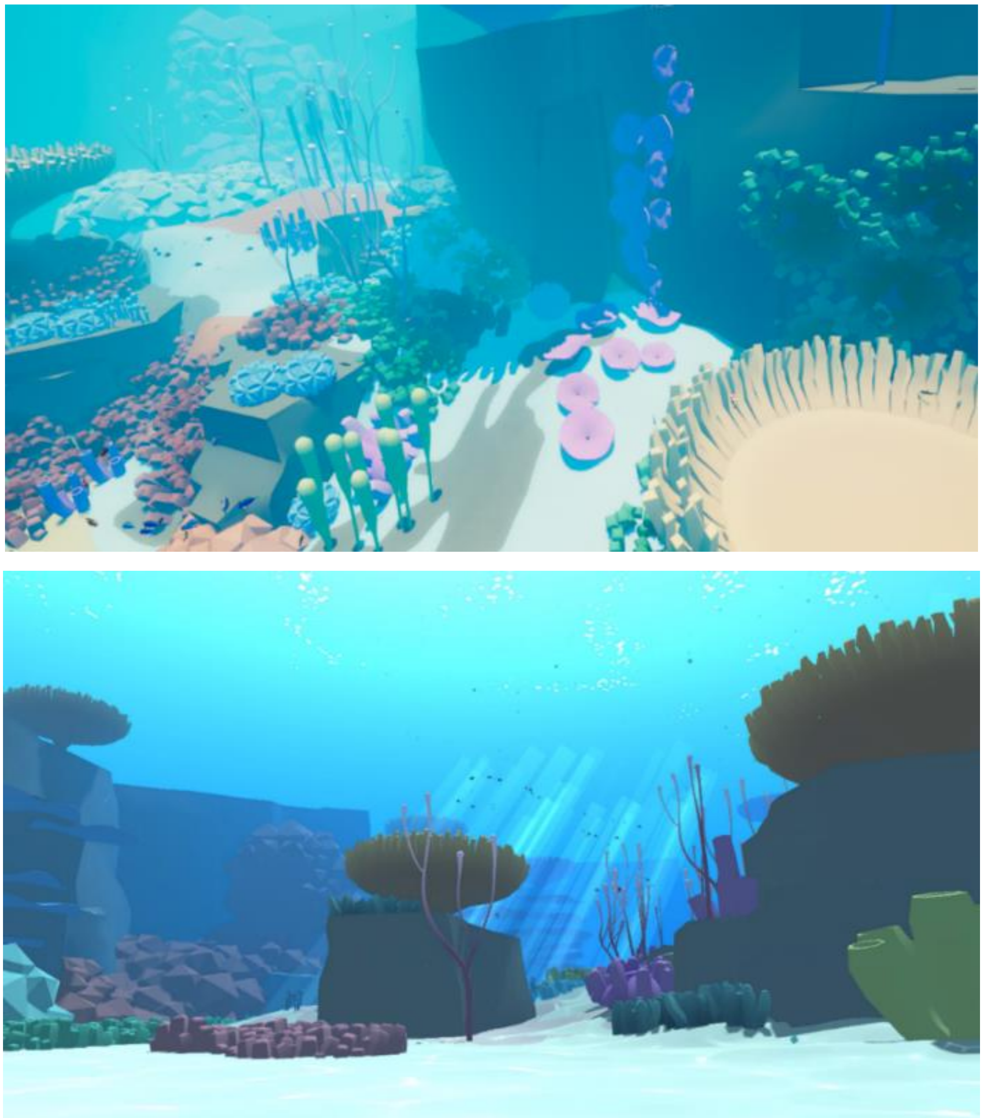


Figure 3.5: Envisioning Corals' GBR from the perspective of a sea turtle (right) and of a coral and a hermit crab (left)

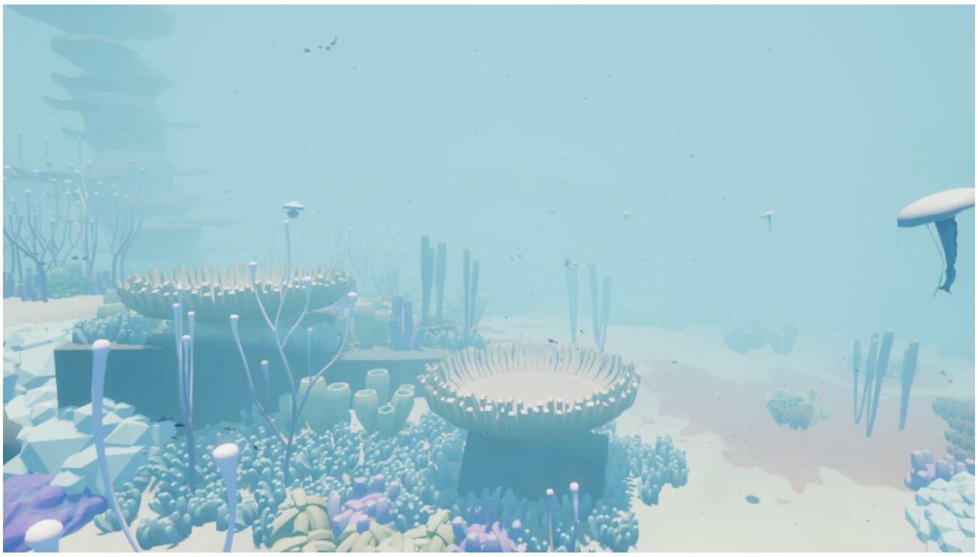


Figure 3.6. Colors fading during the immersive experience.

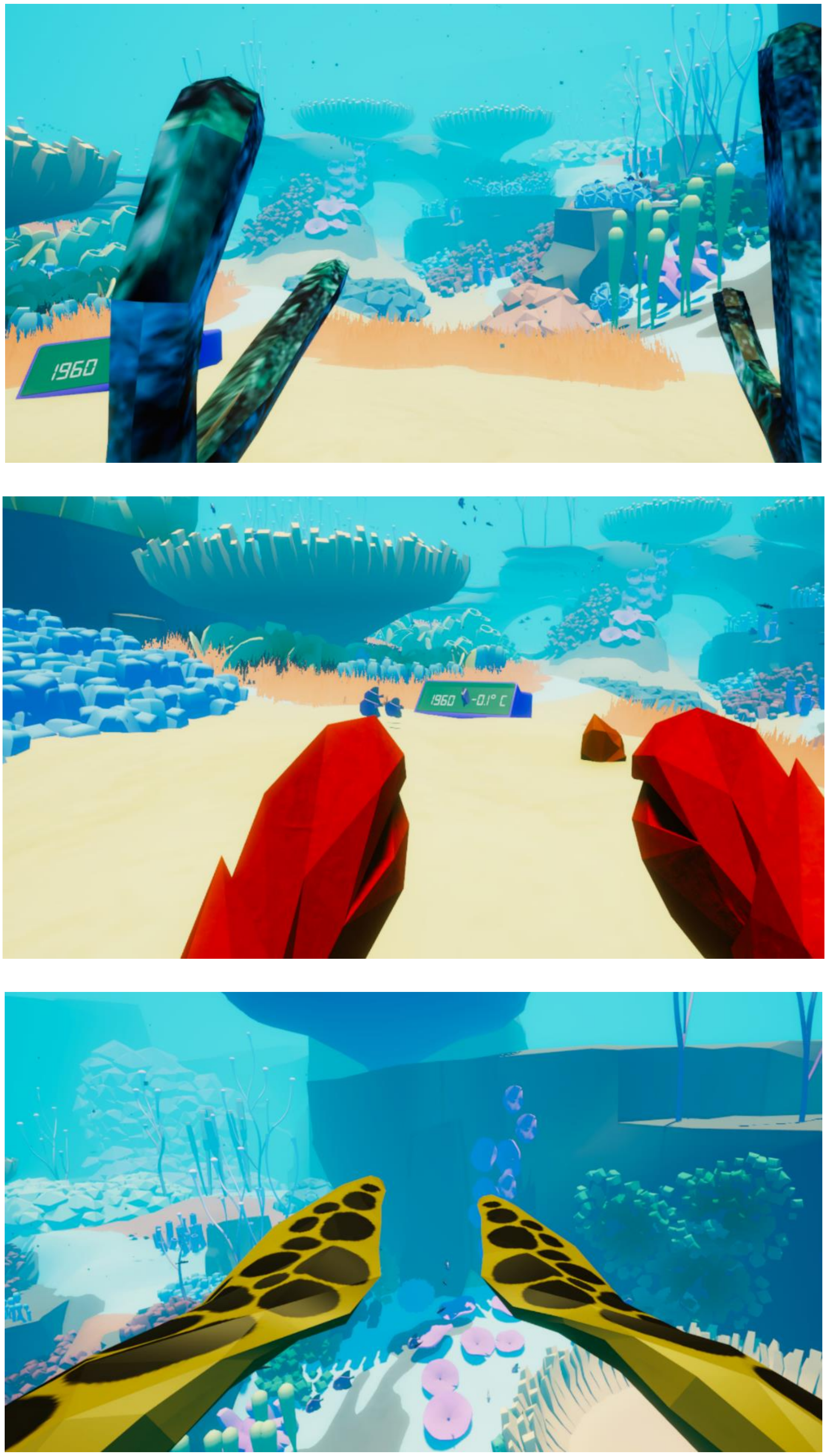


Figure 3.7: Embodiment conditions: Coral, Hermit Crab, Sea Turtle

3.3: Questionnaire outline

For our assessment goals, we developed a self-report questionnaire mainly based on validated scales that we administered to participants via Qualtrics Software, an intuitive web-based survey tool widely used by researchers. As previously mentioned, we conducted the assessment to test the following variables: the Sense of Presence, the Embodiment, the User Experience (UX), and the Learning Motivation. Unfortunately, as we highlighted in the previous chapter, there is no unanimous consensus regarding measurements strategies and procedures for experiments involving IVEs; based on previous studies, we decided to perform our data collection using self-reported measures (Tcha-Tokey et al., 2018; Ahn et al., 2016; Markowitz et al., 2018). To test our variables of interest, we designed a questionnaire consisting of four main blocks that corresponded to the four constructs mentioned above. For each measure, we relied on existing literature and used validated scales, while also adapting some items to fit the specific context of our research. Apart from Presence, Embodiment, UX, and Learning Motivation, we also wanted to investigate participants' familiarity with the VR technology as well as the strength and efficacy of the pro-environmental message provided by our application's contents.

In Figure 3.9 we provided a graphical representation of the questionnaire flow, to make the reader better understand the assessment methodology.

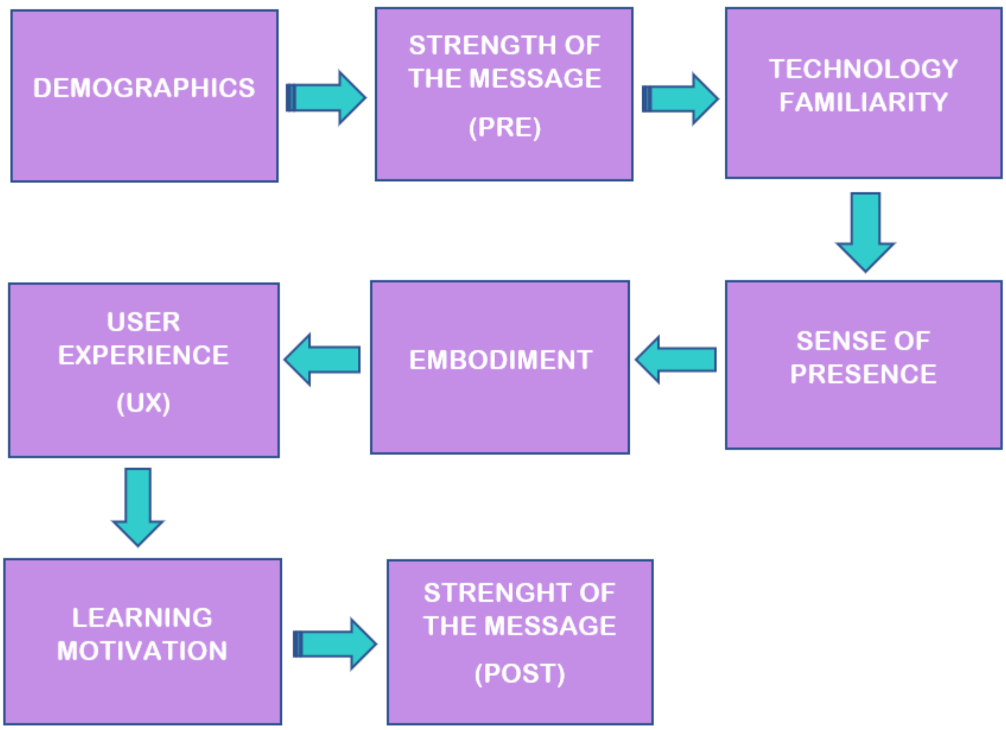


Figure 3.8: Questionnaire blocks outline

The questionnaire had a total of 44 items. The first part was completed by participants before wearing the Oculus Headset and trying the simulation. It consisted of a set of introductory questions concerning demographic information, namely age, gender, educational level, and field of work/study, followed by a multi-item measure for assessing environmental motives taken from the study by Schultz (2001): participants were asked to indicate their degree of concern about the effects of climate change respectively on themselves, on other people, and on other living beings. This specific measure was taken two times, before and after the virtual experience, in order to quantify the effect of our manipulation.

