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Virtual reality and body rotation: Two flight experiences in comparison

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HCI...................... Human Computer Interaction

VR........................ Virtual Reality

IVR...................... Immersive Virtual Reality

HMD.................... Head Mounted Display

UX........................ User Experience

EMG.................... Electromyography

AR........................ Augmented Reality

FOV..................... Field of View

DOF..................... Degree of Freedom

NUI...................... Natural User Interface

GVS..................... Galvanic Vestibular Stimulation

BCV..................... Bone Conductive Vibration

SSQ...................... Simulator Sickness Questionnaire

MSQ.................... Motion Sickness Questionnaire

EEG..................... Electroencephalography

IEEE.................... The Institute of Electrical and Electronics Engineers

GUI...................... Graphical User Interface

CLT..................... Cognitive Load Theory

LTM.................... Long Term Memory

UX........................ User Experience

UI......................... User Interface

PQ........................ Presence Questionnaire

ITQ .... Immersive Tendencies Questionnaire

UEQ..................... User Experience Questionnaire

TAM .... Technologies Acceptance Model

IVE .... Immersive Virtual Environment

VIMS .... Visually Induced Motion Sickness

VE........................ Virtual Environment

MSQ .... Pensacola Motion Sickness Questionnaire

MWL .... Mental Working Load

PDT .... Peripheral Detection Task

HRV..................... Heart Rate Variability

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Introduction

One of the most modern and noteworthy features of Virtual Reality (VR) is the capability to immerse users in a realistic simulated environment, allowing them to not only interact with the virtual world but also explore it physically. Recent advancements in VR technology require the design of effective and easy to use locomotion interfaces (Riecke & Schulte-Pelkum, 2015). In particular, despite the latest HMDs including tracking systems allowing for small walking areas, moving through larger virtual environments remains an issue (Williams et al., 2007). The latest VR technologies do not convey a convincing feeling of self-motion in the absence of actual motion (i.e., vection) (Slater, Usoh, & Steed, 1995; Riecke & Schulte-Pelkum, 2015). This shortcoming is primarily attributable to the discrepancy between the level of immersion that can be induced by a particular VR system and users' experience of feeling as if they were actually present, i.e., sense of presence in the virtual environment (Schubert, Friedmann, & Regenbrecht, 2001).

Embodied interfaces are devices that incorporate bodily motion and proprioceptive stimulation to the simulated experience. Such interfaces are promising for VR because they can improve the level of immersion and User eXperience (UX). At the same time they can also reduce simulator sickness compared to more traditional handheld interfaces, such as gamepads (Bektaş, Thrash, van Raai, Künzler, & Hahnloser, 2021). The aim of the present study is to evaluate the experience conducted with a novel embodied interface called VitruvianVR, using a VR flight scenario. To this end, this dissertation compared VitruvianVR against a gamepad/joystick, referring to performance measures (i.e., accuracy, fails). Furthermore, a series of data from questionnaires about sense of presence, user experience, mental workload, usability and simulator sickness was gathered. In Chapter 1 a brief introduction about VR definitions, evolution and classifications is explained. It will also focus on embodied interfaces, explaining what they are and how they were applied for VR flight scenarios in the already existing literature. Chapter 2 incorporates the point of view of user perception through an approach typical to human-computer interaction. All the remaining sections discuss the proposed case study, explaining hypothesis, methodology and the results obtained.

1

Virtual Reality and Embodied Interfaces

This chapter will introduce and describe Virtual Reality (VR) and embodied interfaces, with special emphasis on their application to flight scenarios.

1.1 Virtual Reality (VR)

1.1.1 Definition

Virtual Reality is nowadays considered a revolution in the field of emerging technologies. The topic has been studied across 60 years of history, but it remains quite complex to define an appropriate, unique and commonly shared construct referred to as VR (Steuer, 1992; Marsh, 1999).

Usually, accepted scientific definitions highlight three common features of VR systems: immersion, perception to be present in an environment, and interaction with that environment (Andersen & Thorpe, 2009; Slater, 2009; Sundar, Xu, & Bellur, 2010). Specifically, immersion relates to the amount of senses stimulated, interactions, and reality's similarity with the stimuli used to simulate environments. This feature can vary according to the properties of the technological system used to convey the simulated environment (Slater, 2009; Freina & Ott, 2015). Presence refers to the extent of which user's feels actually in the place provided by VR (place illusion), along with the reliably and effectively coming from it to perform certain actions (plausibility) (Slater, 2009). While interactivity is consider as the extent to which media would let the user exert an influence on the content and/or form (Steuer, 1992).

More recently, Sherman and Craig (2018) defined VR as having elements that include: *"The virtual world, immersion, interactivity, as well as people on the creating and receiving sides of the medium"* (p.6).

Depending on the technology in use, the user can live a more or less immersive experience. We distinguish non-immersive systems such as such as Desktops, immersive systems, like HMD' and semi-immersive systems, such as traditional flight simulators (Cipresso, Gigli-oli, Raya, & Riva, 2018).

In this dissertation we will refer to the definition of an Immersive Virtual Reality (IVR) which state:

"IVR...isolates the perceptive channels of the subject by "immersing" him sensorially in the three-dimensional world generated by the computer. Immersion is made possible by a display and sound diffusion device which isolates the user from the outside world... " (Pallavicini, 2020; p.32).

In IVR Head Mounted Displays (HMD) and motion sensors are often employed to bridge the gap between the simulation environment and surrounding physical context (Frederiksen et al., 2020). Often, the virtual environment not only convey visual and, auditory stimuli, but also tactile, in a narrative sequence of programmed events to which the users is en- gaged and directly react consistently (Dailey-Hebert, Estes, & Choi, 2021).

1.1.2 Evolution and Classification of VR-enabling devices

This section is divided into two subsection: evolution and classification. Firstly, a brief overview of the main steps in the development of VR are presented. Next, the most widely spread devices enabling VR experiences are summarized.

EVOLUTION

Virtual Reality can be dated back to the 1960ies, with Morton Heilig's *Sensorama*. This prototype featured lenses that enable a 140° horizontal and vertical field of view, stereo earphones, and air discharge nozzles that provide a sense of breezes at different temperatures as well as scent. It could stimulate visual, audio, haptic and olfactory systems at the same time for a multi-sensory experience (Rheingold, 1991; Boas, 2013)

Later, during the 1970ies, the first designed prototype of an HMD was *the Headsight* developed by Philco. It was a helmet with a cathode ray tube display and a tracking system that allowed to track head position. From that moment on, various attempts to im- prove VR devices can be counted (Sutherland, 1965; Foster & Wenzel, 1992; Sturman & Zeltzer, 1994; Boas, 2013; Jerald, 2015). Dr. Frederick P. Brooks Jr., inspired by Suther- land's work started working on molecular graphics: the results was the design of a visual interaction with simulated molecules that included force feedback where the docking of simulated molecules could be felt, *the Grope-III system* (Jerald, 2015). In 1985, Fisher and some NASA researchers developed a viable stereoscopic head tracked HMD with a wide field of view, called *Virtual Visual Environment Display* (VIVED). Based on a scuba diver's face mask with the displays provided by two Citizen Pocket TVs (Jerald, 2015). Another device was built by Foster and Wenzel in 1992: the *Convolvotron*. The device provided localized 3d sounds and was unprecedented as the HMD could be produced at an affordable price, leading to the birth of the VR industry.

At the beginning of the 21st century, although there was little mainstream media attention given to VR, research continued increasingly adopting in depth, a human centered design. A significant advancement occurred in 2006, when Bolas and McDowall built a 150° field of view HMD called *The Wide5*. It was used to study the effects of field of view on UX and behavior, such as estimating the distance with respect to a target depending on the size of the field of view (Jones, Suma, Krum, & Bolas, 2012). Those studies led to the design of a low-cost device called *Field of View To Go* (FOV2GO). Nowadays, the growing interest coming from companies ranging from startups to Fortune 500 have accelerated the evolution process of VR devices and have started to provide resources for VR development (Jerald, 2015). VR devices started being developed in order to run on multiple devices (e.g. Samsung Gear VR with smartphones and Playstation VR with consoles) (Jagneaux, 2017). In 2016, two VR HMD compatible with PC's were released: *Oculus Rift* and *HTC Vive* (Pallavicini, 2020). In 2018, a partnership between Oculus VR, Qualcomm and Xiaomi built the first *standalone (all in one)* HMD with the name of *Oculus Go*. It was the first HMD that didn't require a connection with some external device in order to function. Finally, in 2019, Facebook (Meta nowadays) decided to released on the market the so-called *Oculus (Meta) Quest*, a standalone *roomscale* (in the entire room and not only seated or steady) HMD for VE (Pallavicini, 2020) (Figure 1.1).

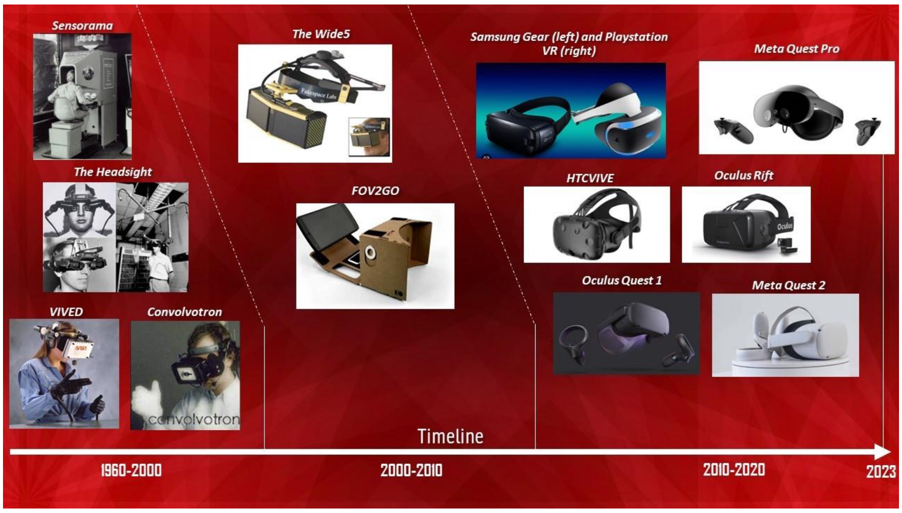


Figure 1.1: Evolution of VR-enabling devices through years.

CLASSIFICATION

Currently, there are many different classifications for VR devices. The first taxonomy refers to the degree of immersion enabled by the device. There are three types of systems in Virtual Reality ascribing to this taxonomy (Kalawsky, Bee, & Nee, 1999):

- Non Immersive Systems such as Desktops, are not very sophisticated devices for Virtual Reality applications, as they are cheap, but do not convey involving experiences. The VR environment is shown through standard monitor and the interaction with it is mediated by keyboards, mice, trackballs or *DataGloves*.

- Fully Immersive Systems give the user the closest experience to reality through high quality graphics and performance as well as substantial reduction of unrelated stimuli. Their main characteristic is that they allow users to isolate themselves from the surrounding environment and to focus only on the virtual one. An example is HMDs which utilize small monitors located in correspondence to each eye in order to supply stereoscopic images.

- Semi-Immersive Systems are a midway between the first two. Flight simulators for example are systems that combine high performance software with stereoscopic vision, increased field of view, haptic feedback, among other Virtual Reality inducing technologies, to deliver a more immersive experience, sometimes even shared with other users.

A different approach is the one that considers hardware, which focuses more on the input and output devices utilized, dividing them in two categories (Anthes, García-Hernández, Wiedemann, & Kranzlmüller, 2016).

1 Output Devices: they represent the visual display, from the users' point of view. This category includes mobile HMDs (e.g. smartphones with additional lenses

mounted at a reasonable distance, Cameface prototypes, stand alone systems and ergonomically designed smartphones), wired HMDs (e.g. HTCVive), haptic devices (e.g. hybrid systems with controllers, vibrotactile elements) and multi-sensory devices (e.g. devices that generates tactile and olfactory feedbacks such as SpotScence).

2 Input Devices: with these types of devices too it is possible to identify three different subcategories focusing on input provision for HMD users: controllers (e.g. hand held joysticks or touchpads with 6 Degree Of Freedom (DOF) tracking information, keyboards, mouse), navigation devices (e.g. traditional treadmills, OmniDirectional Treadmills (ODTs, slidemills and devices to walk or sit) and tracking technologies (e.g. body tracker or gesture tracker such as DataGloves).