Then, after the "Envisioning Corals" experience, participants were asked to complete the second half of the survey. This part opened up with two customized items that we created to investigate the participants' familiarity with VR technology, and continued with the four main blocks, administered in this order:

1. *Sense of presence*: to investigate the sense of presence elicited by our application, we adopted the SUS Scale (Slater, Usoh, Steed., 1994), because it is a fairly short measure but at the same time it includes all the aspects we were interested in. The Slater-Usoh-Steed questionnaire consists of 6 items rated on a 1-7 Likert scale, plus one additional free-response question to collect eventual comments and feedback related to the Sense of Presence experienced in the IVE.

2. *Embodiment*: to assess embodiment sensations we relied on the VEQ (Virtual Embodiment Questionnaire) developed and validated by Roth & Latoschick (2020). The authors divided the embodiment construct into its sub-components, i.e., *Ownership*, *Agency,* and *Body Change*, and then they created 12 items (4 items for each sub-component) to be evaluated using a 1-7 Likert scale.

   We also added another item taken from Schultz (2001). It is a measure to investigate how much individuals feel interconnected with nature, or with the animal avatar in our case; indeed, we modified it to make it consistent with the purposes of our research. This item consists of seven pairs of Venn's circles gradually overlapping (one circle was labeled "self" and the other "animal"): participants were required to select the pair that best represented the connection they perceived with their virtual avatar during the virtual simulation. See Chapter 4 for a graphical representation of this scale.

3. *User Experience*: for the UX assessment we relied on the UEQ-S (User Experience Questionnaire, short version) created by Schrepp (2008) since it is an efficient measure, and possesses the characteristics we were interested in. This survey takes into consideration all the aspects related to UX, i.e., pragmatic qualities as well as hedonic qualities. It consists of 8 items, in the form of semantic differentials, to be rated using a 1-7 Likert scale. UEQ-S measures six factors of UX, namely *attractiveness*, *perspicuity*, *efficiency*, *dependability*, *stimulation*, and *novelty* (Schrepp et al. 2008).

4. *Learning motivation:* finally, we explored the motivation to learn elicited by our VR application. We used the IMMS (Instructional Materials Motivation Survey) from Keller's ARCS model approach (Keller, 2010). The ARCS model focuses on four dimensions, i.e., *attention*, *relevance*, *confidence*, and *satisfaction*. We decided to select only specific items from the original survey, those that seemed most relevant to us, and we slightly modified them to fit the context of our study. We ended up with 8 items, to be evaluated on a 1-5 Likert scale.

Finally, on an exploratory basis, we added a behavioral measure to be analyzed qualitatively: this measure involved a QR code provided by the experimenter, which participants could choose to scan or not. The experimental subjects were told that the QR code contained useful information and links to donate to associations concerned with safeguarding coral reefs. However, the code did not actually contain any donation links, because our main interest was to examine the participants' intentions to frame the code or not after trying "Envisioning Corals". Since previous literature has suggested that teleporting reduces the risk of Cybersickness symptoms in IVE (Clerici et al., 2022), we decided not to include cybersickness assessment in our questionnaire; rather we preferred to conduct an oral debriefing with the participant before starting the experiment, to establish whether he was more or less sensitive to motion-sickness and therefore to understand in which experimental group to place him. In fact, the coral was the best condition for the more sensitive subjects, as it did not require any kind of movement.

Table 1 summarizes all the sources, the scales, and the items we selected in our questionnaire.

Table 1

Overview of the Envisioning Corals questionnaire components

CONSTRUCT	SOURCE	SELECTED ITEMS	EXAMPLES	SCALE
Sense of presence	SUS Scale, Slater, Usoh, & Steed, (1995).	All	During the time of the experience, which was the strongest on the whole, your sense of being in the virtual environment or of being elsewhere?	Likert from 1 (totally disagree) to 7 (completely agree)
Embodiment	Virtual Embodiment Questionnaire, Roth & Latoschik (2020) + INS Schultz, (2001) adapted by Ahn et al. (2016)	All	It felt like the virtual body parts were my body parts	Likert from 1 (totally disagree) to 7 (completely agree)
User Experience (UX)	UEQ-S, Schrepp (2008)	Short Version	Obstructive – Supportive Boring – Exciting	Semantic Differentials
Learning Motivation	IMMS from ARCS, Keller (2010)	01, 05, 12, 16, 23, 24, 34, 36	I enjoyed this lesson so much that I would like to know more about this topic. This lesson was not relevant to my needs because I already knew most of it.	Likert from 1 to 5 (not at all – at all)
Strength of the message	Environmental concern scale, Schultz (2001)	All	I am concerned about environmental problems because of the consequences for plants, marine life, my lifestyle, my	Likert from 1 (not important) to 7 (supreme importance)

			future, people in my country, and all people.	

3.4 Experimental design

We conducted our study inside the MIBTEC facilities at the University of Milano-Bicocca. We recruited participants through social networks and via the Sona System of the UNIMIB; the inclusion criteria for participation concerned "age" and "nationality": based on previous literature, we decided to select a range between 18 and 35 years of age and a sample of Italian mother language people, as this first version of Envisioning Corals is available audio in the Italian language. We conceived the design of our study as follows:

1. *Cybersickness debriefing:* as we mentioned, we decided to conduct a short interview for cybersickness before starting, in order to understand if participants were new to VR and if they suffered from dizziness or general motion sickness (Kim et al., 2018).
2. *Questionnaire, first part*: the experimenter leaves the room while participants fill the first section of the questionnaire (Demographics plus "Environmental concern scale", Schultz., 2001).
3. *VR experience*: the experimenter re-enters the room and the participant wears the Oculus Quest-2 headset, entering the tutorial phase of the simulation: here the subjects learn how to use the controllers and then they are indicated which character to select; we randomly assigned participants to the three animal conditions (unless specific need due to cybersickness). After the tutorial phase, the participant enters the GBR environment and continues the immersive experience independently.
4. *Questionnaire, second part*: after the subject has finished the immersive experience, the experimenter re-enters the room and removes the headset from the subject. Then, participants are asked to complete the second part of the questionnaire (Technology Familiarity, Sense of Presence, Embodiment, User Experience, Learning Motivation, and again Environmental Concern scale).
5. *QR code:* as soon as the participant completes the questionnaire, the experimenter provides the subject with the QR code; after having explained what the QR code contains, the

experimenter asks participants if they wish to frame it or not and marks their answer on a computer file.

6. *Final debriefing*: lastly, the experimenter conducts a debriefing with the subjects to reveal to them the aims of the study before they leave the laboratory.

3.5: Research hypotheses

The present research was conducted to assess the usability of our "Envisioning Corals" virtual simulation; specifically, we aimed at comparing three different VR conditions (Coral, Hermit Crab, Sea Turtle) in terms of their impact on the Sense of Presence, Embodiment, User Experience, and Learning Motivation.

Based on the previous literature (Jones et al., 2017, Ahn et al., 2016, Weller et al., 2022, Fauville et al., 2020, Markowitz et al., 2021) we hypothesized that Envisioning Corals would reduce, thanks to its immersive properties, the distance perceived by some people toward environmental and sustainable issues. In this study, we focused our attention mainly on the immersive aspects of the application: we explored how much participants felt present in the IVE and how much they felt embodied in the virtual character; we also assessed both pragmatic and hedonic qualities of User Experience, as well as the learning motivation aspects elicited by the educational contents. Concerning the specific hypotheses of the present study, we speculated that our application would receive good and satisfying UX ratings and that there would be no significant differences either between the two components (pragmatic and hedonic aspects) or between the three experimental conditions (Hassenzhal., 2007, Greenfeld et al., 2018); in fact, we thought that our application would be effective in involving the participants and that they would find it easy and intuitive in its use. Regarding the construct of Sense of Presence, we hypothesized that the three conditions would have returned comparable results: in fact, even if the three conditions differ in some aspects (the food type, the fact that the coral remains static compared to the other two, and that the sea turtle swims in mid-water), in our opinion these would not have been sufficient to determine significant differences in terms of Presence sensations (Slater, 2018). We also expected participants to rate the level of Embodiment elicited by the application as satisfying, and we were interested in verifying whether there is any aspect that changes the perception of the embodiment for the three different animal characters (Ahn et al., 2016).

Finally, we decided to explore learning aspects, specifically how individuals perceived the educational contents provided by the application and how much they felt as if they could effectively learn from it. This idea stems from a body of literature that has demonstrated how different VR simulations can be effective in delivering educational content and how they can support educational goals through engagement (Markowitz et al., 2018, Nim et al., 2016, Ke et al., 2019). According to Allcoat et al., (2018), VR applications can serve the purpose thanks to their properties: immersion, interactivity, and ability to generate high engagement levels. For this variable, we have not hypothesized statistically significant differences between conditions since we do not expect the educational audio content to differ in complexity and clarity. Below, we will summarize the experimental hypotheses of our research team by dividing them into three:

H1: We hypothesize that our application will elicit an overall good degree of UX in the participants and that this result will be comparable in the three different conditions.

H2: We hypothesize that the three experimental conditions will not differ significantly in terms of the Sense of Presence and Embodiment.

H3: We hypothesize our application to possess useful properties for motivating learning in participants, and a propensity of them to feel able to learn from this experience.

Lastly, we decided to conduct an exploratory investigation on the effectiveness of "Envisioning Corals" in raising awareness and interest in the topics covered; we adopted the "Environmental concern scale" (Schultz, 2001) to qualitatively explore the effectiveness of the application in conveying the pro-environmental message. This will allow us to improve the audio content in the near future and create the best possible version of our application.

Finally, the "QR code" behavioral measure was also conceived as an exploratory qualitative assessment, to begin investigating whether our application elicits in the users the desire to learn more about sustainable issues and to do something to counteract coral bleaching phenomena. In this regard, we expect that most of the experimental subjects will be enticed, by the immersive experience, to agree to scan the QR code.

CHAPTER 4:

Results

4.1 Focus Live event:

Last November MiBTeC participated as a partner at “Focus Live”, an event organized by Focus every year. The three-day event was held at the Museum of Science and Technology “Leonardo Da Vinci” in Milan; here, our team had the opportunity to test for the first time the “Envisioning Corals” application on a large number of people. Furthermore, since the designer had to do data collection for his master’s thesis, we contributed by helping him create a short self-report questionnaire to be administered at the event. On that occasion, almost 200 people tried the VR application: we collected a total of 179 feedbacks and we considered those data as a first useful pilot study. Responses were collected from users with a varied age range: the sample went from 18 to 89 years old (60.3% were young adults, 36.9% were adults, and 2.8% were elders); participants also resulted balanced between males and females (49.7 % females, 48% males, 1.7% N/A, 0.6% other).

Figure 4.1: Focus Live poster and event.

The self-reported questionnaire included a measure of UX taken from the short version of the User Experience Questionnaire (UEQ), (Schrepp, 2008), the same we used in the present study; it also included a measure of Embodiment, specifically Schultz’s (2001) “Inclusion of nature in self” scale that we described in the previous chapter. Both UX and Embodiment measures were rated on a 1-7 Likert scale. Finally, the participants were asked to describe their experience with “Envisioning Corals” through three adjectives for qualitative feedback.

The results were as follows: concerning the Embodiment construct, participants reported positive results, with satisfying frequencies for the scores '4',' 5', and '6' (the Likert scale was rated 1-7, representing seven overlapping Venn diagrams labeled "self" and "animal". For a complete transcription of the survey, see the Appendix).

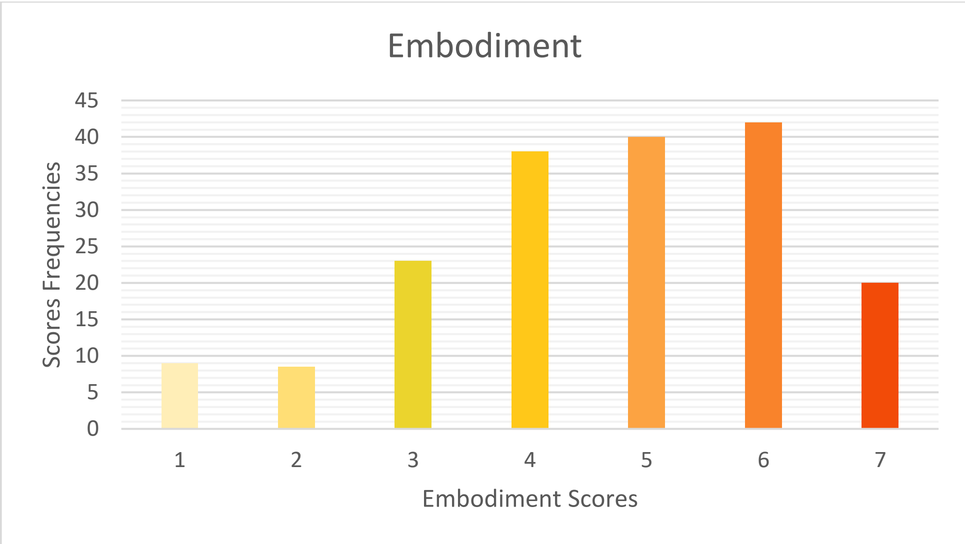


Figure 4.2: Frequencies for the Embodiment scores reported by participants.