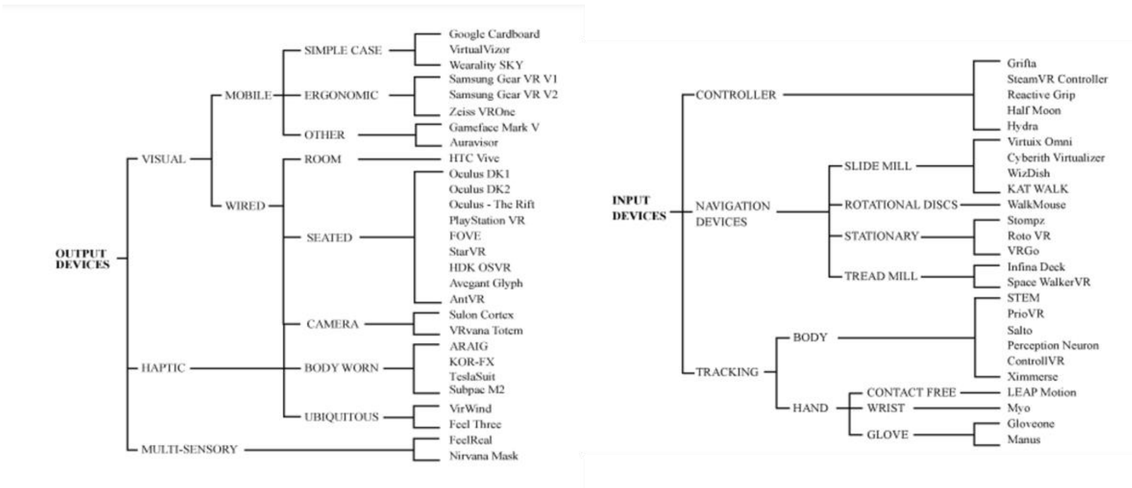


Figure 1.2: Adapted taxonomy of VR devices from Anthes et. al (2016).

Based on this taxonomy as shown in Figure 1.2 the Oculus (Meta) Quest 2 used in this dissertation could be described as a kind of other visual output device with its standalone properties. Controller would be categorized as a controller input device, whereas VitruvianVR can be considered as a new kind of navigation devices in that it is a standing device.

1.2 Embodied interfaces

1.2.1 Definition

The earliest definition of embodiment in VR is explained as the sense that emerges when the properties of a body in the virtual environment are processed as if they were the properties of one's own biological body (Kilteni, Groten, & Slater, 2012). According to Dourish (2004), an embodied interface allows an embodied interaction which necessitates control interfaces that encourage a high level of engagement with the virtual environment during which the system reacts to users' actions in a meaningful way. An embodied interface falls into the subcategory of navigation devices. As a matter of fact, almost all VR technologies require a control interface to mediate between the user's actual physical movements and the movements of the user's avatar/camera through the virtual environment. Control interfaces can vary with respect to the types of physical movements performed by the user, the types of movements that are possible in the virtual environment, and the mapping between physical and virtual movements (Bektaş et al., 2021). Physical movements can range from fine-grained hand movements to full body movements, for instance walking, controlling a vehicle, or flying. Embodied interfaces are not common. Let us think to the common interface Innovative control interfaces for example, handheld control interfaces such as gamepads. They are controlled using physical movements of the thumbs, but may be used to simulate the flight of a bird in VR. While these mappings may be difficult to learn initially, our world is filled with such mappings. For example, the most renowned mapping is that of moving a mouse pointer on a computer screen is a handheld mouse with one or two buttons. In experimental contexts, it has been shown that handheld interfaces, such as conventional joysticks or gamepads, can produce realistic walking behaviour (Thrash et al., 2015), and can lead to better navigation performance (Marchal, Pettré, & Lécuyer, 2011), spatial updating performance (Kitson, Riecke, Hashemian, & Neustaedter, 2015), comfort and precision (Kitson, Hashemian, Stepanova, Kruijff, & Riecke, 2017) than more embodied interfaces. In general, there seems to be a trade-off between user's familiarity with a control interface and the extent to which the mapping between physical and virtual movements is intuitive and enables embodied interaction (Lapointe, Savard, & Vinson, 2011). Embodied interfaces are often used for navigation tasks in virtual environments since they include a rich set of body-aware input techniques that vary from hand-based interaction to whole-body interaction (Jacob et al., 2008).

1.3 Flight scenarios

1.3.1 Currently existing flying interfaces

Various 4DoF flying interfaces have been investigated for immersive VR including hand-held interfaces (Quigley, Goodrich, & Beard, 2004), hand or arm-based gesture commands (Pfeil, Koh, & LaViola, 2013; Monajjemi, Mohaimenianpour, & Vaughan, 2016; Sarkar, Patel, Ram, & Capoor, 2016) voice commands (Quigley et al., 2004; Krishna, Sathish, Ganesan, Babu, & Abilash, 2015; Peshkova, Hitz, & Ahlström, 2016), and even brain-computer interfaces (Yu, Qian, Wu, & Pan, 2014). In general, these interfaces do not provide vestibular cues aligned with the visual motion direction of flight, which can reduce the realism of the flight experience (Hale & Stanney, 2014). Moreover, the mismatch between visual and vestibular/proprioceptive cues can cause or exacerbate Visually Induced Motion Sickness (VIMS), where the user feels motion sick without physically moving (Reason & Brand, 1975).

In the literature, there is only a limited number of embodied control interfaces that have been developed for or employed in flight simulation scenarios (Hashemian, Lotfaliei, Adhikari, Kruijff, & Riecke, 2020). While HMDs can provide convincing visual cues of self-motion (Riecke & Jordan, 2015), it is not possible to provide full physical cues of self-motion without actually flying (B. D. Lawson & Riecke, 2014). Therefore, embodied flying interfaces aim to create a realistic flying experience by providing physical self-motion cues aligned with the proprioceptive sensory cues in an actual flight. These physical self-motion cues can be provided by mechanical setups (Groen & Bles, 2004; Miermeister et al., 2016) or simply user-powered body movements in leaning-based interfaces (Miehlbradt et al., 2018; Pittman & LaViola Jr, 2014; Schulte et al., 2016).

Several embodied flying interfaces use convoluted mechanical setups to provide physical self-motion cues to the user's body. An example of complex mechanical flying interfaces, moving-based flight simulators use motors/actuators to apply limited physical motion cues to the user's body (Groen & Bles, 2004). Harnessing the user from ceiling is another fairly complex mechanical approach for embodied flying interfaces (Krupke et al., 2016; Perusquía-Hernández et al., 2017; Krupke et al., 2015). However, these mechanical interfaces usually have complicated setups and safety hazards, as summarized by Viirre and Bush (2002).

1.3.2 Degree of interface's embodiment

In literature, different types of devices exist for embodied VR flying interfaces. Each characterized by a specific level of physical motion cues and bodily involvement. Clear distinctions can be made based on *the sense of embodiment* generated, namely the subjective experience of feeling embodied in VR, and *the degree of embodiment*, that is the objective degree of embodied movement in VR afforded by an interface. In comparing different VR flying interfaces, this dissertation refers to embodiment not as a user's perceived agency, but as the degree of embodiment afforded by the locomotion interfaces (P. Liu, Stepanova, Kitson, Schiphorst, & Riecke, 2022). Traditional approaches to distinguish these types of interfaces are based on online surveys rather than direct experience, which have identified a trend of users's opinion reporting the expectation that the more body parts involved, the higher degree of embodiment an interface tends to have (Zielasko & Riecke, 2021). The approach that this thesis will consider is the one proposed by P. Liu et al. (2022) in which the chosen interfaces within a spectrum of embodiment were mapped based on the level of bodily involvement on an ordinal scale (Figure 1.3).

The paper distinguishes different type of systems with the following categories:

1. *Handheld Controller (Thumbstick/Touchpad):* An example is Google Earth VR in which the navigation via handheld controller as an input device works by using a trigger button (right hand) to point, select, and drag the environment. As one of the most prevalent control paradigms, the level of physical motion cues/bodily involvement represented by the finger movement of the thumbstick/touchpad controller is the associated with embodied self motion in VR and provided no vestibular self-motion cues, thus they consider it as a low embodied flying interface, even though widely used (Kitson et al., 2017; Perusquía-Hernández et al., 2017; Hashemian et al., 2020; Bektaş et al., 2021).

2. *Superman Flying Gesture:* Gathers all the interfaces with a wireless controller in each hand: participants moves their arms to control flying movements ((Picard-Deland, Pastor, Solomonova, Paquette, & Nielsen, 2020). A typical example of this embodied interaction can be found in *Virtual Superheroes* in which user's hands are tracked with markers. When the participants raises their hands above their head, they flew higher in the virtual city (Rosenberg, Baughman, & Bailenson, 2013).

3. *Fly with Wings:* The main example that falls into this type of interfaces is *Lost Spirit*, a VR experience where standing participants could use their body gestures as a Natural User Interface (NUI) through Microsoft Kinect (Tong et al., 2016). Other studies instead evaluate the same gesture but controlled through a motion tracked shoulder control (Sikström, De Götzen, & Serafin, 2015). An additional interface is *Birdly*, a device that aimes to provide a bird-like flying experience. Users were asked to lie face down on a purpose-built actuated motion platform that allowed them to embody a bird of prey by means of multi-sensory stimulation, including proprioceptive (i.e.,

the flapping arm movements correlate with the wings of the bird), tactile (e.g., headwind simulated by a fan), audio, and olfactory feedback, including some vestibular self-motion cues (Rheiner, 2014). All of these examples showed a high level of bodily involvement, but on the other hand participants quickly became tired with their arms feeling heavy and hurting after several minutes of use due to stretching them to the sides for a long time (Tong et al., 2016).

4. *Leaning-based interfaces:* these types of interfaces are the most studied. The first attempts were made with *AWE*. Researchers tested three prototypes using a custom leaning-based interface with a rotating swivel chair (Kruijff & Riecke, 2018; Quesnel, Stepanova, Aguilar, Pennefather, & Riecke, 2018). The latest prototype tested in the literature is represented by a custom interface called the *Limbic Chair* that supports each thigh in a way that allows users' legs to move independently (Bektaş et al., 2021).

While all these interfaces allow users to easily move horizontally, it still remains hard to find solution for vertical locomotion that also allows a rotation on the roll axe. One of the latest attempts is represented by the *HeadJoystick*, a seated or standing leaning-based flying interface. Users move their head and/or leans in the direction they want to navigate, and the position of the already-tracked HMD is used to control movements (Riecke & Schulte-Pelkum, 2015; Adhikari et al., 2021; Hashemian et al., 2020).

Based on the state of the art just outlined, this dissertation aims to investigate a novel embodied interface for a flight scenario in VR, by comparing a traditional handheld Xbox-ONE Elite Controller (Gamepad) with a standing embodied interface, namely VitruvianVR.

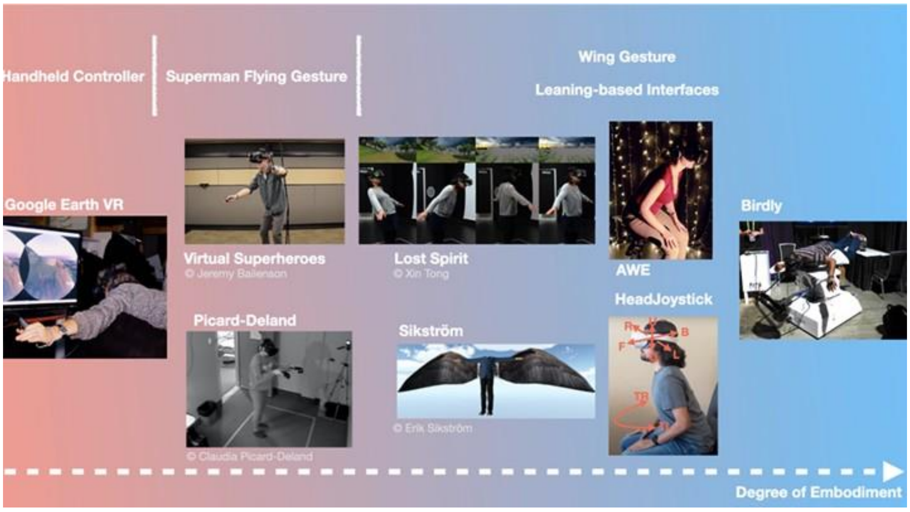


Figure 1.3: Already existing embodied interfaces and their level of degree

2

Human-Computer interaction in VR

This chapter will cover multiple aspects of Human-VR interaction. More specifically section one is about usability, its definition and its guidelines for VR. Section two deals with User eXperience (UX). Section three is about cybersickness, its theories and techniques to reduce it in VR. Section 4 is about cognitive load, its definition and its relation with VR.

2.1 Usability

2.1.1 Guidelines and criteria for VR

The definition of usability from ISO 9241-11 (Guidance on usability) states: *"the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use"* (ISO, 1998; p.3).

Even though there are already existing guidelines for traditional 2D Graphical User Interface (GUI) interfaces (Nielsen, 1993) and evaluation methods, when it comes to virtual environments the panorama is more fragmented. As a matter of fact, there are no shared valid methodological guidelines in order to evaluate and solve usability problems in VR in order to design ”user friendly” VR environments and interfaces (Bach & Scapin, 2010). Notably, methods and guidelines for 2D’s interfaces fail if applied to VR because they cannot consider tridimensionality and the sense of immersion generated from IVR systems (Hix & Gabbard, 2002). More specifically, they do not take into account the characteristics that come from the interaction between the users and the environment, such as *navigation, orientation, manipulation and multimodal input/output* features, and characteristics as a result of that interaction, such as *involvement of the users* (e.g. presence, immersion, comfort), *collateral effects* (e.g. AfterEffects, Cybersickness). In this dissertation in order to describe usability we will mainly focus on the definition taking into account the ease of use, ease of learning and the perceived controller naturalness that plays a role in Virtual Environments (VE) and videogames in general (McGloin, Farrar, & Krcmar, 2011)

2.1.2 Perceived Naturalness of Controller

The perceived naturalness of controller may be related to the degree of the feeling of physical immersion within a Virtual Environment (McGloin et al., 2011). When it comes to the evaluation of an embodied interface it is important to consider how natural the controller of the device is perceived by the users, especially in relation to the type of environment in which the device should be used. The natural mapping motion-capturing controllers embodies the concept of spatial presence by transferring the real-world movements and behaviors of gamers directly into actions in the virtual environment. The more natural the controller is perceived by the user, the greater the levels of perceived spatial presence. Therefore, controllers that rely on the use of real world mental models and realistic behaviors should lead to increased levels of perceived spatial presence and perception of realism (McGloin et al., 2011). Natural mapping motion-capturing controllers makes it more likely that mental models of real-life skills and behaviors can be called upon within the virtual world and as a result enhances the flow of the experience, consequently making it easier to meet the game's challenges (Sweetser & Wyeth, 2005) and ultimately leading to a more enjoyable experiences or mental model (McGloin et al., 2011).

2.2 User Experience (UX)

Considering all of the definitions, UX is a multi-facet concept that consists of various interconnected elements explaining user experience, behaviors and feedback towards products, services, applications, system, software and others. From these perspectives, UX is of key importance also for VR. VR systems are built up from various components, and the interactions occurring in the system can vary (e.g., users, devices and interactions) and influence the UX (Forlizzi & Battarbee, 2004; Hassenzahl & Tractinsky, 2006) through its presence, immersion and engagement (Bulu, 2012) and by reducing the side effects caused by the experience itself (Wang & Suh, 2019).

2.2.1 UX dimensions in the study

ENJOYMENT

The state of enjoyment is described as a positive emotion or a positive affective state (Wankel, 1993). When it comes to perceived enjoyment related to technology, it gains a new frame, specifically it gains a new frame, specifically it is defined as the degree to which using an information technology is perceived as fun (Venkatesh, 2000). Enjoyment in the context of this project is the pleasure the user experiences because of being exposed to a certain media stimulus, particularly an immersive virtual reality interactive game experience (Vorderer, Klimmt, & Ritterfeld, 2004). Previous studies on important factors that produce videogame enjoyment show that perceived interactivity, realism, and spatial presence all work together to explain a significant portion of the variance in enjoyment (Shafer, Carbonara, & Popova, 2014; Shafer & Carbonara, 2015). The variables that lead to enjoyment in those gaming situations should also be important in the process of enjoyment of VR games (Shafer, Carbonara, & Korpi, 2019).

NOVELTY

Novelty reflects whether a system is innovative and creative. Novelty can catch the user's attention and is defined as *"The quality of being new, original, or unusual"* (Qualls, 2015; p.10). Al-Hunaiyyan, Alhajri, Alghannam, and Al-Shaher (2021) also added other aspects of novelty that contribute to UX, such as creation, invention, and innovation, originality or technological advances (Al-Hunaiyyan et al., 2021). The construct of novelty is also related the so called *"novelty effect"*, conceived as an increase in the perceived pragmatic and/or hedonic value, as well as an increase in the arousal and/or valence of the users' emotional response (Koch, von Luck, Schwarzer, & Draheim, 2018). When novelty eventually fades, the increased UX qualities and arousal and valence of the emotional responses disappear. The novelty effect highlights the importance of considering the temporality of the user experience and how the UX changes over time (Karapanos, Zimmerman, Forlizzi, & Martens, 2009). Koch et al. (2018) states that the novelty effect has a complex nature and is mostly present on two occasions: 1) at the moment the new device or system gets implemented and 2) every time changes are made to an existing device or system.

SAFETY

Perceived safety, is described as a standard of the interface functions which has an influence on the user's health and happiness, originally measured as an important factor for driving. (Osswald, Wurhofer, Trösterer, Beck, & Tscheligi, 2012). In order to address the perceived safety it is important also to measure the perceived risks of users. Featherman and Pavlou (2003) defined perceived risks as the extent to which an individual feels vulnerable with respect to potential negative outcomes when using a product or service and proposed several dimensions of perceived risks. Assessing risks and safety can be important especially when they could be a limit in the actual willingness to accept and use a specific virtual reality device (M. Zhang, Shu, Luo, Yuan, & Zheng, 2022).

COMFORT

It is important also to provide a sense of comfort. As stated in the research proposed by Murtza, Monroe, and Youmans (2017) *"The system should be designed to prevent sensations of physical illness during use, by preventing jarring movement lag, increasing realism of visuals, and so on"* (p.2069). It is important to state that comfort also has an impact on the perceived value. In the literature, comfort related to VR devices was study considering the weight of the HMD (Yan, Chen, Xie, Song, & Liu, 2019), the nose pressure load (J. Chang et al., 2014) and the virtual position of a body that can lead to subjective, physiological and cognitive effects consistent with discomfort if placed in an uncomfortable position (e.g. flying) (Choudhary, Kim, Schubert, Bruder, & Welch, 2020). (Clemes, Shu, & Gan, 2014; Patterson & Spreng, 1997; Suhartanto, 2011). For this dissertation it is an important factor to consider due to the nature of the embodied interface, with a view of possibly selling the interface in the future.

OVERALL SATISFACTION

Overall satisfaction refers to the extent in which the users consider themselves satisfied with the use of the technology in all of its aspects altogether (Lewis, 1992). While earlier work would suggest that a priori expectations play a major role in the formation of satisfaction judgments (Lindgaard & Dudek, 2003), other researches have found expectations to evolve during the actual experience with the product (Karapanos et al., 2009).

Different models were proposed in order to explain the features that can affect customers' satisfaction (Park & Lee, 2011). Satisfaction of customers with products and services of a company is considered as the most important factor leading toward competitiveness and success and making the user loyal to one service provider (Hennig-Thurau & Klee, 1997; Hanif, Hafeez, & Riaz, 2010). Customer satisfaction also relates to how customers evaluate the ongoing performance (Gustafsson, Johnson, & Roos, 2005). In VR studies, overall satisfaction represents the game user satisfaction coming from the experience, which was found the be significantly higher compared to traditional monitor games (Shelstad, Smith, & Chaparro, 2017). Also, properties of VR can enhance the overall users experience and satisfaction due to a combined impact of innovative elements and other aspects of the experience itself, like found by Trunfio, Lucia, Campana, and Magnelli (2022) for cultural heritage museum services.

REALISM

Realism is understood as an essentially visual and proprioceptive feature that triggers our senses (Pujol-Tost, 2011). In relation to VR, realism is considered as faithfulness to the environment, including objects and perceived experiences (C. Lee, Rincon, Meyer, Höllerer, & Bowman, 2013). Perceived realism has been shown to influence outcome variables such as presence, involvement, arousal, and excitement (Ivory & Kalyanaraman, 2007). Due to the unique interactive nature of video games, coupled with their multiple feature designs, perceived video game realism is a judgment of how accurately a game and its features have simulated a concept according to the gamer's expectations (McGloin et al., 2011). Elements that can influence are scene realism, meaningfulness and information consistency (Slater et al., 1999). Striving for visual realism is beneficial because it makes users feel more engaged with the experience and contributes to a sense of immersion (McMahan, Bowman, Zielinski, & Brady, 2012).

2.3 Sense of Presence

The core concept of *presence* describes the user's feelings of actually being in the place provided by VR (place illusion) and reliably and effectively performing certain actions (plausibility) (Slater, 2009). According to Schubert et al. (2001), the construct of presence has three main components: realism, involvement, and spatial presence. Realism is defined as the user's evaluation of how convincing the virtual environment is. In the literature, several factors are identified as possible variables influencing the sense of presence: (1) *the ease of interaction* positively correlates with the sense of presence (Billinghurst & Weghorst, 1995); (2) *the user control*, described as the perceived sense of control which can increase the sense of presence (Witmer & Singer, 1998); (3) *the realism of the image* which is described as the degree of realism in the virtual environment, the higher it is, the stronger the sense of presence (Witmer & Singer, 1998); (4) *the duration of the exhibition*, when the experience in the virtual environment exceeds 15 minutes the sense of presence tend to weaken (Witmer & Singer, 1998); (5) *the social presence and social presence factors* which includes the social presence of other individuals (real or avatars), and the ability to interact with them (Heater, 1992); (6) *the quality of the virtual environment*, resulting in quality, realism, and the ability of the environment to be fluid to create interaction are key factors in the user's sense of presence (Hendrix & Barfield, 1996). In light of the many existing notion on presence this dissertation mainly focused on the definition given by Witmer and Singer (1998): *"Presence is defined as the subjective experience of being in one place or environment, even when one is physically situated in another. Presence refers to experiencing the computer-generated environment rather than the actual physical locale"* (pp. 225).

2.4 Technology acceptance model

Based on two psychosocial theories, the Theory of Reasoned Action (Fishbein & Ajzen, 1977) and the Theory of Planned Behavior (Ajzen, 1991); Davis (1989) proposed a model called the Technology Acceptance Model (TAM) in which intention to use a technology is predicted by two user factors, being the perceived usefulness and its perceived ease of use. Perceived usefulness is defined as *"the degree to which a person believes that using a particular system would enhance his or her job performance"* (Davis, 1989, p. 320). Perceived ease of use refers to *"the degree to which a person believes that using a particular system would be free of effort"* (Davis, 1989, p. 320). Several works have shown that perceived usefulness is the strongest predictor of intention to use (King & He, 2006). The TAM is today the most frequently used model of user acceptance (Hsiao & Yang, 2011; Venkatesh, 2000). It is a parsimonious and widely applicable model. Numerous studies have extended it to fit different technologies (Amoako-Gyampah, 2007; Choi & Ji, 2015), different contexts (Brown, Massey, Montoya-Weiss, & Burkman, 2002; Huang, Backman, Backman, & Moore, 2013), and different users (Elias, Smith, & Barney, 2012; Venkatesh & Morris, 2000). Related to VR, studies have found that intention to use was predicted by perceived usefulness and perceived ease of use (Bertrand & Bouchard, 2008; Chow, Herold, Choo, & Chan, 2012; Fetscherin & Lattemann, 2008; Tokel & İsler, 2015). One of the latest model of TAM proposed in the literature also includes aspects of cybersickness, presence, innovativeness and pragmatic and hedonic quality of the device (Sagnier, Loup-Escande, Lourdeaux, Thouvenin, & Valléry, 2020).

2.5 Cybersickness

2.5.1 Definition

Recently, all the advancements outlined above were attempts to fulfill the existing gap between users and their willingness to use Virtual Reality devices. This advancements create an urgent need to solve some of the key problems of VR exposure. Perhaps the main problem is a phenomenon known as ”simulator sickness”, also known in Virtual Environment (VE) as ‘cybersickness’ (Kennedy, Lane, Berbaum, & Lilienthal, 1993; Keshavarz & Hecht, 2011). Cybersickness is a condition that may occur during or after exposure to a VE and it can induce symptoms like headache, eye strain, nausea or vomiting in extreme cases (LaViola Jr, 2000). Around 80% of VR users typically experience some symptoms of sickness, with as many as 50% experiencing symptoms with such severity that they are compelled to terminate a session of VR early (Stanney & Kennedy, 2010),sometimes even reducing the willingness to use VR ever again (Kolasinski, 1995; B. Lawson, Kass, Muth, Sommers, & Guzy, 2001).

Simulator sickness is defined as a syndrome similar to motion sickness that can be experienced as a side effect during and after exposure to different virtual reality environments. Originally, the term “simulator sickness” was linked to effects induced by simulators consisting of a platform, often mobile, and with the visual stimuli generated by a computer, without head-tracking. The invention of HMDs led to developing another term, “cybersickness,” which may lead to unpleasant symptoms, cause by the delay between actual head movements and the generated image. Regardless of the term used, they both indicate the unpleasant symptoms evoked from VR exposure (Sharples, Cobb, Moody, & Wilson, 2008; Bruck & Watters, 2011; Serge & Moss, 2015; J. Lee, Kim, & Kim, 2017). Finally, a study has also suggested a relationship between perceived enjoyment experienced during the VR session and an alleviation of the simulator sickness symptoms (Lin, Duh, Parker, Abi-Rached, & Furness, 2002).