Concerning User Experience, the range of the scale has been presented as a semantic differential with 7 points, then transformed in the following score: -3 (very bad) to +3 (very good) (Schrepp et al., 2008). We found extremely positive results, with users reporting feedback around +2 for each category.

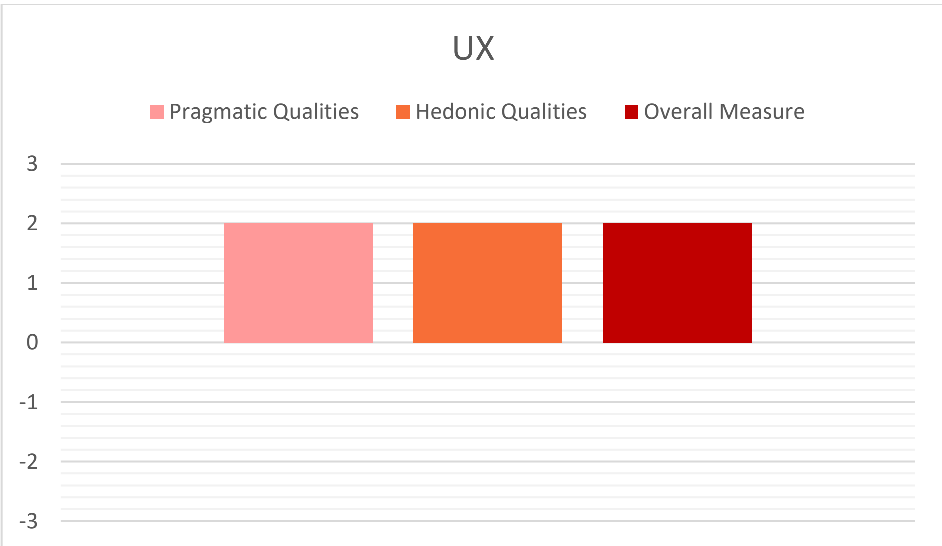


Figure 4.3: Mean scores for the UX construct.

Lastly, in Figure 4.4 the reader can appreciate the Italian adjectives provided by people at Focus Live to describe their experience with the immersive simulation: we re-elaborated the answers in the form of a word cloud.

Figure 4.4: words cloud representing users' responses.

In conclusion, we considered the data collected at the Focus Live event as a good starting point for the present usability study, since the results were very encouraging.

4.2 Laboratory-controlled study:

Since this first pilot has been performed in a more ecological, but less controlled, environment we decided to reproduce the data collection in a laboratory setting inside MiBTeC facilities. In this study, we re-assessed User Experience (Schrepp, 2008) and Embodiment (Roth & Latoschik, 2020) constructs, but we also investigated the Sense of Presence (Slater et al., 1994) and Learning Motivation (Keller, 1987).

- ### 4.2.1. Methodologies

Our study was conducted inside MiBTeC laboratories. Participants completed the first part of the questionnaire (demographics, plus 9 items from the "Environmental Motives Scale" Schultz, 2001) before trying the VR application. The questionnaire was administered via Qualtrics Software with a University of Milano Bicocca license. We used an HP OMEN-X 900- 010 Gaming Cube Desktop with an OMEN BY HP 25 monitor for running the application, and the Oculus Quest-2 devices for providing the immersive simulation. After the virtual experience, participants completed the second half of the questionnaire. Lastly, the experimenter administered a final behavioral measure by showing participants a QR code; participants had the option to choose whether or not to frame it. The QR code was presented as containing links to donate to GBR protection associations, although it actually did not contain any links.

Finally, experimenters conducted a debriefing with participants, to reveal to them the real purpose of the study. The experimental session was conceived to last 40 minutes, divided as follows: 5 minutes for the survey's first completion, 10 minutes for the VR experience (5 minutes for initial instructions, 5 minutes for immersive experience), 15 minutes for completing the questionnaire and 10 minutes for the final debriefing with participants.

- 4.2.2. Sample Characteristics

We recruited a final sample of N = 33 participants (N = 20 females; N = 13 males), divided into three conditions: Coral (N = 14), Hermit Crab (N = 10), and Sea Turtle (N = 9). In the initial screening phase, we had to exclude two participants from the final sample, because of partial completion of the questionnaire's responses due to technical issues involving the Qualtrics software.

We decided to test only young adults between 18 and 35 years old (M=24.8, SD = 2.51) accordingly to similar case studies found in the literature (Ahn et al., 2016); 39.4% of the sample was constituted of males, while the remaining 60.6% was constituted by female subjects. The majority of participants reached a bachelor's degree level education (N = 16, 48.5% of the total sample). A summary of the demographics of our sample can be found in Table 2. Also, analyzing the data from the Technology Familiarity assessment, we found a mean score of 1.97 (measured with a 1-5 scale) indicating a low level of familiarity with VR technologies. Results are provided in table 3.

Table 2.

Demographic characteristics of the sample

Baseline characteristic	Corals		Hermit Crabs		Sea Turtles		Full sample	
	n		*n*		*n*		*n*	%
Gender								
Female	10		6		4		20	60.6
Male	4		4		5		13	39.4
Highest educational level								
High school Diploma	3		3		3		9	27.3
Bachelor's Degree	5		7		4		16	48.5
Master's Degree	5		0		2		7	21.2
PhD or superior	1		0		0		1	3.0
	M	*Mdn*	*M*	*Mdn*	*M*	*Mdn*	*M*	*Mdn*
Age	24.6	25.0	24.7	25.0	25.3	25	24.8	25

Note: *We recruited a total amount of N = 33 participants, divided into three conditions CORAL (N = 14), HERMIT CRAB (N = 10), and SEA TURTLE (N = 9).*

Table 3

Descriptives	
	TECH_FAMILIARITY
N	33
Missing	0
Mean	1.97
Median	2.00
Mode	1.00
Standard deviation	1.02
Minimum	1.00
Maximum	4.50

4.3: Quantitative measures

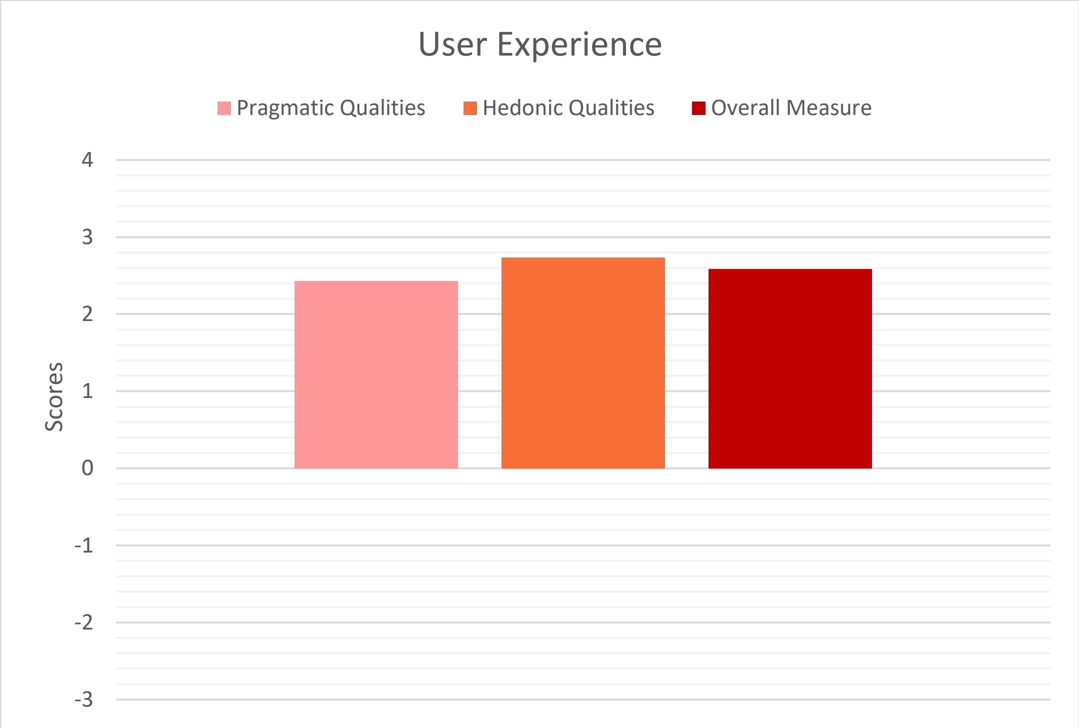
- ### 4.3.1 User Experience (UX)

Regarding UX measure we hypothesized to find a good and satisfying level of UX, concerning both pragmatic and hedonic qualities. For the assessment we decided to use the User Experience Questionnaire, the short version (Schrepp et al., 2008). The 8 items are presented as semantic differentials; each couple of adjectives has been evaluated through a 7- points Likert scale, with positive adjectives coupled with the highest point of the scale and the opposite for the negative ones. Furthermore, items have been grouped into two main components: Pragmatic Qualities and Hedonic Qualities. Results are summarized in Table 4 and Figure 4.5. Looking at the score for each scale, for which the range is between -3 (extremely bad) to +3 (extremely good) it becomes evident that UX resulted in very positive and satisfying feedback for each sub-component (Pragmatic Qualities: 2.430; Hedonic Qualities: 2.734; Overall Measure: 2.582).

Table 4

Descriptives

ITEMS	M	SD	SCALE
Item 1	2.3	0.8	Pragmatic
Item 2	2.4	1.3	Pragmatic
Item 3	2.5	0.8	Pragmatic
Item 4	2.5	0.8	Pragmatic
Item 5	2.8	0.5	Hedonic
Item 6	2.8	0.5	Hedonic
Item 7	2.6	0.8	Hedonic
Item 8	2.8	0.5	Hedonic



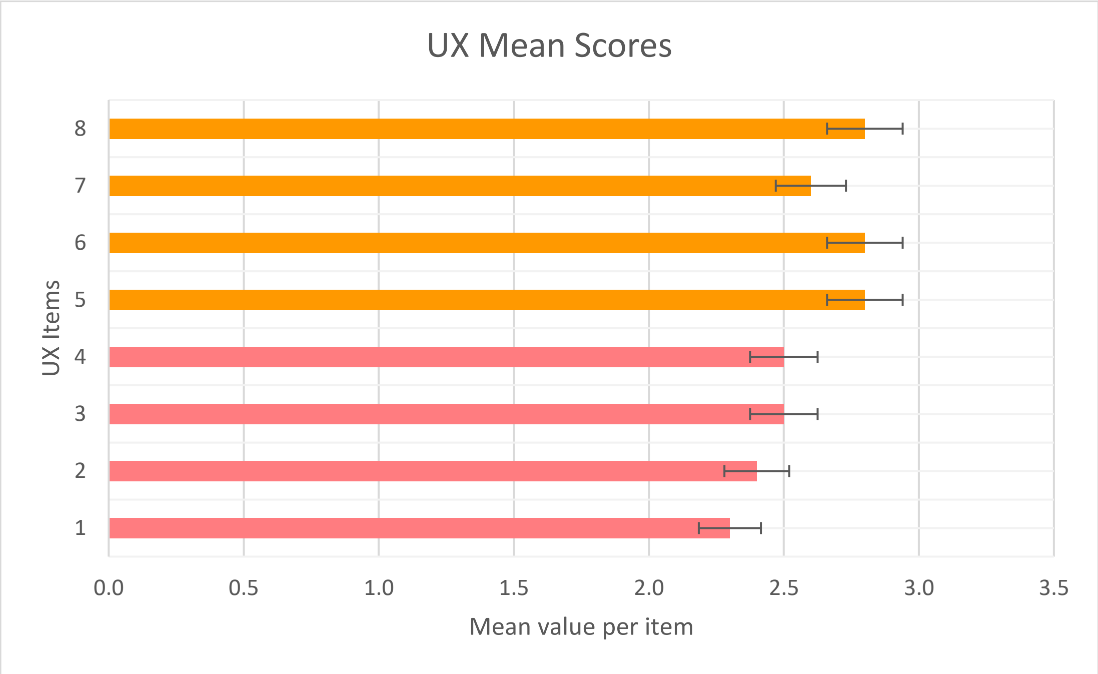


Figure 4.5: Graphical representation of the mean scores and 95% CI in UX constructs. Error bars represent the standard error mean.

- **4.3.2 Sense of Presence**

We tested participants using the SUS questionnaire (Usoh et al., 2000). The first result we hypothesized was to find no differences between conditions concerning this construct; based on Usoh et al., (2000) we computed the variable “Presence”, corresponding to the total number of ‘6’ or ‘7’ scores (measured via a 1-7 Likert scale) given by each subject amongst the six items of the questionnaire. To test our hypothesis, we performed a One-Way ANOVA comparing the “Presence” means in coral, hermit crab, and sea turtle conditions: since we detected a violation of normality with the Shapiro-Wilk test ($p = 0.030$), we opted for a One-Way Welch’s ANOVA in order to avoid Type-I errors (Delacre et al., 2019). Levene’s test for the homogeneity of variances reported a non-significant p-value ($p = 0.114$), indicating homogeneous variances.