2.5.2 Theories

Several theories have been developed to explain why individuals suffer from motion sickness. According to authors focused on virtual simulators, they may be also applicable in the field of simulator sickness during exposure to virtual reality (Brooks et al., 2010). The literature concerning simulator sickness in VR has offered a variety of theories in order to possibly explain the cybersickness phenomena. A classic distinction divides them in six different main theories (Dużmańska, Strojny, & Strojny, 2018). In this dissertation we mainly focused on three of them:

- *The Sensory Conflict Theory* (Reason & Brand, 1975; Ng, Chan, & Lau, 2020) explains motion and simulator sickness through a concept of conflict that arises between different sensory systems: the signals coming from visuo-vestibular and non-vestibular proprioceptors differ from one another leading to a mismatch with expectations based on previous experience. The Vestibular system is crucial for the occurrence of Simulator Sickness symptoms. Continuous exposure to a stimulus results in an eventual disappearance of symptoms due to adaptation even if the conflict remain presents.

- *Neural Mismatch Model* (Reason, 1978; Recenti et al., 2021) explains simulator sickness in terms of discrepancies between expectations derived on the basis of present moves and contents kept in the neural storage that contains information about typical combinations of command signals (efference) and the integrated patterns of inputs from the orientation senses generated by them (reafference).

- *Postural Instability Theory* (Riccio & Stoffregen, 1991; Recenti et al., 2021) tried to give an alternative to the *sensory conflict theory* since for the reaserchers the state described in the SC theory occurs too often making it not unusual. Furthermore, the difference between what one's senses of experience and what an individual expects to feel is immeasurable. The theory declares that the symptoms of motion or simulator sickness are experienced when one has been exposed to long-lasting postural instability and has not yet learned how to adjust to this situation and maintain proper balance (e.g. rollercoaster, travelling in a ship).

2.5.3 How to reduce Simulator Sickness in VR

Many different theories have been proposed in order to explain the mechanisms behind the simulator sickness phenomena, however not as many proposal have been advanced in order to reduce the symptoms of cybersickness (Weech, Moon, & Troje, 2018). It was discovered that high rates of rotational acceleration and unpredictable motion have also been observed to cause sickness in simulators and virtual reality (McCauley & Sharkey, 1992; Kolasinski, 1995; Pausch, Crea, & Conway, 2017; LaValle, 2017). LaValle (2017) argues in his book that acceleration is the factor mostly contribuiting to cybersickness because it causes strong vection. Vection is caused by a mismatch between the virtual environment and the physical environment in the visual and vestibular systems, which has been argued as the root source of cybersickness in sensory mismatch theory. Vection can be intensified by exposure time, spatial velocity and lots of moving details in the scene (LaValle, 2017). One preventative approach has been to avoid situations that generate sensory mismatch: for example, Dorado and Figueroa (2014) implemented camera movement in VR that avoids accelerations as much as possible.

Another technique includes galvanic vestibular stimulation (GVS) to prevent symptoms of simulator sickness in virtual environments. It works by applying an electrical current to electrodes near the mastoid processes in order to stimulate vestibular afferent nerves in order to recouple visual and vestibular cues in flight simulator task (Cevette et al., 2012) and a driving simulator (Reed-Jones, Reed-Jones, Trick, & Vallis, 2007). Stimulation can also be conducted with a bone-conductive vibration (BCV) (Weech et al., 2018; Weech & Troje, 2017), striking (i.e., *PhantomLegs*) (S.-H. Liu et al., 2019), airflow and seat vibration (D'Amour, Bos, & Keshavarz, 2017), and foot-based vibrotactile feedback (Kruijff et al., 2016; Terziman, Marchal, Multon, Arnaldi, & Lécuyer, 2012).

Recently, a 'point and teleport' method for moving in a virtual world has become a set standard, where a user specifies a position to which they will relocate upon a button press minimizing the accelerations of the visual scene (Bozgeyikli, Raij, Katkoori, & Dubey, 2016) after a visual cutout transition (e.g., blurring, vignette, blink) (Habgood, Moore, Wilson, & Alapont, 2018). However this can disrupt VR immersion (Boletsis & Cedergren, 2019; Bozgeyikli et al., 2016), diminishing presence in realistic environments (Freitag, Rausch, & Kuhlen, 2014; Ruddle, Volkova, & Bülthoff, 2011; Usoh et al., 1999), and reducing the sense of direction (Cliburn, Rilea, Parsons, Surya, & Semler, 2009). Visual modification approaches employ strategies that adjust how users view their VR surroundings. A common technique is represented by reducing the FOV which uses subtle visual cues for smooth movements from the user's viewpoint (Buhler, Misztal, & Schild, 2018; Fernandes & Feiner, 2016) although it has been shown to have negative effects on performances in virtual environments (Al Zayer, Adhanom, MacNeilage, & Folmer, 2019) and the technique can degrade the *sense of immersion* during the experience (Freitag et al., 2014; Ruddle et al., 2011; Usoh et al., 1999).

In order to both 'recouple' the visual and vestibular systems during navigation of a VR environment and senses of immersion it is possible to use motion platforms to move the body along with visually-simulated motion (Riecke, Caniard, & Schulte-Pelkum, 2006; Roston & Peurach, 1997). Body movement approaches that either leverage physical devices that drive explicit body movement or other limbs to emulate walking actions, treadmill-based solutions with walk-in-place motion (Frissen, Campos, Sreenivasa, & Ernst, 2013; Iwata, 1999; Swapp, Williams, & Steed, 2010) rotation chair-based solutions to incorporate physical spinning (Rietzler et al., 2018), arm swinging interaction techniques that mimic physical leg walking actions (Pai & Kunze, 2017), and VR walking that consists of input with trigger buttons from conventional game controllers to reduce whole-body movement (Sarupuri, Hoermann, Steinicke, & Lindeman, 2017) are the typical approaches used. On the other hand these interfaces require bulkier devices (e.g., treadmills, chairs), larger interaction spaces (e.g., arm swinging), or greater manual effort (e.g., trigger button input) (Peng et al., 2020).

2.6 Mental Workload

2.6.1 Definition and measures

Mental workload (MWL) is one of the most widely used concepts in ergonomics and human factors and represents a topic of increasing importance (Wickens, 2008). MWL is a peculiar concept that has intuitive appeal, but remains surprisingly difficult to define. An analogy is often made between mental and physical load, in that each expresses two components – stress (i.e., task demands) and strain. Demands (stress) can have multiple facets, such as time pressure and task complexity. If demands begin to exceed capacity, skilled operators can either adjust their strategy to compensate or else performance necessarily degrades (Wickens, 2008). Thus, MWL as a multidimensional construct, is determined by characteristics of the task (e.g. demands, performance), of the operator (e.g. skill, attention) and, to a degree, the environmental context in which the performance occurs. Stanton (2004, chap. 39-1) have suggested that MWL reflects the level of attentional resources required to meet both objective and subjective performance criteria, which may be mediated by task demands, external support, and past experience. In order to measure the MWL, it is possible to consider three categories of basic parameters: measures of task performance in the primary and/or the secondary task, subjective reports and physiological metrics. Monitoring attention to and workload from a primary task may be conducted by assessing performance on a secondary task. In any real-world dual task situation where one task takes priority over the other, performance on the secondary task (in terms of errors and time) is closely associated with the spare capacity unused by the primary task. A suitable tool to assess operators' workload from a primary task is the concurrent performance on a peripheral detection task (PDT) (Van Winsum, Herland, & Martens, 1999). MWL is a subjective state as well; people are able to express themselves in words or indications on scales in post-task responses. Furthermore, physiological measures are a natural type of workload index since work demands physiological activity by definition. As a matter of fact it can increase pupil size, heart rate and decrease heart rate variability (Wickens, 2008; Nenna, Orso, Zanardi, & Gamberini, 2022).

2.6.2 Mental Workload in Virtual Reality

In virtual reality, the concept of mental workload should be taken in consideration when realizing immersive training contexts. While numerous studies have demonstrated benefits of VR training on learning/skill performance (X. Zhang, Jiang, Ordóñez de Pablos, Lytras, & Sun, 2017), only a few studies have specifically examined the cognitive demands of VR training (G. I. Lee & Lee, 2018). The MWL of trainees should be considered when creating a good training method (Leung, Yucel, & Duffy, 2010). A training that requires too high or too low MWL is neither useful nor does it promote training performance. The relationship between training performance and MWL is similar to an inverted-U curve where in the best training performance will occur under proper MWL (Hwang et al., 2008). Based on these, in our dissertation was important to consider mental workload for flight experience in a trial and task situation, considering the interfaces different effects on users' MWL.

3

The present study

This chapter presents the material and methods deployed for the study. It is structured with a first section that describes the idea of study and how it differs from previous research. The second section is about the methodology applied, including information about the apparatus, materials, experimental design, procedure and participants.

3.1 Flight Simulation

3.1.1 Virtual reality scenario and apparatus

In order to conduct the present study, a VR scenario was built. More specifically, a hang-glider flight simulation was built and employed in order to run the experiences (McKenzie, 1994; Walker et al., 1999; Bektaş, van Raai, Thrash, Künzler, & Hahnloser, 2018; Bektaş et al., 2021). In this experiment participants were asked to fly through rings in the air, in a classic *reach-the-target* game (i.e., trial). While doing so, participants were also requested to count the total number of the birds that they saw while flying in the environment (i.e., task). The reason behind this trial-task setup was to test differences between the stimuli processing with respect to the level of mental workload (Bektaş et al., 2021). A workstation Intel(R) Core(TM) i9 9900K @ 3.60GHz CPU, NVIDIA GeForce RTX 2080 Ti (11GB) GPU, and 32 GB RAM was used to render the virtual environment in the Unity3D 2020.3.39f game engine (*Unity*, 2021). The virtual environment was displayed through a Meta Quest 2 VR headset at a resolution of 1080 × 1200 pixels across a 110° (total) field of view with a refresh rate of 90 Hz. The scenarios were run through the *Air Link* mode allowed by the HMD, which uses Internet connection for mirroring the worksta- tion's desktop. The virtual environment was designed as a flying practice exercise over a natural mountainous landscape to provide a rich visual self-motion cues and a naturalistic visual reference frame.

Figure 3.1: The virtual Environment employed for the experiment represented from above.

3.1.2 Traditional hand-held controller interface: Gamepad

One of the two devices used was a XboxONE Controller Élite gamepad. The gamepad's dimensions are 15.50 × 6.10 × 10.80 cm, and it weighs approximately 230 gr. During the experiment, the left and the right analog joysticks of the gamepad enabled movements along the pitch, yaw and roll axes. More specifically, the left analog joystick allowed movements both on the Y axe (forwards and backwards) and on the X axe (left and right), while the right analog joystick allowed to move only on the X axe (left and right) as shown in Figure 3.2. In the resting state of the gamepad, there was a dead zone surrounding the central position of the joystick where it did not produce any movement on the display. The maximum translational velocity of the gamepad was 50m/s which the same also for VitruvianVR.