As shown in Table 5, the results of the One-Way Welch’s ANOVA showed no differences in the three conditions ($F(2, 17.3) = 0.237$, $p = 0.792$); therefore, we do not have enough evidence to reject the null hypothesis and we cannot say that the means of the three groups differ significantly (Figure 4.6). The SUS questionnaire has also an optional ‘free response’ question at the end: this item required participants to focus on the aspects that contributed the most to give a sense of presence; as for all the other items in our questionnaire, the answers were collected in the Italian language. We found the responses to this item very interesting since they provided us with helpful feedback regarding the Sense of Presence elicited by our application; moreover, in this way, we collected some useful tips to improve different aspects of “Envisioning Corals”. We decided to select only the most representative answers to be reported here, marked with the participant’s code:

C04: “*il fatto che l'ambiente virtuale fosse a 360° ha contribuito alla sensazione che mi trovassi veramente nella simulazione, mentre le forme degli oggetti nell'ambiente mi ricordavano fossi in un gioco”.*

C07: *“La visione a 360°, il fatto che girandomi dietro/guardando in alto vedessi il retro dell'ambientazione e non un "muro", la musica e i suoni”*

C09: “*L'elemento che ha contribuito ad una netta immedesimazione è stato poter osservare il mare con i suoi relativi elementi, cosa che nella realtà difficilmente si riesce ad osservare*”.

C12: “*La possibilità di agire sull'ambiente ha contribuito molto alla sensazione di farvi parte*”.

C14: “*Vedere anche sopra e sotto di me lo scenario ha reso l'esperienza molto reale. Inoltre, vedere le parti del corallo al posto delle mie mani ha aiutato a immedesimarmi nel corallo stesso”.*

P06: “L*a presenza di oggetti, piante e scogli mi ha dato l'impressione di essere davvero immersa nell'ambiente. L'aspetto poco realistico (non 'fotografico') degli scogli e della barriera corallina mi ha un po' tirato fuori da questa sensazione”*

T04: "*Le pinne sono state un elemento che mi ha fatto "navigare" meglio nell'ambiente marino*".

T05: "*La percezione di essere "dentro" l'ambiente era molto forte, sicuramente dipeso in gran parte dall'essere in movimento e dalle pinne*".

T06: "*Inizialmente mi sentivo così tanto dentro all'ambiente virtuale che avevo paura di cadere e persino di toccare le meduse*".

Table 5

Means, Standard Deviations, and Welch's One-Way for "Presence"

Measure	**Coral**		**Hermit Crab**		**Sea Turtle**		*F*
	M	*SD*	*M*	*SD*	*M*	SD	
Presence	2.43	1.99	2.00	1.15	2.33	2.45	0.237

Note: the statistical test showed no significant difference in respect of Presence among the three conditions (Coral, Hermit Crab, Sea Turtle).

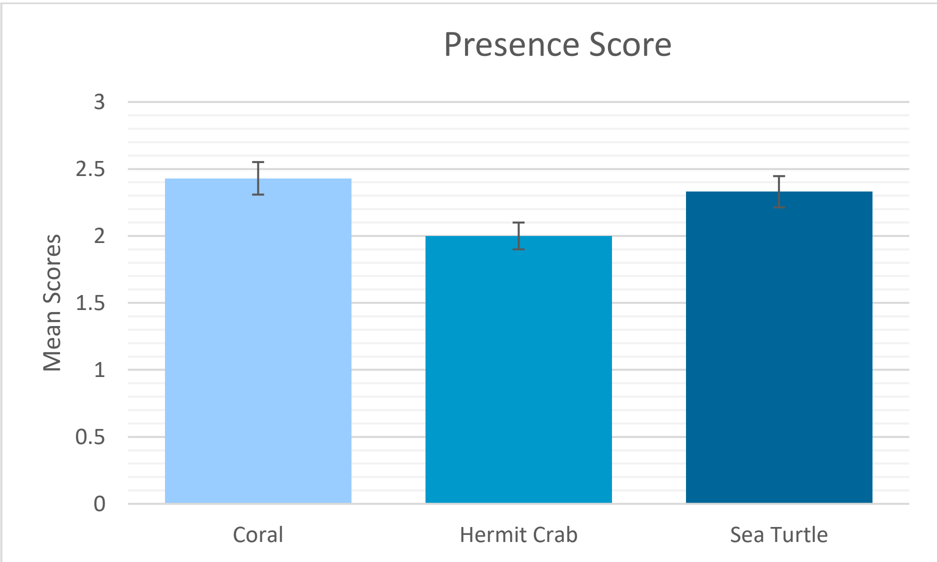


Figure 4.6: Bar charts of Mean scores and 95% CI of Sense of Presence. Error bars represent the standard error mean.

- **4.3.3 Embodiment**

The second hypothesis concerned embodiment: we assumed that there would have been no significant differences for this construct in corals, hermit crabs, and sea turtles. In fact, we hypothesized that, even though some distinctions are present, these would not have been sufficient to cause significantly different results in the embodiment reports. We were interested in testing this hypothesis specifically because the coral condition, unlike the hermit crab and sea turtle ones, has the whole body reproduced in VR; for the other two, only the forelimbs were visible (claws for the hermit crab, flippers for the turtle).

To test our hypothesis, we first calculated the scores pertaining to the three factors of the embodiment scale (assessed via a 1-7 Likert scale) namely Ownership, Agency, and Change (Roth & Latoschik., 2019). We computed the descriptive analyses and then we verified the distribution of our data: the Shapiro-Wilk test of normality reported a normal distribution for 2 out of 3 variables (Ownership: $p = 0.014$; Agency: $p = 0.262$; Change: $p = 0.113$); the Levene's test for homogeneity was significant for all three constructs, indicating that the variances of the three factors respect homogeneity (Ownership: $p = 0.311$; Agency: $p = 0.656$; Change: $p = 0.550$). Therefore, based on the literature (Delacre et al., 2019) we decided to compute Welch's One-Way ANOVA to compare the means in the three groups: as shown in Table 5, results reported no significant differences between the coral, hermit crab, and sea turtle conditions for the Ownership score ($F (2, 19.8) = 2.726$, $p = 0.090$), for the Agency score ($F (2, 17.8) = 1.125$, $p = 0.347$), and for the Change score ($F (2, 18.7) = 0.352$, $p = 0.708$). Figure 4.7 reports the graph of this analysis.

Table 6

Means, Standard Deviations, and Welch's One-Way Analyses of Variance of Embodiment's components.

Measure	**Coral**		**Hermit Crab**		**Sea Turtle**		*F*
	M	*SD*	*M*	*SD*	*M*	SD	
Ownership	4.95	1.359	4.75	0.986	5.64	0.751	2.726
Agency	6.34	0.577	6.00	0.540	6.08	0.696	1.125
Change	4.50	1.590	4.08	1.068	4.06	1.419	0.352

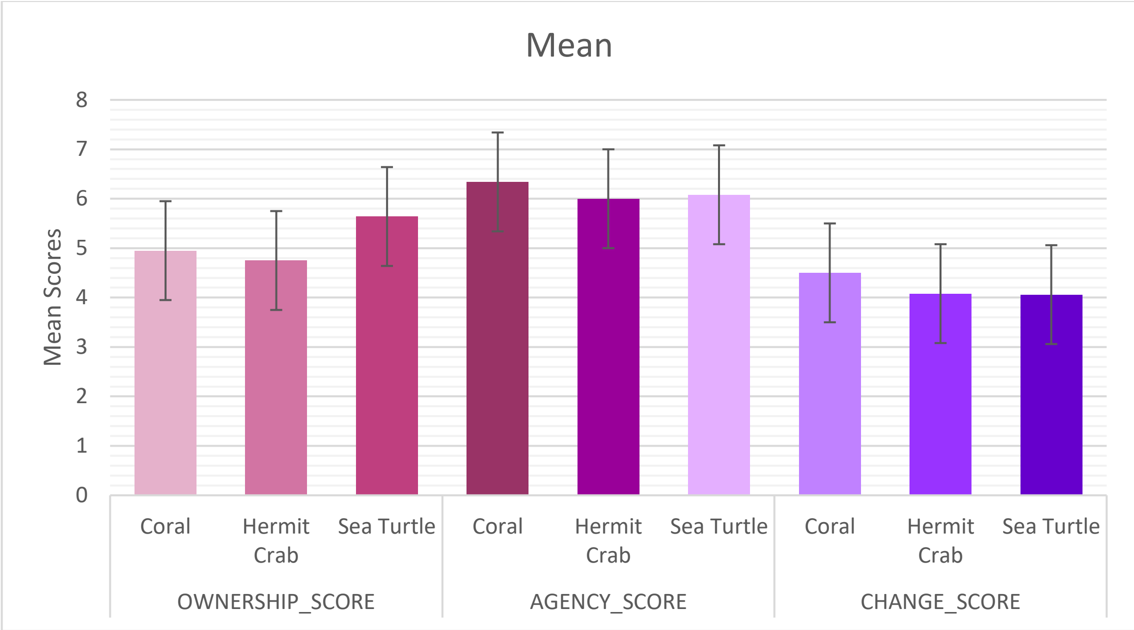


Figure 4.7: Bar charts of mean scores and 95% CI for the Embodiment. Error bars represent the standard error mean.

We also included an extra item called "Inclusion of nature in self" (Schultz, 2001): it required participants to select one out of seven Venn's circles gradually overlapping, the one that best represented the connection they perceived between oneself and the virtual avatar during the simulation. The scale was measured via a 1-7 Likert scale.

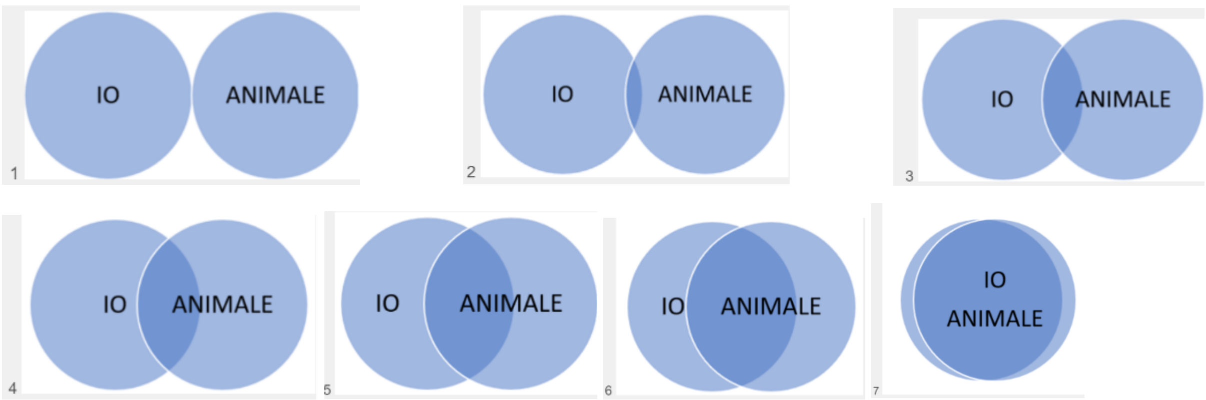


Figure 4.8: Embodiment's Venn Diagrams items (Schultz, 2001)

Results descriptives reported a higher number of counts for the fifth and sixth Venn diagrams (M = 5). (Figure 4.9).

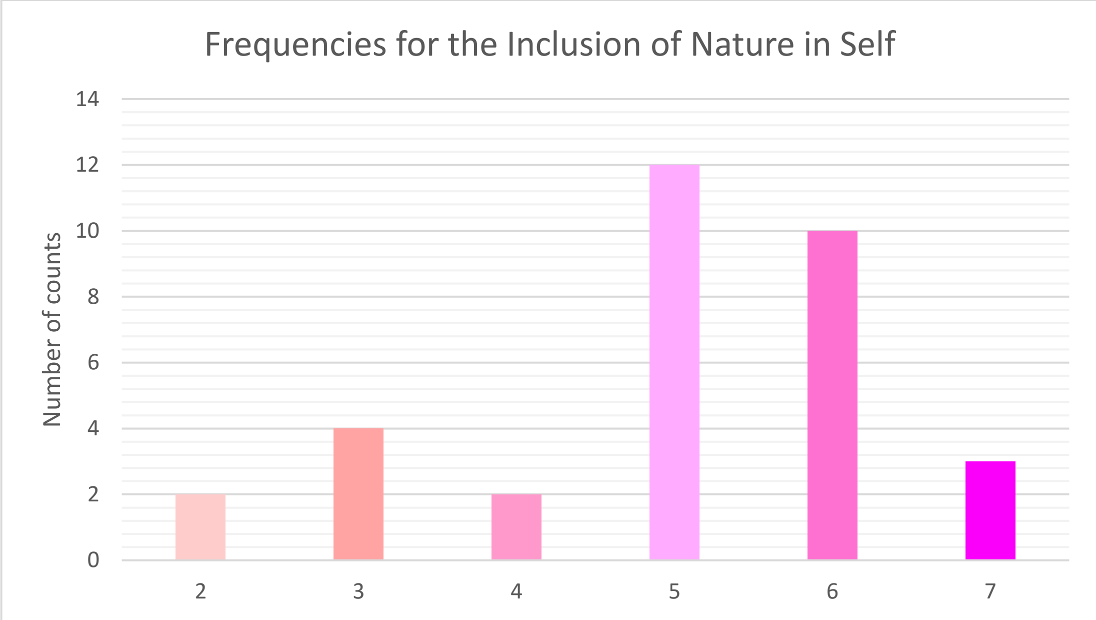


Figure 4.9: Graph representing the frequencies for the number of counts relative to INS measure.

We also split the results among the three groups: Table 7 reports the means calculated for each group and Figure 4.10 represents the frequencies.

Table 7

Means and Standard Deviations of responses to INS item.

Measure	**Coral**		**Hermit Crab**		**Sea Turtle**	
	M	*SD*	*M*	*SD*	*M*	SD
Inclusion of Nature in Self	5.29	1.38	4.40	1.35	5.22	1.20

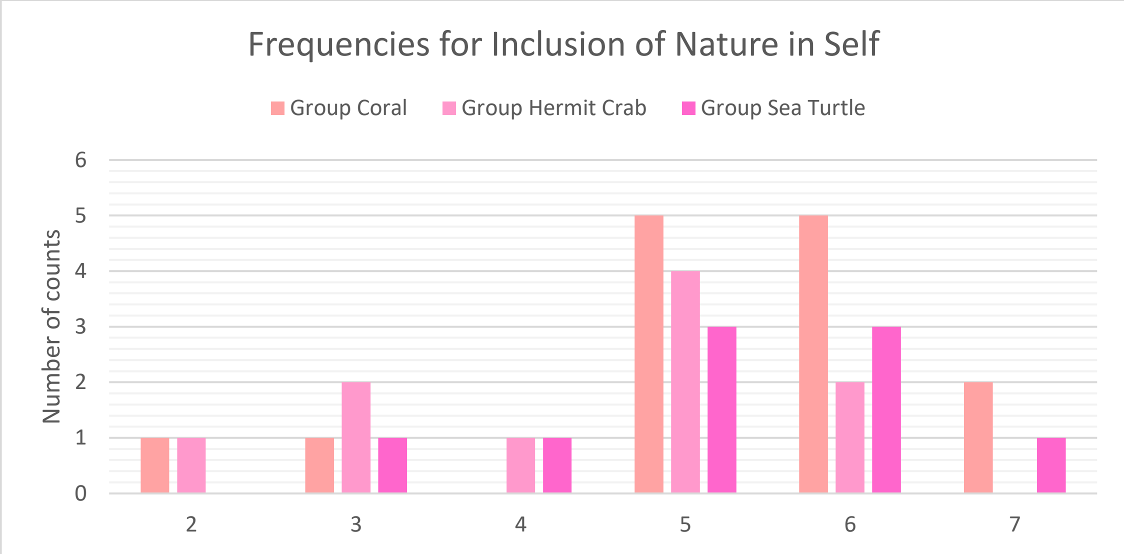


Figure 4.10. Frequencies of counts relative to each group.

- **4.3.4 Learning Motivation**

We also wanted to investigate the propensity of participants to infer that the "Envisioning Corals" simulation had educational properties, and we also wanted to understand how much users feel that they can learn from it. We hypothesized that the results would be satisfactory. To assess the Learning Motivation of our experimental subjects, we adopted the Instructional Material Motivation Survey (IMMS) (Keller, 1987): it is based on the ARCS model of the same author, and it is aimed at evaluating the students' motivation toward specific teaching materials.

Since it is a very long scale (32 items) we decided to adapt it for the context of our study: as shown in Table 1 (Chapter 3), we selected the 8 items that best fitted our study's purposes, two items for each component of the ARCS model (namely, Attention, Relevance, Confidence, and Satisfaction). IMMS scoring is calculated on a 1-5 Likert scale. Based on Keller (2010), we computed the means of the scores of each dimension of the model; then we calculated the means for the overall measure we called the "Learning Motivation Score". Tables 8 and 9 summarize the descriptives: the overall results were promising since the averages of the scores were high, and Attention and Satisfaction scores were very close to the maximum (Attention M = 4.76, Relevance M = 3.08, Confidence M = 4.00, Satisfaction M = 4.64). We computed the One-Way ANOVA to see if there were any differences between the means in the three conditions. We computed the descriptives and then we checked for the Analysis of the Variance's assumptions for the "Learning Motivation Score": both the Shapiro-Wilk and Levene's tests reported a p-value higher than 0.05 ($p = 0.833$ for the Shapiro-Wilk test, $p = 0.638$ for the Levene's), therefore we proceeded with the Fisher's ANOVA (Wilkinson, 1999). The results, reported in Table 9, showed no statistically significant differences (F (2, 30) = 1.08, p = 0.354). (Figure 4.11).

Table 8

Descriptives	ATTENTION_SCORE	RELEVANCE_SCORE	CONFIDENCE_SCORE	SATISFACTION_SCORE
N	33	33	33	33
Missing	0	0	0	0
Mean	4.76	3.08	4.00	4.64
Median	5.00	3.00	4.00	4.50
Standard deviation	0.453	0.378	0.586	0.641
Minimum	3.50	2.50	2.50	3.50
Maximum	5.00	4.00	5.00	5.50

Table 9

Descriptives	Group	LEARNING_MOTIVATION_SCORE
N	Coral	14
	Hermit Crab	10
	Sea Turtle	9
Mean	Coral	4.10
	Hermit Crab	4.03
	Sea Turtle	4.25
Std. error mean	Coral	0.0982
	Hermit Crab	0.113
	Sea Turtle	0.0884
Median	Coral	4.13
	Hermit Crab	4.06
	Sea Turtle	4.13

Table 10

Means, Standard Deviations and Fisher's One-Way ANOVA of Motivation.

Measure	**Coral**		**Hermit Crab**		**Sea Turtle**		*F*
	M	*SD*	*M*	*SD*	*M*	SD	
Motivation	4.10	0.367	4.03	0.357	4.25	0.265	1.08

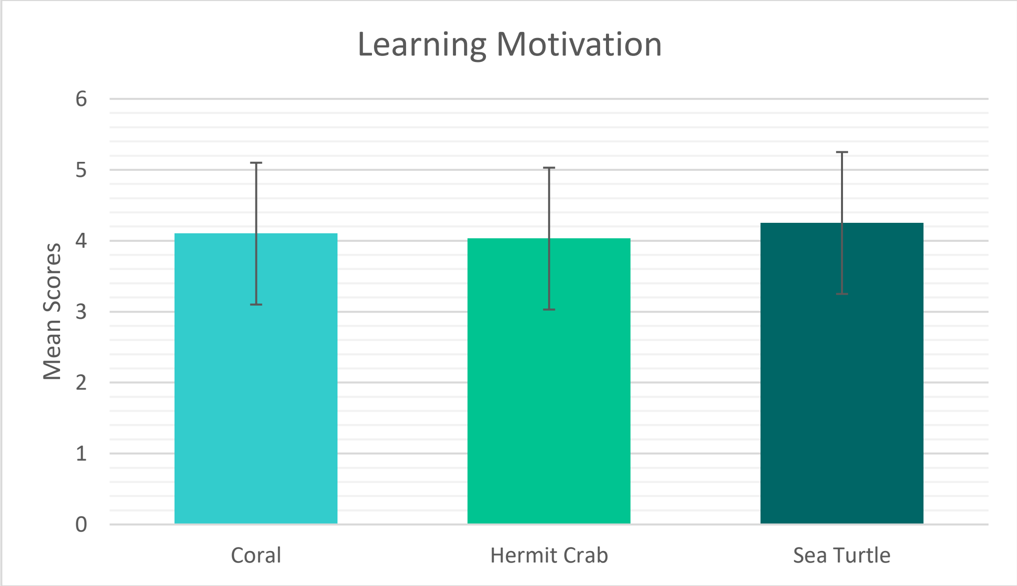


Figure 4.11: Bar charts of mean scores and 95% CI for the Learning Motivation. Error bars represent the standard error mean.

4.4 Correlations among variables

Finally, we were interested in investigating the possible existing relationships among the different variables assessed in our study. To do so, we ran the analyses considering each variable of our study relying on Pearson correlations (Pearson, 1897). The results revealed some significant correlations, specifically:

- Positive Pearson's correlation between "Learning Motivation" and "Ownership": $r(33) = 0.377$, $p = 0.015$.
- Positive Pearson's correlation between "Learning Motivation" and the overall "UX Score": $r(33) = 0.480$, $p = 0.005$.
- Positive Pearson's correlation between "Presence" and the overall "UX Score": $r(33) = 0.396$, $p = 0.022$.
- Positive Pearson's correlation between "Presence" and "Ownership": $r(33) = 0.400$, $p = 0.021$.
- Positive Pearson's correlation between "Presence" and "Agency": $r(33) = 0.409$, $p = 0.018$.

Table 11

Correlation Matrix

		LEARNING_MOTIVATION_SCORE	PRESENCE
LEARNING_MOTIVATION_SCORE	Pearson's r	—	
	p-value	—	
	N	—	
PRESENCE	Pearson's r	0.162	—
	p-value	0.367	—
	N	33	—

Note. * p < .05, ** p < .01, *** p < .001

Correlation Matrix

		LEARNING_MOTIVATION_SCORE	OWNERSHIP_SCORE
LEARNING_MOTIVATION_SCORE	Pearson's r	—	
	p-value	—	
	N	—	
OWNERSHIP_SCORE	Pearson's r	0.377 *	—
	p-value	0.015	—
	N	33	—

Note. H_a is positive correlation

Note. * p < .05, ** p < .01, *** p < .001, one-tailed

Correlation Matrix

		LEARNING_MOTIVATION_SCORE	AGENCY_SCORE
LEARNING_MOTIVATION_SCORE	Pearson's r	—	
	p-value	—	
	N	—	
AGENCY_SCORE	Pearson's r	0.283	—
	p-value	0.111	—
	N	33	—

Correlation Matrix

		LEARNING_MOTIVATION_SCORE	CHANGE_SCORE
LEARNING_MOTIVATION_SCORE	Pearson's r	—	
	p-value	—	
	N	—	
CHANGE_SCORE	Pearson's r	0.314	—
	p-value	0.075	—
	N	33	—

Correlation Matrix

		LEARNING_MOTIVATION_SCORE	UX_SCORE
LEARNING_MOTIVATION_SCORE	Pearson's r	—	
	p-value	—	
UX_SCORE	Pearson's r	0.480 **	—
	p-value	0.005	—

Note. * p < .05, ** p < .01, *** p < .001

Correlation Matrix

		PRESENCE	UX_SCORE
PRESENCE	Pearson's r	—	
	p-value	—	
UX_SCORE	Pearson's r	0.396 *	—
	p-value	0.022	—

Note. * p < .05, ** p < .01, *** p < .001

Correlation Matrix

		PRESENCE	OWNERSHIP_SCORE	AGENCY_SCORE	CHANGE_SCORE
PRESENCE	Pearson's r	—			
	p-value	—			
OWNERSHIP_SCORE	Pearson's r	0.400 *	—		
	p-value	0.021	—		
AGENCY_SCORE	Pearson's r	0.409 *	0.300	—	
	p-value	0.018	0.089	—	
CHANGE_SCORE	Pearson's r	0.245	0.538 **	0.153	—
	p-value	0.170	0.001	0.395	—

Note. * p < .05, ** p < .01, *** p < .001

Correlation Matrix

		OWNERSHIP_SCORE	AGENCY_SCORE	CHANGE_SCORE	UX_SCORE
OWNERSHIP_SCORE	Pearson's r	—			
	p-value	—			
AGENCY_SCORE	Pearson's r	0.300	—		
	p-value	0.089	—		
CHANGE_SCORE	Pearson's r	0.538 **	0.153	—	
	p-value	0.001	0.395	—	
UX_SCORE	Pearson's r	0.207	0.158	0.097	—
	p-value	0.248	0.381	0.591	—

Note. * p < .05, ** p < .01, *** p < .001

4.5 Qualitative exploratory measures:

- #### 4.5.1.Strength of the message

Finally, we have added, on an exploratory basis, two further measures. The first concerns the message conveyed by the application: in fact, we started exploring whether our application can be effective in transmitting the environmental message. To do so, we relied on an adaptation of the scale developed by Schultz et al., (2001) which measures environmental concerns through 12 items on a 1-7 Likert scale. We selected 9 items that better fitted our study (See Table 1 in Chapter 3).

The items were administered to participants before and after experiencing the "Envisioning Corals" application. Data were analyzed using a paired sample T-test (McNemar, 1947) to compare pre- and post-immersive experience data means. Results showed a possible effect of the application in influencing the response to some items of environmental concern (Table 12): indeed, there was a significant difference between:

- The means of "Plants" measured before (M = 5.30, SD: 1.403) and after the simulation (M = 5.67, SD = 1.339); t(32)= -3.464, p = 0.002.
- The means of "Marine Life" measured before (M = 5.61, SD: 1.144) and after the simulation (M = 6.18, SD = 0.950); t(32)= -4.669, p < 0.001.
- The means of "Birds" measured before (M = 4.79, SD: 1.495) and after the simulation (M = 5.27, SD = 1.606); t(32)= -4.175, p < 0.001.
- The means of "People in my community", measured before (M = 6.18, SD: 0.917) and after the simulation (M 6.39, SD = 0.864); t(32)= -2.935, p < 0.006.