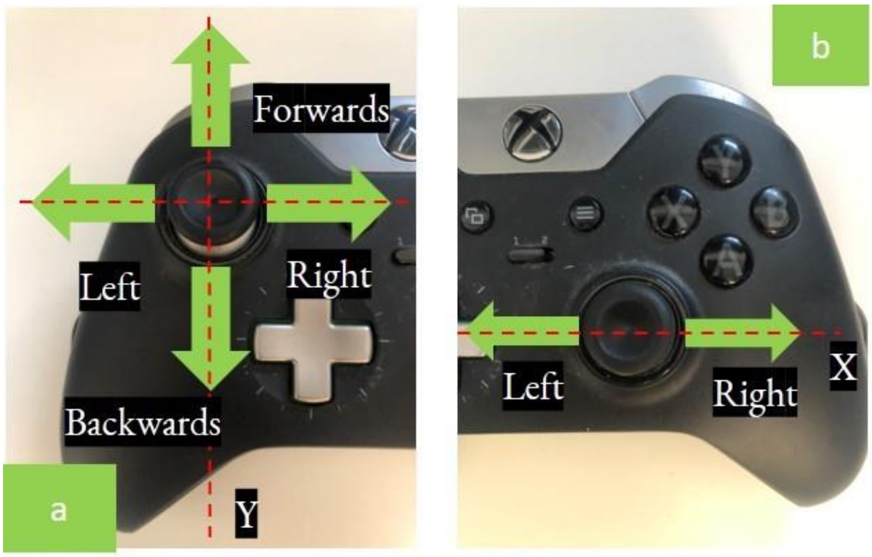
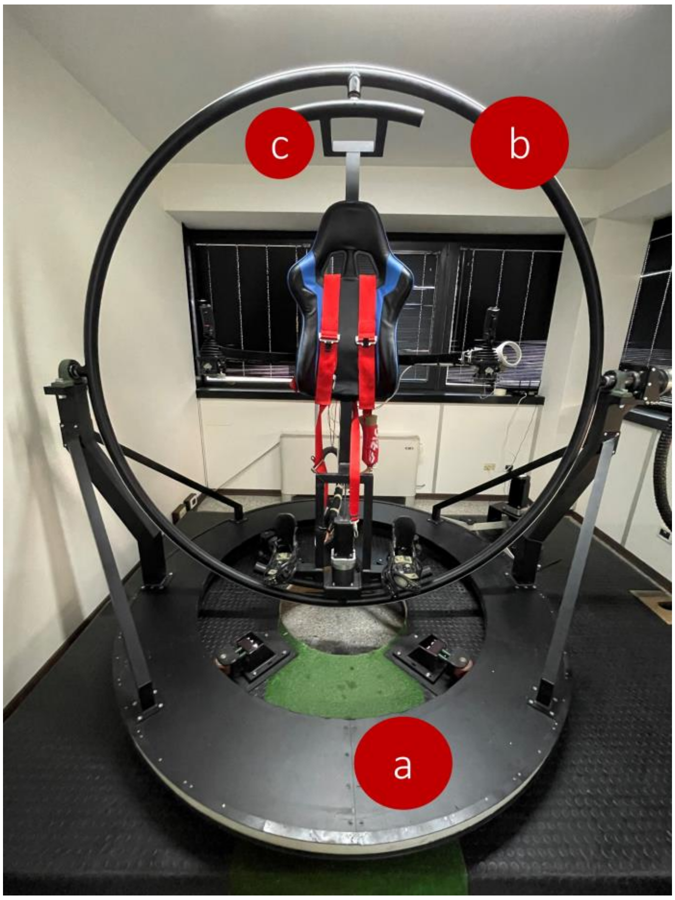


Figure 3.2: Gamepad left analog movements (a); right analog movements (b).

3.1.3 Embodied controller interface: VitruvianVR

VitruvianVR (*VitruvianVR*, 2022) is a mechanical system with a gyroscopic structure. The machine uses automated and industrial components built to guarantee high performances and reactivity in VEs. VitruvianVR is an interface that allows a bodily rotation across 360°. This functionality is enabled by the conjunction of 3 different rings (Fig- ure 3.3a) that rotate in 3 different directions either on the X or Y axes.



(a) VitruvianVR three-ring structure: Ring A (a); Ring B (b) Ring C (c).

(b) VitruvianVR's Joystick A (backrest left) and Joystick B (backrest right).

Figure 3.3: VitruvianVR Structure.

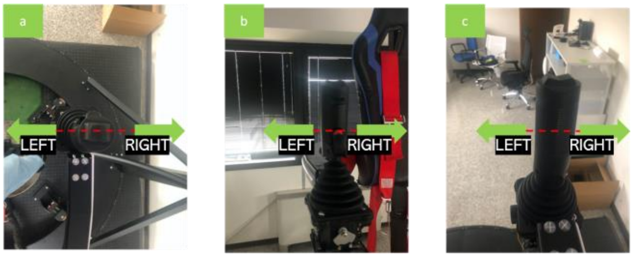
Specifically:

- \- **Ring A** (Basis): Represented by the large ring at the basis of the machine; it can rotate the whole machinery towards both the right and the left onto the yaw axe (Y axe). It has a diameter of 205cm.
- \- **Ring B**: This ring allows a user rotation on the pitch axe (X axe). The forward movement allows a maximum rotation of 90°. The backward rotation has a range of 30° degrees. The ring has a diameter size of 215cm.
- \- **Ring C**: This ring allows the user to rotate onto the roll axe (Y axe). The rotation has a range of 160° in both directions. The ring has a diameter of 193cm.

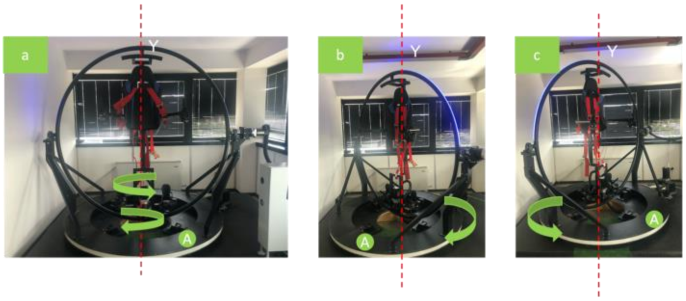
The rotation capabilities of the interfaces on all the axes can be combined to generate complex bodily rotations.

When it comes to the controllers, the VitruvianVR features a dual joystick (sidestick) control interface, through which the user can control the rotation of the device's rings. One sidestick is placed to the left of the backrest, while the other one is on the right. The distance between the two joysticks allows the user to hold them while maintaining their arm pronated and extended at a degree of 20°, with his/her hands open and rotated at a degree of 90°. The distance between the joystick is about 1m, while the user's arm extension is around 50cm.

Joystick A (located at the left of the backrest if seen with a frontal point of view like in Figure 3.3b) is built with a rubber base equipped with a sidestick with a red button on its back. Joystick A allows only one input on the X axe, meaning that it allows the users to move the sidestick towards the left and the right. This action controls the rotation on the yaw axe (Y axe) of the larger ring at the basis of the machine (Ring A), allowing the VitruvianVR to rotate in the same directions Figure 3.4. The input on the Y axe (forward and backward) does not offer any kind of output, resulting in no movement from the device.



(a) Joystick A allowed inputs.



(b) VitruvianVR Rotations allowed from Joystick A (a). Joystick A moved to the right (b). Joystick A moved to the left (c)

Figure 3.4: Joystick A.

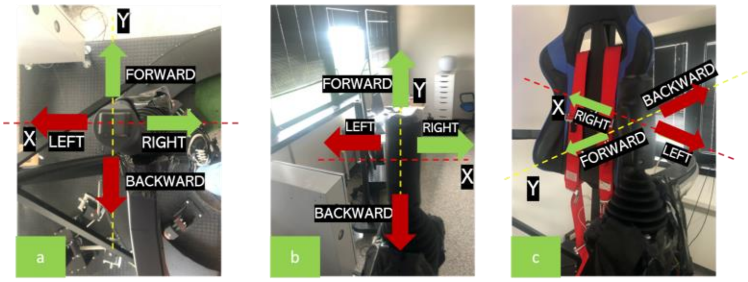
In addition, the red button on the back of the sidestick does not offer any kind of input in this experiment.

Joystick B (placed on the right of the backrest if seen with a frontal point of view as in Figure 3.3b) is built with a rubber base and it is equipped with a sidestick with a red button on its back. Joystick B allows two different types of input:

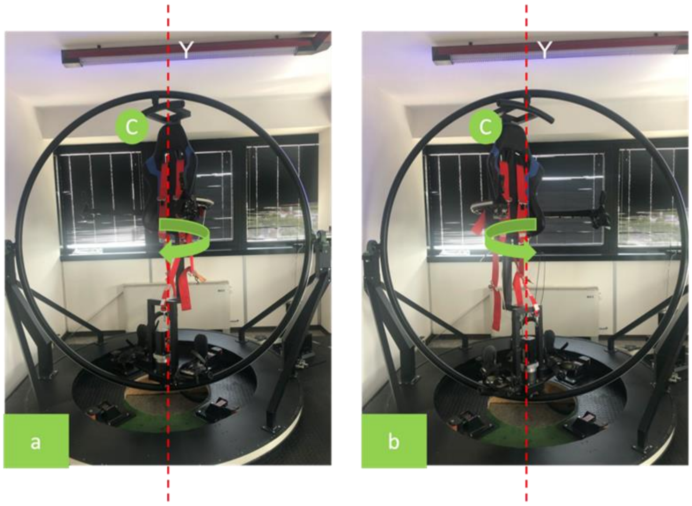
- Y axe input: the forward and backward movements of the controller, which control the rotation of the user on the pitch axe (X axe) by rotating Ring B, allowing the user to bend forward in a prone position, or backward in a supine position (Figure 3.5c).

- X axe input: the right and left movements of the controller, which control the rotation of the user on the roll axe (Y axe) by rotating Ring C, allowing the user to rotate left or right (Figure 3.5b). This results in a possible inclination when the user is rotated in a prone position.

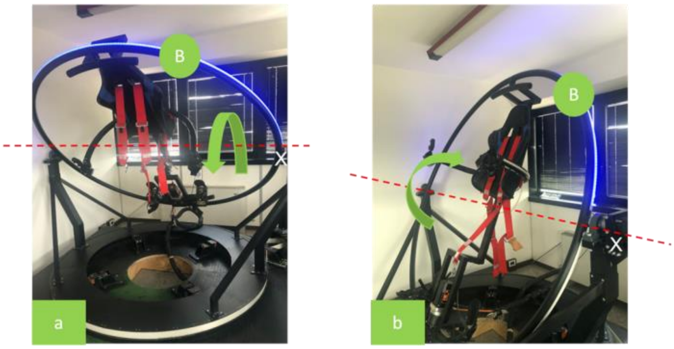
The red button on the back of the sidestick does not control any kind of input in this experiment.



(a) Joystick B allowed inputs.



(b) VitruvianVR rotations allowed from Joystick B onto the roll axe. Joystick C moved to the right (a). Joystick B moved to the left (b)



(c) VitruvianVR rotations allowed from Joystick B onto the pitch axe. Joystick A moved forward (a). Joystick A moved to the backward (b)

Figure 3.5: Joystick B.

3.2 Research gap

The idea of the study was to introduce a novel embodied interface for IVR flight experiences, namely VitruvianVR. At the same time, this dissertation aimed to identify more natural and realistic body position for hang-glider flight scenario experiences, without using a leaning-based interface as done previously (Bektaş et al., 2021). The interface provided offers a standing embodied position, which has received little attention by research so far. This dissertation compares this novel interface with a standard handheld controller following the methodology applied in previous research (Kitson et al., 2017; Perusquía-Hernández et al., 2017; Hashemian et al., 2020; Bektaş et al., 2021). Notably, one of the key properties missing before was the opportunity to move and fly on the roll axe, along with the yaw and pitch axes, in a way that does not require a physical effort that can compromise the UX in a prolonged session of the experience (Rheiner, 2014; Perusquía-Hernández et al., 2017).

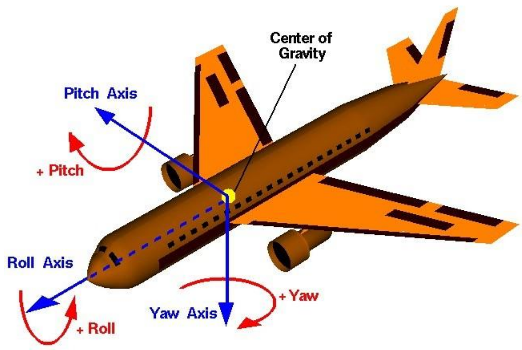


Figure 3.6: Axes of rotations.

3.3 Hypothesis

To start, the first research question investigates the relationship between the type of interface and the user experience. The literature indicates clearly that utilizing embodied interfaces (e.g. Kinect) to run VR experiences leads to better experiences (Tong et al., 2016). More specifically it can increase enjoyment, sense of presence and realism compared to handheld devices (e.g. gamepads/joysticks) (Hashemian et al., 2020; Marchal et al., 2011). As a consequence, we hypothesized that

H1: Perceived UX is higher when using VitruvianVR compared to handheld devices.

The second research question was focused on the performance. The literature on this topic is quite conflicting. A study conducted by Bowman, McMahan, and Ragan (2012) showed how embodied interfaces can improve performances compared to traditional handheld devices by reducing number of failures ((Rognon, Wu, Mintchev, Ijspeert, & Floreano, 2018)). Similar results were found from a study on telepresence (Higuchi, Fujii, & Rekimoto, 2013). However, it was also found that using embodied interfaces do not lead to better performances, they can result in users having a preference for traditional handheld devices (Bektaş et al., 2021). Also, it is important to state that traditional handheld devices are considered the easiest interfaces to learn and the most familiar to interact with (Kitson et al., 2017).

So, we hypothesized that

H2: Performance would be better when using a traditional hand held interface as compared to VitruvianVR.