Table 12

Paired Samples T-Test

			Statistic	df	p		Effect Size
ST_PRE_1	***ST_POST_1***	Student's t	-3.464	32.0	0.002	Cohen's d	-0.6030
ST_PRE_2	***ST_POST_2***	Student's t	-4.669	32.0	< .001	Cohen's d	-0.8127
ST_PRE_3	***ST_POST_3***	Student's t	-4.175	32.0	< .001	Cohen's d	-0.7268
ST_PRE_4	***ST_POST_4***	Student's t	-1.789	32.0	0.083	Cohen's d	-0.3114
ST_PRE_5	***ST_POST_5***	Student's t	-0.273	32.0	0.786	Cohen's d	-0.0476
ST_PRE_6	***ST_POST_6***	Student's t	-0.529	32.0	0.601	Cohen's d	-0.0920
ST_PRE_7	***ST_POST_7***	Student's t	-1.979	32.0	0.056	Cohen's d	-0.3446
ST_PRE_8	***ST_POST_8***	Student's t	-2.935	32.0	0.006	Cohen's d	-0.5110
ST_PRE_9	***ST_POST_9***	Student's t	-1.437	32.0	0.160	Cohen's d	-0.2501

T-test results

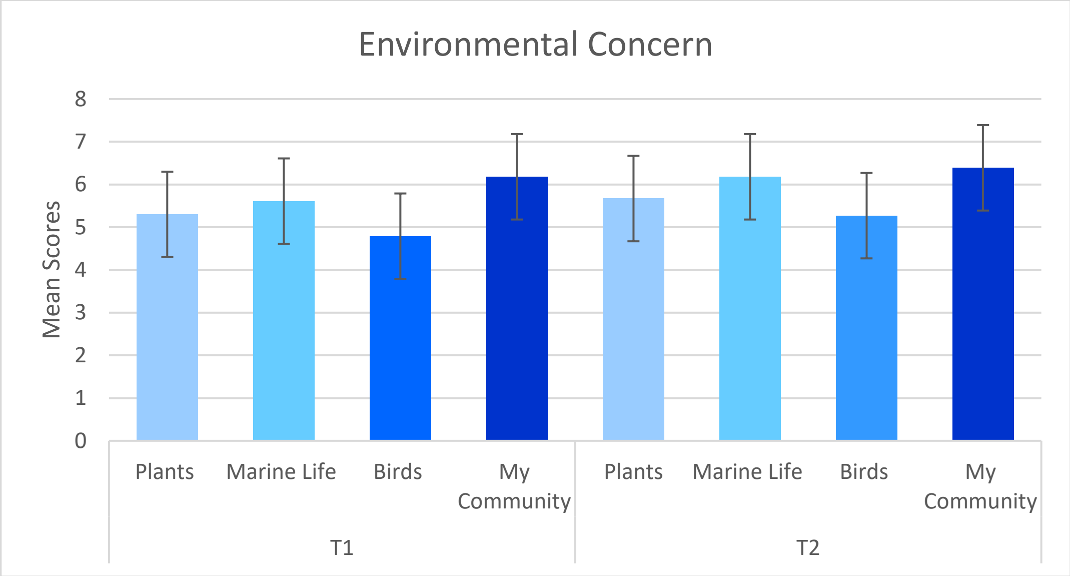


Figure 4.12: Bar charts of mean scores and 95% CI for Environmental Concern at T1 and T2. Error bars represent the standard error mean.

- 4.5.2. QR code

The second further explorative measure is a behavioral measure: we created an ad-hoc QR code to be administered to participants at the end of the experience, to see if they were motivated in the future to learn more about coral reefs protection and eventually donate to environmental associations.

Figure 4.13: QR code we used in our study.

According to the data we collected, only 2 participants out of 33 preferred to not scan the QR code; the remaining 31 participants decided to scan it. We did not observe differences among groups, therefore the three conditions seem to be comparable, as for the other measures. We remain cautious in suggesting a possible involvement of the "Envisioning Corals" simulation in increasing environmental concern and in motivating individuals to act;

CHAPTER 5:

Discussion and final conclusions

5.1. Discussion of results

We are now going to examine the key findings of the present study while evaluating their impact in respect of pre-existent literature. The main objective of our proposal was to evaluate the human factors, and exploratively the educational implications, involved in an immersive VR application designed to communicate the phenomenon of coral bleaching and promote environmental sustainability. We adopted a self-report questionnaire predominantly composed of validated items from existing literature to evaluate three conditions – corals, hermit crabs, and sea turtles – which correspond to the three animal avatars the users can embody in the simulation.

The study is configured mainly as a usability study, with the addition of exploratory measures related to the effectiveness of the virtual simulation in providing educational contents. Specifically, we measured the Sense of Presence, the Embodiment, the User Experience (UX), and the Learning Motivation; we also exploratively assessed the efficacy of our application through the "Environmental Concerns scale" (Schultz., 2001) and through the behavioral measure. We will start interpreting the quantitative results, before reviewing the evidence from the exploratory measures. Finally, we will consider the limitations present in our research and lastly, we will outline possible future directions for our work.

- 5.1.1. Quantitative results

Consistently to H1, results indicated that there were no significant differences among the three groups with respect to the User Experience (UX) variable. In fact, participants reported good ratings in all items of UX (split between Pragmatic Qualities, Hedonic Qualities, and Overall measure) for coral, hermit crabs, and sea turtle conditions. Therefore, it appears that all three conditions of the Virtual Immersive Experience possess qualities that users find appealing, and the simulation seems to promote positive interactions and provide support to users.

So, we speculate that our attempt to make the three conditions comparable, despite the differences between the three animals, was successful.

With regard to H2, our results showed that there were no statistically significant differences among the three groups in relation to Sense of Presence and Embodiment constructs; taking into consideration the Presence scores, the evaluations' means were comparable between corals, hermit crabs, and sea turtles: this is a positive result for us, since the objective of our study was to verify the comparability between conditions. As for the UX findings, the existing differences between the three animals (namely the shape of their body, the type of food they eat, and the way they move or do not move) were not sufficient to generate significantly different responses in the participants. However, a greater sample size will be necessary in order to definitely confirm these preliminary results.

The Sense of Presence measure (Slater et al., 1994) also included a free response item (the English translation of the question is: "Which aspects of the simulation helped you to feel a sense of presence, and which instead diminished it?" Responses were given in Italian): we analyzed them qualitatively in order to collect feedback to improve our application. Summarizing the answers, we found that the possibility to act on the surrounding environment and the sounds and music accompanying the immersive experience helped participants to detach from the real context and immerse in the simulation; furthermore, the movements of the hands, faithfully reproduced in VR, as well as the good interaction between the forelimbs and the food contributed to generating Sense of Presence. Conversely, the elements that diminished the Sense of Presence, as reported by participants, were the "cartoonish styled" instead of the "photographic" aspect of the simulation, and the fact that the food has been represented in the IVE in a stylized and unrealistic manner (See chapter 4 for reading the participants' responses).

Regarding the Embodiment assessment, measured through its Ownership, Agency, and Body Change sub-components (Roth & Latoschik, 2020), showed no differences in the three conditions, indicating comparability among the groups; in our view, the most notable dissimilarities with respect to Embodiment were that the coral's body was fully represented in VRE, whereas for the other two animals only their forelimbs were visible to users (this was due to purely technical reasons we are trying to solve: in fact, virtually representing vertical bodies that develop horizontally in the simulation is a very complex task); also, the coral condition was the only one where participants were not required to use the teleport. Nevertheless, participants did not report differing ratings: indeed, even if the "coral" group showed slightly higher average scores, these results did not significantly differ from those of "hermit crab" and "sea turtle" groups.

Concerning the Learning Motivation construct, significant results in line with H3 have been observed. The means of the ARCS's components scores (i.e., "Attention", "Relevance", "Confidence", and "Satisfaction", Keller., 1987) were all satisfying, with Attention and Satisfaction almost reaching the maximum score. The results of the Analysis of Variance indicated that there were no significant differences in the mean scores of the three groups across any of the components. We interpreted these findings to suggest that the visual and audio content provided by the "Envisioning Corals" application in each condition do not significantly differ in terms of motivating users to learn. Additionally, the high average scores reported by coral, hermit crab, and sea turtle groups indicate that participants perceived the experience as effective in conveying educational content, and they felt confident in their ability to learn from the simulation. In light of these results, we can speculate that our application possesses useful properties for motivating learning processes in users (Kaminska et al., 2019).

Finally, we conducted Pearson's correlation analyses to explore possible relationships among our variables. Results showed a significant positive correlation between "Learning Motivation" and "Ownership" scores, indicating that as one variable increases, the other also increases. However, we cannot draw any conclusions about the causality of this relation; we just speculated that an increase in the "Ownership" component may contribute to increasing participants' learning motivation, maybe via the effect of some mediators. It would be interesting to deepen these effects in the future, through mediation models. We also found a positive correlation between "Ownership" and the "Sense of Presence" variables. Additionally, "Sense of Presence" correlated positively with the Overall User Experience measure and with "Agency". Regarding the relationship between UX and Presence, we speculated that perhaps more Sense of Presence could generate a better User Experience (Sagnier et al., 2019).

The last significant correlation we found was between "Learning Motivation" and "UX" scores: as for the other results, it is difficult to speculate on the direction of this relationship (Kaminska et al., 2019); further studies will be surely necessary to manipulate these variables and provide answers.

- 5.1.2. Explorative measures results

In addition, we conducted an exploratory analysis to evaluate the effectiveness of our VR application in conveying the environmental message. To assess participants' environmental concerns, we administered the items from Schultz (2001) both before and after the immersive virtual experience. Comparing the scores of the three groups, we found possible evidence that the application may have influenced participants' concerns regarding the negative effects of climate change, but only towards specific items. Therefore, we supposed that "Envisioning Corals" could be a useful tool for raising awareness about environmental issues and increasing people's concerns. Interestingly, these exploratory findings were not limited to the marine world: in fact, the items that revealed significant differences were "Marine Animals", "Plants", and "Birds". This suggests a possible cascading effect, where an increase in concern for ocean inhabitants extends to other animals. Additionally, an increase was observed in the item regarding “People in my community”.

After reasoning on the results, we thought that the outcomes of this scale might be biased due to insufficient time elapsed between the initial administration of the items and the subsequent one. In the future, we want to increase the duration of the virtual experience to check for any possible effect. The second exploratory investigation focused on behavioral intention. We used a behavioral measure: the experimenter asked participants to either scan or not scan a QR code as they saw fit (they were previously informed that the code contained a link to donate to GBR protection associations). The qualitative results revealed that participants were inclined to scan the QR code after experiencing the immersive application, with 31 out of 33 participants choosing to do so. As this was an exploratory assessment, we cannot draw any definitive conclusions. However, we can speculate that “Envisioning Corals” may have an effect on influencing not just thoughts and emotions, but also behavior. More in-depth studies are necessary to investigate this variable, adding control conditions as well.

5.2 Limitations

Certainly, our study is not exempt from limitations. A major limitation pertains to the size of our participants’ sample. Indeed, we recruited a small sample size, and this brings two main issues (Button et al., 2013): firstly, the reduced representativeness which limits the generalizability of our results, and second the decreased statistical power, which increases the risk of committing Type II errors.
Also, the sample is not gender-balanced, and we ended up having more female than male participants: specifically, 39.4% of the sample were males, and the remaining 60.6% were females. Furthermore, the number of participants is not balanced in the three conditions: the “Coral” group indeed had more subjects than the other two, namely “Hermit Crab” and “Sea Turtle”.

Another limitation pertaining to our study is the narrow age range of our sample. To mitigate potential difficulties in using this new technology, and to follow other case studies in this field (Weech et al., 2019), we limited our participants to those aged between 18 and 35. However, a more diverse sample would enable us to assess the effectiveness of our application not only among individuals who are accustomed to using technology, but also among those who have less experience and may uncover issues that we have not yet discovered (Lokka & Coltekin, 2020). Certainly, the pilot study we conducted at the Focus Live event had greater ecological validity as well as a much more diverse age range, and the results seemed very encouraging.

We considered two other significant limitations to be acknowledged. First, the immersive VR experience was limited to a short duration of only five minutes. By extending it, it may be possible to investigate whether the observed effects are amplified or diminished over time. Second, the assessment methodology used in this study relied solely on self-report measures: while useful for assessing subjective experience, this method is subject to biases and may not provide a complete picture of the entire experience. A diversified set of measures, including physiological and behavioral measures, may provide a more comprehensive assessment of the effects of the "Envisioning Corals" application.

5.3 Further directions

One of the key directions for the future of this study is undoubtedly to increase the sample size and balance it across the three different conditions, as well as by gender. We would also like to test our application on a sample with a different age range, especially with older individuals to investigate which elements might be supportive and which ones might be obstacles for them.