Thirdly, the VitruvianVR was built with the aim of contrasting cybersickness with the aim to eliminate it completely. The idea arose from the sensory conflict theory (Reason & Brand, 1975), attempting to resolve the mismatch between visuo-vestibular and non-vestibular proprioceptors. Different motion platforms to move the body along with visually-simulated motion were used in the literature (Pai & Kunze, 2017; Sarupuri et al., 2017; Bektaş et al., 2021; Hashemian et al., 2020; Rheiner, 2014; Marchal et al., 2011). Mixed results about perceived cybersickness were found in the literature regarding the effects of bodily motion allowed by rotating interfaces (Nguyen-Vo, Riecke, Stuerzlinger, Pham, & Kruijff, 2019; Bektaş et al., 2021; Pai & Kunze, 2017) We hypothesized that

H3: Cybersickness would be reduced in the condition in which participants interacted with VitruvianVR compared to traditional handheld interfaces.

Finally, the last research question focused on the usability of the interfaces. It is important to state that familiarity effect with the device can influence usability. Nowadays the handheld interface (i.e., controller) is widely spread, making it hard to find someone who has never used it at all. This effect had an impact on previous research, making users find handheld interface more usable than any other type of interface (Marchal et al., 2011; Kitson et al., 2015, 2017).

We hypothesized that

H4: VitruvianVR would convey a lower level of usability compared to traditional hand held devices.

Along with the H4 cited above, another hypothesis was made based on previous research on usability and mental workload. Harder controls can engage our elaboration of elements more in VR (Bektaş et al., 2021), creating an overload in users' perception, fatigue and elaboration of stimuli. The last hypothesis refers to this and states

H5: VitruvianVR would be linked to higher mental workload as compared to the hand-held controller

3.4 Methods and materials

This section reports the methods and materials. Firstly, it describes the purpose and information about the virtual reality scenario built, along with the apparatus used and the functionality allowed. Afterwards the full methodology is introduced starting from the experimental design, setting and task description, to materials for data collection, procedure and participants.

3.4.1 Adaptation and functions in the Virtual Environment

XboxONE ÉLITE CONTROLLER

In order to use the XboxONE Élite Controller in the VE, its analog joysticks were configured in order to control the movements of the Hang-Glider in the virtual scenario. More specifically, the left analog joystick allows movements on the pitch and roll axes. Moving the left stick on the Y axe forward allows the users to move the hang glider down in the VE, while moving it onto the Y axe backward allows upward movement in the VE (both are movements on the pitch axe). Using the same stick but moving it on the X axe results in a change of direction in the VE towards left and right while tilting the hang glider in the opposite direction. In other words, a left movement of the joystick tilts the VE character to the left and inclines the hang glider to the right. The opposite occurs for a right movement of the stick (movements onto the roll axe). This decision was made to reproduce exactly the same movements allowed by joystick of the VitruvianVR, thereby balancing the movement control variable. The right analog joystick allows movements on the yaw axe. Specifically, moving the right stick on the X axe towards the right allows the user to change the direction of the hang-glider towards right, and likewise for a left movement of the right stick (yaw axe). The maximum translational velocity of the gamepad was 50m/s,the same as that of the VitruvianVR. The input movement followed the one's retrieved in the VitruvianVR condition.

VITRUVIANVR

In order to pair the movements of the VitruvianVR with the movements of the character in the VE the solution depicted in Figure 3.7 was adopted. This solution works by gathering the inputs coming from the gyroscope of the left controller of the Meta Quest 2, attached to the machine by a mechanical support. Moving the interface with its controllers would move the left controller of the Meta Quest 2, generating the input to control the character in the VE. The left analog stick of the VitruvianVR allows movements on the pitch and roll axes. Specifically, moving the left stick on the Y axe forward allows the users to tilt the Ring B forward, resulting in moving the hang glider down in the VE, and viceversa for a movement of the left stick on the Y axe backwards (both are movements on the pitch axe). Using the same stick but moving it on the X axe to the left or right rotates Ring C movements consistent with the hand movements. In the VE those movements allow the user to rotate their character's body leftward or rightward. Moving the stick rightward results in tilting body's character to the right, and inclines the hang-glider to the left. The opposite applies in the case of a leftward movement of the stick (both are movements onto the roll axe). This setting decision was applied to reproduce the same body movements that would be performed in a real-life scenario, to pursue a greater naturalism and embodiment from the controllers.

Figure 3.7: Meta Quest Controller support to VitruvianVR.

3.4.2 Experimental Design

In this experiment a within-participant design was applied, with a single two-level factor comparing a handheld controller and an embodied interface. Therefore, each participant completed two experimental sessions, each with one of the two interfaces. To face the problems of residual effects deriving from specific variables measured in the study (e.g., cybersickness, sense of presence), data were analyzed considering the order of use as an independent between variable (Table 3.1).

independent variable: type of interface used (within)	
VT	GP
VitruvianVR	Gamepad
independent variable: order of use (between)	
GP2-VT1	GP1-VT2
VitruvianVR-Gamepad	Gamepad-VitruvianVR

Table 3.1: Experimental design independent variables.

3.4.3 Setting

The experiment was conducted in one of the laboratories of the Human Inspired Technology Research Centre. The data gathering was conducted between December 2022 and January 2023.

3.4.4 VR trial-task description

For the present study, a trial-task in VE has been devised. The trial-task consisted of a series of rings located in the environment, and participants were asked to pass through as many rings as possible. More specifically, participants followed a pre-defined path starting from a point A and reached a point B, like a classic reach-the-target game. Rings were laid out such that users had to perform substantial rotations to get from one ring to the next one. Subsequent rings also differed in their yaw and pitch orientations to ensure that users had to control their movement in different directions and had to control more than one Degree of Freedom (DoF) simultaneously to pass through the rings. Units of distance are arbitrary in a virtual world, but a spatial unit of 1 in the Unity game engine, (thereafter referred to as unit) roughly corresponded to 1 meter in the physical world. For example, moving the joystick forward resulted in a forward movement in the virtual environment at a constant speed of 50 units per second. Movement speed was constant to prevent speed from becoming a confounding variable for the assessment of participants' performance and cybersickness. A total of 3 different trials were run for each participant in each session

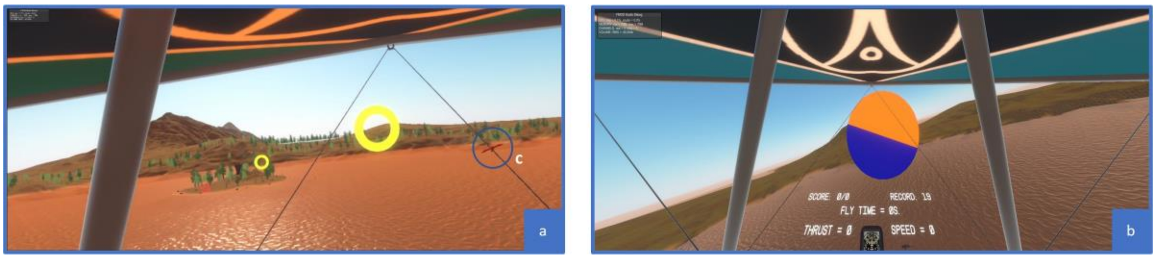


Figure 3.8: Screenshots of the VE representing task (c) and trial (a) and controls training (b).

to prevent them from learning the path. Each trial differed for the location of the rings and in the area in which target stimuli appeared. Additionally, their order of presentation was randomized from one session to the other. Audio feedback was provided to inform users if they passed through a ring. No sounds were emitted if they weren't able to pass through a ring. Moreover, at given moments, a red bird spawned, and the participant was instructed to detect and report it to the researcher. A bird was chosen in order to simulate a more realistic scenario in which participants were asked to alert some companions during the flight. The positions of the birds spawned differed from trial to trial. Each trial presented a total amount of 19 rings and 4 birds. Finally, participants were asked not to turn back if they missed any rings.

3.4.5 Materials for data collection

Various data have been collected. The data collected can be divided in two categories: self reports (i.e., questionnaires, interview) and data log measures (i.e., performance measures). For self-reported data, a total of 7 questionnaires were employed, moreover participants were asked to answer to a brief semi-structured interview at the end of the experience. Furthermore, participants' interaction with the environment were also logged. A detailed description of the materials follow.

SELF REPORT MEASURES

Personal data questionnaire

The personal data questionnaire (AppendixA) was meant to gather data regarding users' background (i.e., gender, age, dominant hand, education, previous experiences with hang-glider, previous experiences with flight or driving simulators). Participants also had to indicate their previous experiences with handheld controllers and with VR on a 8-point frequency scale (1= never, 8= everyday). Participants who indicated that they use one of the two devices more than once a month were excluded from the study.

Standardized Questionnaires

Four standardized questionnaires were used: *Simulator Sickness Questionnaire (SSQ) (Kennedy et al., 1993), Immersive Tendencies Questionnaire (ITQ) (Witmer & Singer, 1998), Presence Questionnaire (PQ) (Witmer, Jerome, & Singer, 2005) and NASA TLX (Hart & Staveland, 1988)*.

SSQ Designed as a refinement of the Pensacola Motion Sickness Questionnaire (MSQ) for computer-based simulators, the SSQ asks participants to provide subjective severity ratings of 16 symptoms on a scale from 0 (no perception) to 3 (severe perception) after the exposure to a virtual experience (Kennedy et al., 1993). The ratings for the participants' symptoms involve three non-mutually exclusive categories: nausea (N), oculomotor disturbance (O), and disorientation (D) (Walter et al., 2019). The score of each category is computed as the sum of its symptom scores multiplied by a constant scaling factor. Moreover, a total simulator sickness score (TS) combining the three sub-scales can be computed. In general, higher scores on each scale indicate stronger perceptions of the underlying sickness symptoms and are therefore undesired, especially for VR experiences (Bimberg, Weissker, & Kulik, 2020). It is suggested that total scores can be associated with negligible (< 5), minimal (5 – 10), significant (10 – 15), and concerning (15 – 20) symptoms (AppendixC).

ITQ The ITQ evaluates the user's tendency to be involved or immersed. The ITQ is composed of 18 items, that try to identify users' tendencies in 3 different factors: involvement in common activities, tendencies to maintain focus and tendencies to play videogames. Involvement items investigate the respondents' propensity to get involved passively in some activity, such as reading books, watching television, or viewing movies. Items in the Focus cluster investigate about their state of men- tal alertness, their ability to concentrate on enjoyable activities, and their ability to block out distractions. The attention focus scale deals with the ability to ignore the disturbing effects of the environment. While, the games cluster has two items: one asking how frequently they play video games, and another asking whether they get involved to the extent that they feel like they are inside the games. Commitment to games involves examining the increased interest in a computer or video game. The ITQ showed significant correlation with the PQ and can be used to provide a possible explanation on the results gained from the above mentioned questionnaire (Witmer & Singer, 1998). For each item, participants indicated the frequency in which a specific situation occurs on a 7 point scale (1-Never; 7-Often) (AppendixB).

PQ The PQ is a 32-item questionnaire assessing 2 dimensions of presence (realism and immersion) in 4 factors: adaptation/immersion; involvement, sensory fidelity and interface quality (Witmer et al., 2005). Adaptation/Immersion items address the perceived proficiency of interacting with and operating in the Virtual Environment (VE) and how quickly the user adjusted to the virtual experience. Generally speaking, better task performance in VE and quickly adapting to the new environment suggests that the user is more immersed in that environment. Involvement items address the psychological state experienced as a consequence of focusing one's mental energy and attention on a coherent set of stimuli or meaningfully related activities or events but also the degree of which an interface is intuitive for the users, so that it immediately facilitates the users' ability to control activities in the VE, thereby increasing their involvement. Sensory Fidelity items address the degree of which users' are allowed to examine objects inside a VE with their senses (e.g. sight, touch or hear). Interface Quality items address the degree with which control interfaces or displaying devices interfere or distract from the performance and event, facilitating the users' to concentrate on tasks. In the present study, items 13 and 17 were excluded because they were meant to evaluate the haptic stimulation. For each item participants were asked to answer on a 7-point likert scale (AppendixD).

NASA TLX NASA TLX (Hart & Staveland, 1988) is a subjective workload assessment that allows to compute an overall workload score based on a weighted average of ratings on six subscales: mental demand, physical demand, temporal demand, performance, effort, and frustration level. Physical demand, defined as how much physical activity was required and if it was demanding, slack or strenuous. Temporal Demand investigated the time pressure and the pace of the task, if ti was slow or rapid. Overall Performance regarded respondent's perception of success in performing the task and their satisfaction. Effort regarded how hard did the users had to work (mentally and physically) to accomplish their level of performance. Frustration level indicated how irritated, stressed, and annoyed versus content, relaxed, and complacent did users felt during the task. The NASA TLX consists of two parts: ratings and weights; in this dissertation only the first part was employed to address the mental workload of users in line with previous research (Nenna et al., 2022). Ratings for each of the six subscales are obtained from the subjects following the fulfillment of a task. A numerical rating ranging from 0 to 100 (least to most taxing) is assigned to each scale (Cao, Chintamani, Pandya, and Ellis, 2009; AppendixG).

Ad Hoc Questionnaire

In this dissertation, two ad hoc questionnaires were created adapting tools employed in previous studies to measure multiple aspects of UX and usability in conjunction, as previously done in other research that needed to addresses more than one aspects of the two construct (Zatta et al., 2022).

UX The UX questionnaire consisted of 25 items to which users had to indicate on a 7-point Likert scale their level of agreement (1="I completely disagree" , 7="I completely agree"). The questionnaire assessed the following dimensions:

- Enjoyment (3 items adapted from Ijaz, Ahmadpour, Wang, and Calvo, 2020 and Lin et al., 2002): items addressed the degree that using an information technology is perceived as fun (Venkatesh, 2000). An exemplary item was *"I enjoyed my- self during the experience"*.
- Novelty (4 items adapted from the work of Al-Hunaiyyan et al. 2021): described as the degree that a system is creative and innovative (Qualls, 2015) measured on 4 su-dimensions: originality, creativity, innovation and technological advancement. An exemplary item was *"the *device* is a creative system"*.

– Perceived safety (2 items adapted from P. Liu et al., 2021): described as a standard of the interface functions which influences on the user's health and happiness (Osswald et al., 2012). An exemplary item was "*I felt safe while utilizing *the device*"*.

– Comfort (3 items adapted from the work of P. Liu et al., 2021): referring to the extent to which a system is designed to prevent sensations of physical uneasiness during use (Murtza et al., 2017). It was measured on three different factors, addressing three different feelings: feeling comfortable, feeling relaxed and feeling tense. An exemplary item was *"I felt relaxed while utilizing *the device*"*.

– Overall satisfaction (2 items adapted from the post study system usability questionnaire of Lewis, 1992): the items measured the extent to which the users considered themselves satisfied with the use of the technology in all of his aspects summed up together. An exemplary item was *"Overall, I am satisfied with *the device*"*.

– Perceived realism (4 items adapted from Lin et al. 2002, Stavroulia, Baka, Lanitis, and Magnenat-Thalmann, 2018 and McGloin et al., 2011): the items involved the faithfulness of the environment, the objects and the perceived experiences as seen or felt in the real world which are replicated in a IVE, including their behavior (C. Lee et al., 2013). An exemplary item was *"I perceived all the sensation felt while interacting in the flight simulation in VR through *the device* consistent with those one I would feel in a real world experience"*.

– Perceived usefulness (3 items adapted from the work of Fussell and Truong 2020): the degree to which a person believes that using a particular system would enhance his or her job performance (Davis, 1989). An exemplary item was *"I think that using *the device* would improve my performance in flight* *training".*

– Intention to use (4 items derived from the works of Shin, Biocca, and Choo 2013, Balog and Pribeanu 2010 and Fussell and Truong 2020): represents the acceptance of a technology, defined as the degree to which a person has a favorable or unfavorable evaluation or appraisal of the technology in question, growing up a will to try or how much effort they are planning to exert in order to use the system in the future for VR flight scenarios (Fussell & Truong, 2020). An exemplary item was *"If made available, I intend to use *the device* for flight training in a the future".*

Usability The usability questionnaire concerning the controls measured three aspects of usability: ease of learning, ease of use and perceived controller intuitiveness. The first aspects cited was defined as how easy a system is to learn to use (Nassar, 2012). Items were adapted from the work of Lund (2001) such as *"I easily remember how to use *the device*".* The same research was also used to retrieved 6 items for ease of use of the devices, such as *"I can use *the device* successfully every time".* Perceived controller intuitiveness was meant as the degree of intuition afforded by the controllers and was measured with 9 items adapted from different works present in the literature. The construct features items taken from Yoon and Manurung (2010), Zhao and Allison (2020), Nabiyouni, Saktheeswaran, Bowman, and Karanth (2015), and McGloin et al. (2011) (AppendixF).

Finally, an adaptation of the Microsoft Desirability toolkit (Benedek & Miner, 2002) was administered. Participants were presented a list of 30 adjectives, and were asked to choose the 5 that best described their experience (AppendixI).

Interview

In order to evaluate in depth the experience, a semi-structured interview at the end of the experience was conducted. The interview was built to explore details about users' perception and opinions regarding the experience. At the beginning of the interview the experimenter asked the participants to think back to both experiences, and then he asked the following questions:

°1 *"Was there an experience that you liked the most between the two? And If so, how come? Why?"*.

°2 *"Did the bodily rotations on different axes allowed by VitruvianVR during the VR experience, compared to the standing situations with controller/joystick have an impact on your experience? If so, What was the impact? And how?"*

DATA LOG MEASURES

Performance Measures

In order to assess performance 5 different aspects of the trial were considered. Firstly, the number of rings in which participants could pass through in each scenario was counted, and represented *accuracy* of task accomplishment. Each time that a user crashed or before the end of the path was counted as a *failure*. The frequency of failures for each interface was collected. Additionally, the number of hits with the spawning birds was also counted in each scenario, along with false alarms (that is when a user claimed to see a bird that either was not a bird or was not actually present, or had already been spotted), following the signal detection theory (Green, Swets, et al., 1966). Finally, time to complete each scenario was consider with a pre-set maximum duration of 210 seconds.

3.4.6 Procedure

The whole study procedure had a duration approximately of 90 minutes per participants. The session started with signing the informed consent form. Next, participants were invited to learn how to use the system with a in a purposefully devised training phase with each of the two interfaces under examination. Participants were asked either to hold the controller in their hands or to mount on the VitruvianVR, depending on the starting condition. They were then taught how to use the interface. Specifically, they were taught how to control the hang-glider in the VE using the device and were asked to familiarize themselves with the commands. This phase was divided into two parts: the first one involved the researcher reading out the instruction to participants, and the second one involved participants interacting in two VEs with the interface. The first one was devised to let them train with the controls, and the second one was meant to familiarize them with a trial facsimile. This second part lasted two minutes in total. The controls training consisted of a task of an environment with a static hang-glider fluctuating in a natural mountainous landscape. A series of blue ring targets, in which the upper half of each ring featured an orange area, appeared. Participants were asked to fully cover with the tip of the hang-glider the orange area with the tip of the hang-glider, to make the area no longer visible, utilizing the commands previously illustrated by the researcher. After one minute, participants were asked to familiarize themselves with the VE in a shorter version of a trial (1-minute duration). The participants who were not able to understand the commands in this time frame (i.e., 2 minutes) were excluded from the study. The order of presentation of the two interfaces were counterbalanced within participants.

EXPERIMENTAL PHASE

Participants had to complete three trials with each interface, in which they had 210 seconds to fly through as many rings as they could in three different *"scenes"* (i.e., pre-set paths) in

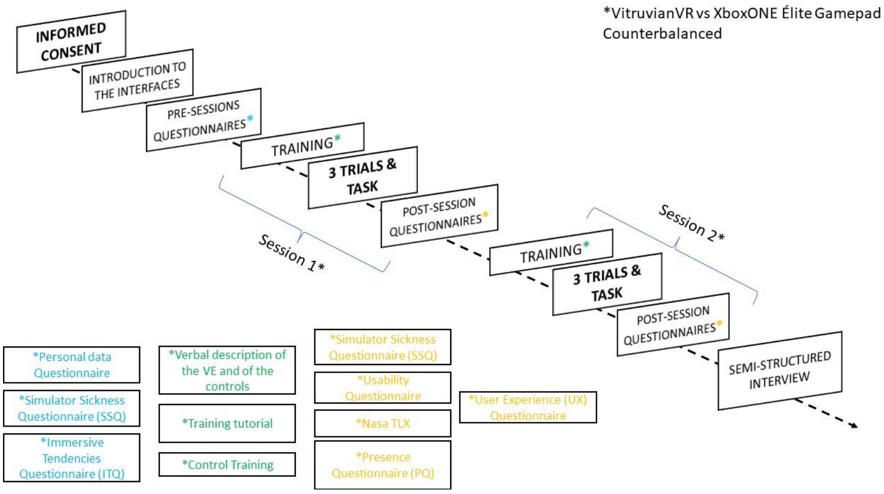


Figure 3.9: Procedure of the study.

the same VE. After completing the main trial with each interface, participants were asked to answer to the SSQ, PQ, UX questionnaire, NASA TLX and usability questionnaires. By answering these questionnaires participants also had the opportunity to rest for about 20 minutes before using the other interface. After using the second interface, participants were again asked to answer the same questionnaires. After that, they were asked to answer to the final semi-structured interview.

All of the phases of the research are summarized in Figure 3.9.

3.5 Participants

A total amount of 48 participants (22 males and 26 females) between 18-30 years old (M = 22.85, Mdn = 23, SD = 2.10) took part in this study. All of them were Italian native speaker. Most of them were right-handed (91.66%) while just 3 were left-handed. Only one was ambidextrous. Among them, just one had previous experience with a hang glider in a physical context. 7 participants reported to have had a previous experience with a flight or driving simulator. 43.75% of participants utilizes handheld controllers less than once a year, 29.17% less than once a month, 10.42% once per month, 2.08% just tried it once. 14.58% of participants reported to have never used an hand held device. The frequencies of previous experiences with HMDs were different: 29.17% of them reported that they had used it just once in their life, 14,58% less than once a year and 10.42% less than once a month. A higher percentage of participants reported instead to have no previous experiences with IVR and HMDs (45.83%). Participants had mainly low or very little experience for both the interfaces. As expected, the gamepad was a device with which participants reported to be more familiar, as compared to the VitruvianVR.

4

Analysis and results

This chapter reports the analyses and the results of the study. Its structure is divided into a first section that describes how data were processed before starting the analyses. The second section includes all the results retrieved from the measurement.

4.1 Data processing

In the following section the data processing applied in order to prepare the data analysis will be described.

4.1.1 Self-report measures

Questionnaires

In order to analyze the data collected using questionnaires, different steps were made, as follows:

ITQ The scores obtained from the Immersive Tendencies Questionnaire (ITQ) were computed for each sub-scale following the scoring instructions given by the authors (Witmer & Singer, 1998).

SSQ The scores gathered from the Simulator Sickness Questionnaire (SSQ) were adjusted for each phase and each sub-scale following the scoring instruction by Walter et al. (2019). More specifically, each score was multiplied by *3.74* for the Total scale, by *9.54* for Nausea symptoms, by *7.58* for Oculomotor symptoms and by *13.92* for Disorientation. In addition, a delta score was computed for the total subscale. More specifically, we subtracted the score gained at each phase with that of the previous one (Kennedy, Stanney, & Dunlap, 2000; Dużmańska et al., 2018). We had 3 different times of measurement: t0, represented by participants before the experimental sessions (N=48), t1 after the first session (N=24 with GP1 and N=24 with VT1) and t2 after the second session (N=24 with GP2 and N=24 with VT2). With this in mind we found three different delta times for the SSQ Total scale:

$$0 - 1 = t1 - t2;\ 1 - 2 = t2 - t1;\ 0 - 2 = t2 - t0 \tag{4.1}$$

PQ The scores obtained from the Presence Questionnaire (PQ) were averaged following the scoring instructions by Witmer et al. (2005). Accordingly, the scores of items 22 and item 23 were reversed following the same instructions (the reversed items are indicated with an asterisk and visible in the AppendixD).

UX The scores obtained from the User eXperience (UX) ad hoc-questionnaire were averaged for each dimension (i.e., *enjoyment, novelty, comfort, safety, overall satisfaction, realism, perceived usefulness and intention to use)*. Items 3 and 12 were reversed (as indicated with an asterisk in the AppendixE).

Usability The scores obtained from the usability ad hoc-questionnaire were averaged for each dimension (i.e., *ease of learning, ease of use, perceived intuitiveness of controller)*. Items 13, 18 and 19 were reversed (as indicated with an asterisk in the AppendixF).

Interview

All the interviews were held in Italian. The recordings were transcribed to identify thematic areas for each question, in addition to frequencies of the users' answers. Afterwards those frequencies were transformed into percentages and reported in tabs that contain both questions and frequencies of answers.

4.1.2 Data log measures

Performance measures

The absolute task accuracy (i.e., number of rings passed through) was transformed into percentages. The same procedure was performed with the bird-reporting task. The number of failures was counted to identify frequencies with each interface. The number of false alarms when reporting a bird was also counted.

4.2 Data analyses and main results

In this section the results of the study will be reported. In the first section the results related to participants' performance will be described. In the second section the results coming from the self-report measures will be explained.

4.2.1 Data log measures results

Performance

A series of two-way ANOVAs with the order of the scene as the between-participants factor (1 vs 2 vs 3) and the interface as the other between-participants factor (GP vs VT) were run.