As with any scientific investigation, also for the present research there is more to explore and discover, in order to gain a deeper understanding of human factors involved in the use of VR technologies. For instance, we thought that we would like to further investigate the "movement" issues in VR: in the "Envisioning Corals" application, we have implemented a type of movement called "teleporting", which functions much like virtual teleportation. It is effective in reducing the cybersickness that users may experience in the virtual environment (Bozgeyikli et al., 2016), but it is not realistic at all and this could have an impact on the immersion and the Sense of Presence; therefore, we plan to create new versions of the application in the future with continuous and realistic movement, potentially using specialized tools such as the "Virtualizer" a locomotion platform for walking in VR which works much like a treadmill. We will therefore be able to investigate whether a more realistic type of movement increases Sense of Presence and Embodiment.

In the future, we could also explore other aspects related to our application, such as spatial and temporal distance. For instance, we could investigate whether our application is effective in reducing the perceived spatial distance between users and GBRs, as well as whether it has the potential to increase the perception of the proximity in time between climate change and its effects.
In addition, as we already mentioned, we aim at increasing the duration of the entire immersive experience to see if this will result in any changes in UX, Sense of Presence, Embodiment, and Learning Motivation. A possible further direction could be to assess the learning performances of users, to

quantify the overall learning acquisition during the immersive virtual experience, and study the possible influence of other variables on the learning performance.

Finally, an area of investigation that we have not explored yet regards the effect of novelty (Jeno et al., 2019). Specifically, we would like to investigate whether the scores obtained in the constructs of Sense of Presence, Embodiment, User Experience, and even more importantly Learning Motivation, decrease as individuals become more accustomed to the VR experience. We could do so by dividing participants into two experimental groups (namely “VR beginners” and “VR experts”) and testing them after the immersive simulation, or we could do so by conducting a longitudinal study in order to avoid biases related to groups’ differences. The latest future direction we have considered involves “psychological distance” (Jones et al., 2017). Specifically, we intend to investigate how Envisioning Corals impacts the perceived psychological distance between coral bleaching phenomena and people or populations who live or work in close proximity to the Great Barrier Reef. Our intention is to test future iterations of our application on the population residing on Magoodhoo Island, located in the Maldives archipelago, which is recognized as one of the world’s most renowned coral areas and the site of the UNIMIB Marhè research center.

An application like “Envisioning Corals” could be distributed free of charge to schools of all grades to conduct environmental education and awareness campaigns on issues such as coral bleaching phenomena. Additionally, our virtual simulation could serve as an interactive tool in museums, exhibitions, or educational trails that address topics related to climate change, environmental sustainability, and coral reef conservation.

REFERENCES:

Ahn, S. J., Bostick, J., Ogle, E., Nowak, K. L., McGillicuddy, K. T., & Bailenson, J. N. (2016). Experiencing nature: Embodying animals in immersive virtual environments increases the inclusion of nature in self and involvement with nature. *Journal of Computer-Mediated Communication*, *21*(6), 399-419

Ahn, S. J., Le, A. M. T., & Bailenson, J. (2013). The effect of embodied experiences on self-other merging, attitude, and helping behavior. *Media Psychology*, *16*(1), 7-38.

Allcoat, D., & von Mühlenen, A. (2018). Learning in virtual reality: Effects on performance, emotion, and engagement. *Research in Learning Technology*, *26.*

Ambrosio, A. P., & Fidalgo, M. I. R. (2020). Past, present and future of Virtual Reality: Analysis of its technological variables and definitions. *Culture & History Digital Journal*, *9*(1), e010-e010.

Baker, A. C. (2001). Reef corals bleach to survive change. *Nature*, *411*(6839), 765-766.

Bar-Anan, Y., Liberman, N., & Trope, Y. (2006). The association between psychological distance and construal level: evidence from an implicit association test. *Journal of Experimental Psychology: General*, *135*(4), 609.

Batson, C. D., Early, S., & Salvarani, G. (1997). Perspective taking: Imagining how another feels versus imaging how you would feel. *Personality and social psychology bulletin*, *23*(7), 751-758.

Black, R., Adger, W. N., Arnell, N. W., Dercon, S., Geddes, A., & Thomas, D. (2011). The effect of environmental change on human migration. *Global environmental change*, *21*, S3-S11

Bozgeyikli, E., Raij, A., Katkoori, S., & Dubey, R. (2016, October). Point & teleport locomotion technique for virtual reality. In *Proceedings of the 2016 annual symposium on computer-human interaction in play* (pp. 205-216).

Brewer, G. D. (1999). The challenges of interdisciplinarity. *Policy sciences*, *32*(4), 327-337.

Burdea, G. C., & Coiffet, P. (2003). *Virtual reality technology*. John Wiley & Sons.

Clerici, M., Boffi, P., Lanzi, P. L., Coppola, L., Murone, C., & Gallace, A. (2022, October). One day in a Roman Domus: Human Factors and Educational Properties Involved in a Virtual Heritage Application. In *2022 IEEE International Symposium on Mixed and Augmented Reality Adjunct (ISMAR-Adjunct)* (pp. 692-697).

Climate Change Evidence & Causes, update 2020, An overview from the Royal Society and the US National Academy of Sciences

Connolly-Boutin, L., & Smit, B. (2016). Climate change, food security, and livelihoods in sub-Saharan Africa. *Regional Environmental Change*, *16*(2), 385-399.

Delacre, M., Leys, C., Mora, Y. L., & Lakens, D. (2019). Taking parametric assumptions seriously: Arguments for the use of Welch's F-test instead of the classical F-test in one-way ANOVA. *International Review of Social Psychology*, *32*(1).

Eisenack, K. (2013). A climate change board game for interdisciplinary communication and education. *Simulation & Gaming*, *44*(2-3), 328-348.

Fauville, G., Lantz-Andersson, A., & Säljö, R. (2014). ICT tools in environmental education: reviewing two newcomers to schools. *Environmental Education Research*, *20*(2), 248-283.

Fauville, G., Queiroz, A. C. M., & Bailenson, J. N. (2020). Virtual reality as a promising tool to promote climate change awareness. *Technology and health*, 91-108.

Ferrer-Torregrosa, J., Jiménez-Rodríguez, M. J., Torralba-Estelles, J., Garzón-Farinós, F., & Fernández-Ehrling, N. (2020). Virtual Reality in the Science Classroom: A Review of the Literature. Journal of Educational Technology & Society, 23(1), 1-14.

Field, A. P., & Wilcox, R. R. (2017). Robust statistical methods: A primer for clinical psychology and experimental psychopathology researchers. *Behaviour research and therapy*, *98*, 19-38.

Freeman, D. (2008). Studying and treating schizophrenia using virtual reality: a new paradigm. *Schizophrenia bulletin*, *34*(4), 605-610.

Freeman, D., Reeve, S., Robinson, A., Ehlers, A., Clark, D., Spanlang, B., & Slater, M. (2017). Virtual reality in the assessment, understanding, and treatment of mental health disorders. *Psychological medicine*, *47*(14), 2393-2400.

Garcia-Palacios, A., Hoffman, H., Carlin, A., Furness III, T. A., & Botella, C. (2002). Virtual reality in the treatment of spider phobia: a controlled study. *Behaviour research and therapy*, *40*(9), 983-993.

Glynn, P. W., & D'croz, L. (1990). Experimental evidence for high temperature stress as the cause of El Niño-coincident coral mortality. *Coral reefs*, *8*(4), 181-191.

Gobet, F. (2018). The future of expertise: The need for a multidisciplinary approach. *Journal of Expertise*, *1*(2), 107-13.

Gonzalez-Franco, M., & Peck, T. C. (2018). Avatar embodiment. towards a standardized questionnaire. *Frontiers in Robotics and AI*, *5*, 74.

Greenfeld, A., Lugmayr, A., & Lamont, W. (2018). Comparative reality: Measuring user experience and emotion in immersive virtual environments. In *2018 IEEE International Conference on Artificial Intelligence and Virtual Reality (AIVR)* (pp. 204-209).

Hassenzahl, M. (2007). The hedonic/pragmatic model of user experience. *Towards a UX manifesto*, *10*, 2007.

Hassenzahl, M. (2008, September). User experience (UX) towards an experiential perspective on product quality. In *Proceedings of the 20th Conference on l'Interaction Homme-Machine* (pp. 11-15).

Hoegh-Guldberg, O., Mumby, P. J., Hooten, A. J., Steneck, R. S., Greenfield, P., Gomez, E., ... & Hatziolos, M. (2007). Coral reefs under rapid climate change and ocean acidification. *science*, *318*(5857), 1737-1742

Hoegh-Guldberg, O. (2011). Coral reef ecosystems and anthropogenic climate change. *Regional Environmental Change*, *11*(1), 215-227.

Höök, M., & Tang, X. (2013). Depletion of fossil fuels and anthropogenic climate change—A review. *Energy policy*, *52*, 797-809.

Hornsey, M., Harris, E., Bain, P. *et al.* Meta-analyses of the determinants and outcomes of belief in climate change. *Nature Climatic Change* **6**, 622–626 (2016).

IPCC, 2012: Glossary of terms. In: Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation [Field, C.B., V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor, and P.M. Midgley (eds.)]. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change (IPCC). Cambridge University Press, Cambridge, UK, and New York, NY, USA, pp. 555-564.

Javaid, M., & Haleem, A. (2020). Virtual reality applications toward medical field. *Clinical Epidemiology and Global Health*, *8*(2), 600-605.

Jeno, L. M., Vandvik, V., Eliassen, S., & Grytnes, J. A. (2019). Testing the novelty effect of an m-learning tool on internalization and achievement: A Self-Determination Theory approach. *Computers & Education*, *128*, 398-413.

Jones, C., Hine, D. W., & Marks, A. D. (2017). The future is now: Reducing psychological distance to increase public engagement with climate change. *Risk Analysis*, *37*(2), 331-341.

Kamińska, D., Sapiński, T., Wiak, S., Tikk, T., Haamer, R. E., Avots, E., ... & Anbarjafari, G. (2019). Virtual reality and its applications in education: Survey. *Information*, *10*(10), 318.

Kaur, A., & Chahal, H. S. (2018). Role of social media in increasing environmental issue awareness. *Researchers World*, *9*(1), 19-27.

Keller, J. M. (1987). Development and use of the ARCS model of instructional design. Journal of Instructional Development, 10(3), 2-10.

Keller, J. M. (2010). *Motivational design research and development* (pp. 297-323). Springer US.

Keller, J. M. (2010) Instructional materials motivation survey (IMMS): technical manual. Tallahassee, FL: Florida State University.

Kim, H. K., Park, J., Choi, Y., & Choe, M. (2018). Virtual reality sickness questionnaire (VRSQ): Motion sickness measurement index in a virtual reality environment. *Applied ergonomics*, *69*, 66-73.

Lacetera, N. (2019). Impact of climate change on animal health and welfare. *Animal Frontiers*, *9*(1), 26-31.

Lanier, J., “Dawn of the new everything: A journey through virtual reality”, 2017.

Lantz, B. (2013). The impact of sample non-normality on ANOVA and alternative methods. *British Journal of Mathematical and Statistical Psychology*, *66*(2), 224-244.

Laugwitz, B., Held, T., & Schrepp, M. (2008, November). Construction and evaluation of a user experience questionnaire. In *Symposium of the Austrian HCI and usability engineering group* (pp. 63-76). Springer, Berlin, Heidelberg.

LaViola Jr, J. J. (2000). A discussion of cybersickness in virtual environments. *ACM Sigchi Bulletin*, *32*(1), 47-56.

Lindgren, R., & Johnson-Glenberg, M. (2013). Emboldened by embodiment: Six precepts for research on embodied learning and mixed reality. *Educational researcher*, *42*(8), 445-452.

Markowitz, D. M., Laha, R., Perone, B. P., Pea, R. D., & Bailenson, J. N. (2018). Immersive virtual reality field trips facilitate learning about climate change. *Frontiers in Psychology*, *9*, 2364.

McCloy, R., & Stone, R. (2001). Virtual reality in surgery. *Bmj*, *323*(7318), 912-915.

McNemar, Q. (1947). Note on the sampling error of the difference between correlated proportions or percentages. *Psychometrika*, *12*(2), 153-157.

Milgram, P., Takemura, H., Utsumi, A., & Kishino, F. (1995). Augmented reality: A class of displays on the reality-virtuality continuum. In *Telemanipulator and telepresence technologies* (Vol. 2351, pp. 282-292).

Olabi, A. G., & Abdelkareem, M. A. (2022). Renewable energy and climate change. *Renewable and Sustainable Energy Reviews*, *158*, 112111.

Pace, P. (1997). Environmental education in Malta: Trends and challenges. *Environmental Education Research*, *3*(1), 69-82.

Pearson, K. (1897). Mathematical contributions to the theory of evolution.—on a form of spurious correlation which may arise when indices are used in the measurement of organs. *Proceedings of the royal society of London*, *60*(359-367), 489-498.

Pecl, G. T., Araújo, M. B., Bell, J. D., Blanchard, J., Bonebrake, T. C., Chen, I. C., ... & Williams, S. E. (2017). Biodiversity redistribution under climate change: Impacts on ecosystems and human well-being. *Science*, *355*(6332).

Queiroz, A. C. M., Kamarainen, A. M., Preston, N. D., & da Silva Leme, M. I. (2018). Immersive virtual environments and climate change engagement. *Proceedings of the immersive learning research network*, 153e164.

Queiroz, A. C. M., Fauville, G., Herrera, F., Leme, M. I. da S., & Bailenson, J. N. (2022). Do Students Learn Better with Immersive Virtual Reality Videos Than Conventional Videos? A Comparison of Media Effects with Middle School Girls. *Technology, Mind, and Behavior*, *3*(3: Autumn). https://doi.org/10.1037/tmb0000082

Riva, G., & Gaggioli, A. (2019). *Realtà virtuali: gli aspetti psicologici delle tecnologie simulative e il loro impatto sull'esperienza umana*. Giunti Psychometrics.

Roth, D., & Latoschik, M. E. (2019). Construction of a validated virtual embodiment questionnaire. *arXiv preprint arXiv:1911.10176.*

Sagnier, C., Loup-Escande, É., & Valléry, G. (2019). Technology acceptance of virtual reality: A review. *Le travail humain*, *82*(3), 183-212.

Schneider, S. H. (2011). *Encyclopedia of climate and weather* (Vol. 1). Oxford University Press.

Schultz.P. W. (2001). The structure of environmental concern: Concern for self, other people, and the biosphere. *Journal of environmental psychology*, *21*(4), 327-339.

Scurati, G. W., Bertoni, M., Graziosi, S., & Ferrise, F. (2021). Exploring the use of virtual reality to support environmentally sustainable behavior: A framework to design experiences. *Sustainability*, *13*(2), 943.

Sheehan, M., & Hino, J. (2020). Using virtual reality to teach climate change: The effects of an immersive experience on students' perceptions and attitudes. Journal of Geoscience Education, 68(4), 408-420.

Slater, M., Usoh, M., & Steed, A. (1994). Depth of presence in virtual environments. *Presence: Teleoperators & Virtual Environments*, *3*(2), 130-144.

Slater, M., & Wilbur, S. (1997). A framework for immersive virtual environments (FIVE): Speculations on the role of presence in virtual environments. *Presence: Teleoperators & Virtual Environments*, *6*(6), 603-616.

Slater, M., & Sanchez-Vives, M. V. (2016). Enhancing our lives with immersive virtual reality. *Frontiers in Robotics and AI*, *3*, 74.

Slater, M. (2017). Implicit learning through embodiment in immersive virtual reality. In *Virtual, augmented, and mixed realities in education* (pp. 19-33). Springer, Singapore.

Spence, A., Poortinga, W., & Pidgeon, N. (2012). The psychological distance of climate change. *Risk Analysis: An International Journal*, *32*(6), 957-972Talero, G. (2004). Environmental education and public awareness. *WorldFish: Victoria, BC, Canada*.

Stoutenborough, J. W., Liu, X., & Vedlitz, A. (2014). Trends in public attitudes toward climate change: the influence of the economy and Climategate on risk, information, and public policy. *Risk, Hazards & Crisis in Public Policy*, *5*(1), 22-37.

Tcha-Tokey, K., Loup-Escande, E., Christmann, O., & Richir, S. (2016). A questionnaire to measure the user experience in immersive virtual environments. In *Proceedings of the 2016 virtual reality international conference* (pp. 1-5).

Tcha-Tokey, K., Christmann, O., Loup-Escande, E., Loup, G., & Richir, S. (2018). Towards a model of user experience in immersive virtual environments. *Advances in Human-Computer Interaction*.

Toscano, M. A., Liu, G., Guch, I. C., Casey, K. S., Strong, A. E., & Meyer, J. E. (2002). Improved prediction of coral bleaching using high-resolution HotSpot anomaly mapping. In *Proceedings of the Ninth International Coral Reef Symposium, Bali, 23-27 October 2000,* (Vol. 2, pp. 1143-1147).

Uiterkamp, A. J. S., & Vlek, C. (2007). Practice and outcomes of multidisciplinary research for environmental sustainability. *Journal of Social Issues*, *63*(1), 175-197.

Usoh, M., Catena, E., Arman, S., & Slater, M. (2000). Using presence questionnaires in reality. *Presence*, *9*(5), 497-503.

Weller, R., Cepok, J., Arzaroli, R., Marnholz, K., Große, C. S., Reuter, H., & Zachmann, G. (2022). Effects of immersion and navigation agency in virtual environments on emotions and behavioral intentions. *Frontiers in Virtual Reality*, *3*, 97.

Wheeler, T., & Von Braun, J. (2013). Climate change impacts on global food security. *Science*, *341*(6145), 508-513.

Wiederhold, B. K. (2020). Embodiment empowers empathy in virtual reality. *Cyberpsychology, behavior, and social networking*, *23*(11), 725-726.

Wilkinson, L. (1999). Statistical methods in psychology journals: Guidelines and explanations. *American psychologist*, *54*(8), 594.

Winter, A., Appeldoorn, R. S., Bruckner, A., Williams Jr, E. H., & Goenaga, C. (1998). Sea surface temperatures and coral reef bleaching off La Parguera, Puerto Rico (northeastern Caribbean Sea). *Coral reefs*, *17*(4), 377-382

Witmer, B. G., & Singer, M. J. (1998). Measuring presence in virtual environments: A presence questionnaire. *Presence*, *7*(3), 225-240.

Witmer, B. G., Jerome, C. J., & Singer, M. J. (2005). The factor structure of the presence questionnaire. *Presence: Teleoperators & Virtual Environments*, *14*(3), 298-312.

Wu, J. S., & Lee, J. J. (2015). Climate change games as tools for education and engagement. *Nature Climate Change*, *5*(5), 413-418.

Wu, X., Lu, Y., Zhou, S., Chen, L., & Xu, B. (2016). Impact of climate change on human infectious diseases: Empirical evidence and human adaptation. *Environment international*, *86*, 14-23.

https://climate.nasa.gov/global-warming-vs-climate-change/

https://www.climate.gov/news-features/understanding-climate/climate-change-global-temperature

http://thepolarhub.org/project/ecochains-arctic-crisis

APPENDIX

QUESTIONNAIRE

<u>Demographics</u>:

- **Quanti anni hai**? (Aperta)
- **Con quale genere ti identifichi**? (Uomo, Donna, Non-Binario, Altro)
- **Qual è il tuo livello di istruzione conseguito**? (Scuola primaria, Scuola Secondaria di Primo Grado, Scuola Secondaria di Secondo Grado, Laurea Triennale, Laurea Magistrale, Dottorato)
- **Qual è il tuo ambito lavorativo e/o di studio**? (Aperta)

<u>Environmental Motives pre-assessment:</u>

Molte persone sono preoccupate a causa dei problemi ambientali; tuttavia le persone differiscono per quanto riguarda le conseguenze che le preoccupano di più.Di seguito ti verranno elencate diverse aree dove i problemi ambientali possono avere effetti dannosi: per ognuna, ti chiediamo di valutare quanto sei preoccupata/o utilizzando una scala da 1 a 7.

Sono preoccupatoa/o per i problemi ambientali a causa delle conseguenze per:

- **Piante** (scala Likert, da 1 a 7, per niente - del tutto)
- **Animali marini** (scala Likert, da 1 a 7, per niente - del tutto)
- **Uccelli** (scala Likert, da 1 a 7, per niente - del tutto)
- **Il mio stile di vita** (scala Likert, da 1 a 7, per niente - del tutto)
- **La mia salute** (scala Likert, da 1 a 7, per niente - del tutto)
- **Il mio futuro** (scala Likert, da 1 a 7, per niente - del tutto)
- **L'umanità** (scala Likert, da 1 a 7, per niente - del tutto)
- **Le persone a me vicine** (scala Likert, da 1 a 7, per niente - del tutto)
- **Le generazioni future** (scala Likert, da 1 a 7, per niente - del tutto)

<u>Technology familiarity:</u>

- **Avevi mai utilizzato questa tecnologia (Realtà Virtuale) prima d'ora**? (scala Likert, da 1 a 5, mai – tutti i giorni)

- **Come valuteresti il tuo livello di esperienza precedente nell'utilizzo di tecnologie per la Realtà Virtuale**? (scala Likert, da 1 a 5, nessuna esperienza – molto esperto)

Sense of Presence:

Di seguito ti verranno proposte diverse affermazioni: dopo averle lette attentamente, ti chiediamo di rispondere ad ogni affermazione utilizzando una scala da 1 a 7.

- **Ho avuto la sensazione di "essere lì" nell'ambiente virtuale**: (scala Likert, da 1 a 7, per niente – del tutto)
- **Ci sono stati momenti durante l'esperienza in cui l'ambiente virtuale era la realtà per me**: (scala Likert, da 1 a 7, in nessun momento – sempre).
- **L'ambiente virtuale mi è sembrato più simile a:** (scala Likert, da 1 a 7, immagini che ho visto - luoghi che ho visitato).
- **Ho percepito più forte la sensazione di essere altrove o dentro l'ambiente virtuale**? (scala Likert, da 1 a 7, essere altrove – essere nell'ambiente virtuale)
- **Penso all'ambiente virtuale come ad un luogo simile ad altri luoghi in cui sono stato oggi** (scala Likert, da 1 a 7, per niente – del tutto).
- **Durante l'esperienza ho pensato spesso di trovarmi davvero dentro l'ambiente virtuale** (scala Likert, da 1 a 7, per niente – del tutto).
- **Utilizza questo spazio se desideri fare ulteriori commenti sulla tua esperienza. In particolare, quali elementi hanno contribuito a darti la sensazione di essere veramente nella simulazione, e quali fattori hanno agito per tirarti fuori da questa**? (Aperta)

Embodiment

Di seguito ti verranno proposte diverse affermazioni: dopo averle lette attentamente, ti chiediamo di indicare per ognuna il tuo livello di accordo o disaccordo su una scala da 1 a 7, dove 1 indica il valore di accordo più basso e 7 il valore più alto (scala Likert, da 1 a 7, fortemente in disaccordo – fortemente d'accordo).

- **Sentivo come se il corpo virtuale fosse il mio corpo**
- **Sentivo come se le parti del corpo virtuale fossero le mie parti del corpo**
- **Il corpo virtuale mi sembrava un corpo animale**
- **Sentivo che il corpo virtuale appartenesse a me**
- **I movimenti del corpo virtuale sembravano i miei movimenti**

- **Mi sentivo come se stessi controllando i movimenti del mio corpo virtuale**
- **Mi sentivo come se stessi causando i movimenti del mio corpo virtuale**
- **I movimenti del corpo virtuale erano sincronizzati con i miei movimenti**
- **Sentivo come se il peso del mio corpo fosse cambiato**
- **Sentivo come se l'altezza del mio corpo fosse cambiata**
- **Sentivo come se la larghezza del mio corpo fosse cambiata**
- **In questa sezione ti chiediamo di selezionare il diagramma che meglio descrive la relazione che hai percepito durante l'esperienza virtuale fra te e l'animale che hai impersonato** (scala Likert, da 1 a 7, totalmente distaccati – totalmente connessi)

<u>User Experience</u>

Di seguito ti verranno proposti diversi slider: muovi il cursore nella direzione che ritieni più opportuna dopo aver osservato gli aggettivi proposti (Likert, da 1 a 7)

- **Ostruttiva – Di supporto**
- **Complicata – Facile**
- **Inefficiente – Efficiente**
- **Confusa – Chiara**
- **Noiosa – Appassionante**
- **Non interessante – Interessante**
- **Convenzionale – Originale**
- **Usuale – Moderna**

<u>Learning Motivation</u>

Di seguito ti verranno proposte 8 domande relative alle tue impressioni sull'applicazione appena provata: per ognuna, ti chiediamo di rispondere utilizzando una scala che va da 1 a 5 (Scala Likert, da 1 a 5, fortemente in disaccordo – fortemente d'accordo).

- **L'applicazione ha catturato la mia attenzione**
- **L'applicazione ha stimolato la mia curiosità**
- **Ritengo che questa esperienza mi sia stata utile**
- **Mentre provavo l'applicazione sentivo che i concetti contenuti sarebbero stati facili da apprendere**

- **Mentre provavo l'applicazione sentivo di poter essere autonoma/o nell'apprendere i concetti**
- **Nel complesso ho apprezzato questa esperienza**
- **Questa esperienza mi è piaciuta così tanto che vorrei saperne di più sull'argomento**

Environmental Motives post-assessment:

Molte persone sono preoccupate a causa dei problemi ambientali; tuttavia le persone differiscono per quanto riguarda le conseguenze che le preoccupano di più.Di seguito ti verranno elencate diverse aree dove i problemi ambientali possono avere effetti dannosi: per ognuna, ti chiediamo di valutare quanto sei preoccupata/o utilizzando una scala da 1 a 7.

Sono preoccupatoa/o per i problemi ambientali a causa delle conseguenze per:

- **Piante** (scala Likert, da 1 a 7, per niente - del tutto)
- **Animali marini** (scala Likert, da 1 a 7, per niente - del tutto)
- **Uccelli** (scala Likert, da 1 a 7, per niente - del tutto)
- **Il mio stile di vita** (scala Likert, da 1 a 7, per niente - del tutto)
- **La mia salute** (scala Likert, da 1 a 7, per niente - del tutto)
- **Il mio futuro** (scala Likert, da 1 a 7, per niente - del tutto)
- **L'umanità** (scala Likert, da 1 a 7, per niente - del tutto)
- **Le persone a me vicine** (scala Likert, da 1 a 7, per niente - del tutto)
- **Le generazioni future** (scala Likert, da 1 a 7, per niente - del tutto)