Regarding task accuracy, measured as the amount of rings passed, the ANOVA showed a main effect of the interface factor ($F(1,237) = 12.44$, $p<.001$, $\eta G^2 = 0.098$) in that the scores of the participants that used the Gamepad (M = 80.30, SD = 28.90) were statistically higher compared to the VitruvianVR (M = 71.60, SD = 26.0) indicating higher task accuracy with the Gamepad ($t(45.89) = 11.63$, $p<.001$). Furthermore, it showed a main effect of the order of the scene ($F(1,237) = 1.01$, $p<.001$, $\eta G^2 = 0.098$). Post-hoc t-tests for independent samples with Bonferroni's correction method showed that the scores of the participants during the first trial were statistically lower compared to the ring scored during the third trial ($t(95) = -4.04$, $p<.001$), indicating a learning effect for both interfaces.

There were no differences in the number of failures between the two interfaces, even though, the Gamepad had a higher frequency of failures (9.72%) compared to VitruvianVR (4.86%), possibly due to the better comprehension and intuition of the control reported during the interview.

Secondly, considering the number of birds reported, it emerged a main effect of the order of the scene ($F(1,237) = 8.49$, p =.003, $\eta G^2 = 0.16$). No differences were found

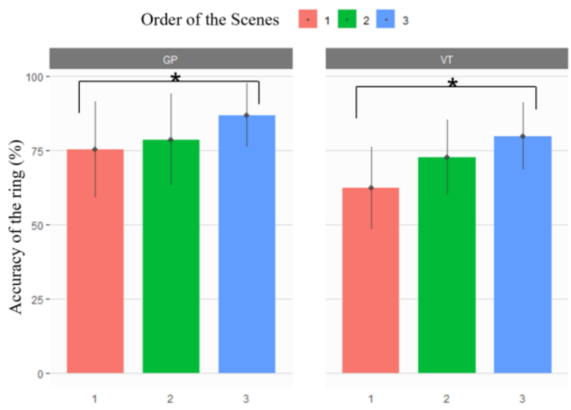


Figure 4.1: Performance Order of the scenes x Interface for the accuracy of the ring pass through percentage frequencies scores.

between the Gamepad (M = 86.3, SD = 20.7) and VitruvianVR (M = 85.4, SD = 18.6). In that post-hoc t-tests for independent samples (Bonferroni correction) showed that the birds reported by the participants during the first trial were statistically lower compared to the birds reported during the third trial (t(95)= -2.5, p =.01), and also between the third trial and the second trial (t(95)= -2.17, p =.03), indicating that at a longer exposure the better it is the detection.

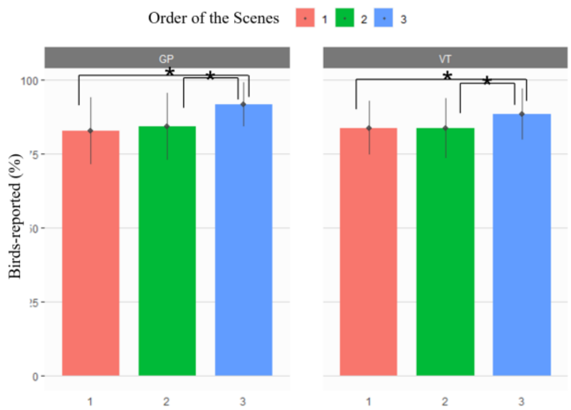


Figure 4.2: Performance Order of the scenes x Interface for the accuracy of the bird-reporting task percentage frequencies scores.

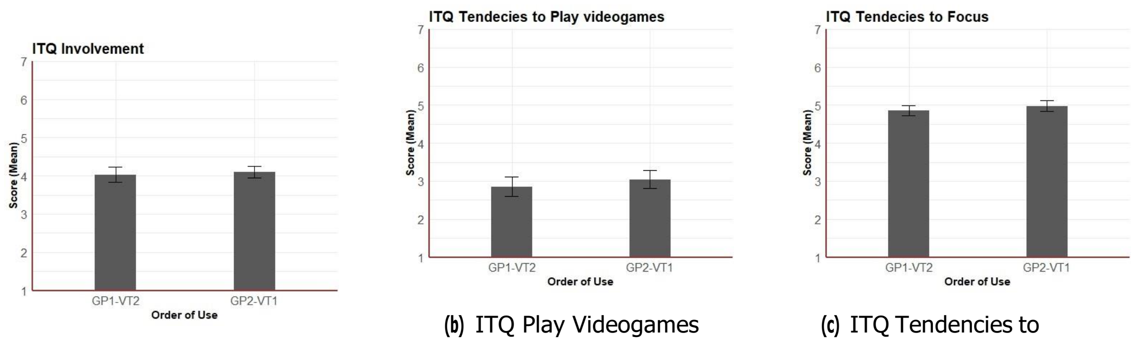
The number of false alarms counted was the same for both interfaces. In that with the gamepad false alarm recorded with the gamepad was 6.94%, exactly the same as the VitruvianVR (6.94%).

4.2.2 Self report measures results

QUESTIONNAIRES

Immersive tendencies Questionnaire

The scores at the Immersive tendencies questionnaire were compared between the two samples (GP1-VT2 vs GP2-VT1) to investigate possible differences. A series of indipendent samples t-tests was applied for each sub-scale and for the total amount of the score. No statistical difference was found in the two samples, in that GP1-VT2 (M = 4.28, SD = 0.51) and GP2-VT1 (M = 4.41, SD = 0.58) can be consider having the same characteristics (t(45.34) = -0.87, *p* = 0.39), indicating that both groups reported the same tendency to get immersed in virtual environments (Figure 4.3).



(a) ITQ Involvement sub-scale Order of Use scores (mean).

(b) ITQ Play Videogames sub-scale Order of Use scores (mean).

(c) ITQ Tendencies to maintain Focus sub-scale Order of Use scores (mean).

Figure 4.3: Immersive Tendencies Questionnaire (ITQ) Order of Use (between-participants factor) scores (mean).

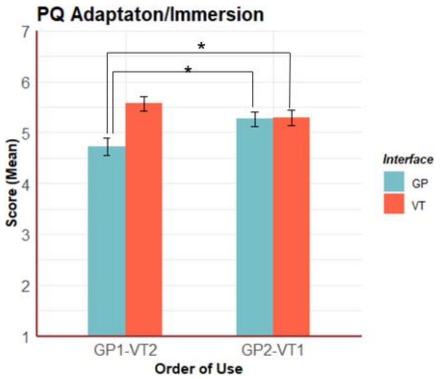
Presence Questionnaire

According to the Shapiro-Wilk's test for multivariate normality the variables followed a normal distribution, therefore parametric tests were run. A series of mixed two-way

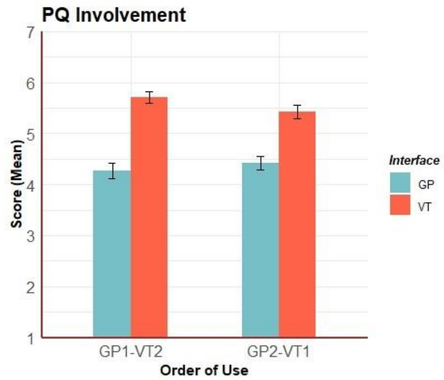
ANOVAs were applied with the order of use as the between-participants factor (GP1- VT2 vs GP2-VT1) and the interface as the within-participants factor (Gamepad vs VitruvianVR). The analysis was run for each of the PQ subscales, specifically, Adaptation/Immersion, Involvement, Interface Quality and Sensory Fidelity.

The analyses showed a main effect of type of interface on the sense of presence. More specifically, regarding the PQ Adaptation/Immersion scale, the ANOVA showed that the main effect of the interface factor was statistically significant ($F(1,46) = 10.25$, $p<0.01$, $\eta G^2 = 0.082$) in that the scores of the participants for VitruvianVR (M = 5.43, SD = 0.73) were higher as compared to the scores of when they interacted with the Gamepad (M = 4.99, SD = 0.81) indicating higher adaptation and immersion to the VE with more controller naturalness for VitruvianVR (Figure 4.4a). Secondly, for the PQ Involvement scale results showed that the main effect of the interface factor was statistically significant ($F(1,46) = 91.72$, $p<0.01$, $\eta G^2 = 0.48$) in that the scores of the participants for VitruvianVR (M = 5.56, SD = 0.63) were higher as compared to the scores for when they interacted with the Gamepad (M = 4.34, SD = 0.63), indicating higher involvement for VitruvianVR (Fig- ure 4.4b). Similar results were obtained for the PQ Interface Quality scale showing that the main effect of the interface factor was statistically significant ($F(1,46) = 9.93$, $p<0.01$, $\eta G^2 = 0,057$) in that the scores of the participants for VitruvianVR (M = 5.30, SD = 0.94) were higher as compared to the scores of when they interacted with the Gamepad (M = 4.84, SD = 0.97) indicating higher perceived interface quality for VitruvianVR (Figure 4.4d). Finally, the analyses on the PQ Sensory Fidelity scale showed that the main effect of the interface factor was statistically significant ($F(1,46) = 9.63$, $p<0.01$, $\eta G^2 = 0.057$) in that the scores of the participants for VitruvianVR (M = 4.70, SD = 1.08) were higher as compared to the scores of when they interacted with the Gamepad (M = 4.195, SD = 1.04) indicating higher sensory fidelity for the VitruvianVR (Figure 4.4c).

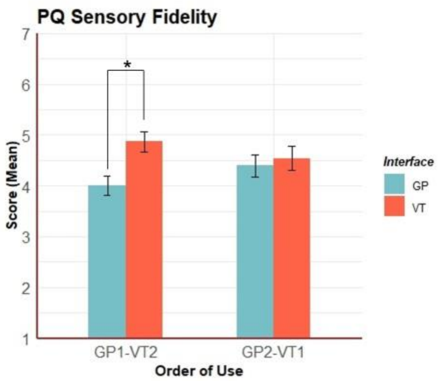
The two-way Order of Use x Interface interaction effect also showed a statistically significant difference for the PQ Adaptation/Immersion scale ($F(1,46) = 9.06$, $p<0.01$, ηG^2



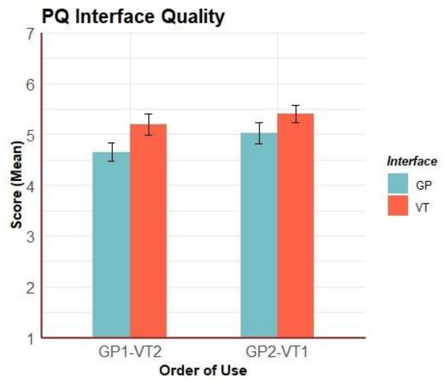
(a) PQ Adaptation/Immersion sub-scale Order of Use x Interface scores (mean). *p<.05



(b) PQ Involvement sub-scale Order of Use x Interface scores (mean). *p<.05



(c) PQ Sensory Fidelity sub-scale Order of Use x Interface scores (mean). *p<.05



(d) PQ Interface Quality sub-scale Order of Use x Interface scores (mean). *p<.05

Figure 4.4: Presence Questionnaire (PQ) Order of Use x Interface mean scores for Adaptation/Immersion and Involvement sub-scales. *p<.05

= 0,073). Independent samples post-hoc t-tests with Bonferroni's correction method showed that the scores of the participants who interacted with the Gamepad as the first interface (M = 4.72, SD = 0.83) were statistically lower compared with those of participants who interacted with the Gamepad as the second interface (M = 5.27, SD = 0.70), t(44.78) = -2.46, p = .003, d = -0.55. The scores of participants who interacted with VitruvianVR as the first interface (M = 5.29, SD = 0.73) were statistically higher compared with those of participants who interacted with the Gamepad as the first interface (M = 4.72, SD = 0.83), t(45.26) = 2.53, p =.002, d = 0.57 (Figure 4.4a). The two-way Order of Use x Interface interaction effect was found also for the PQ Sensory Interface scale ($F(1,46) = 4.78$, p = 0.034, $\eta G^2 = 0.029$). No statistical difference was found neither for the PQ Involvement scale ($F(1,46) = 2.93$, $p > 0.05$, $\eta G^2 = 0.028$) or for the PQ Interface Quality scale ($F(1,46) = 0.33$, $p > 0.05$, $\eta G^2 = 0.001$).

In short, the results indicated that users' felt a higher sense of presence while interacting with the VitruvianVR. Furthermore, utilizing VitruvianVR as the first interface can have a beneficial effect on the PQ Adapatation/Immersion scale and PQ Sensory Fidelity scale by increasing the perception of the interface used as second.

UX ad Hoc Questionnaire

The data gathered with the UX ad hoc questionnaire were considered as normally distributed according to the Shapiro-Wilk's test, therefore parametric analyses were run. A series of two-way mixed ANOVAs with the order of use as the between-participants factor (GP1-VT2 vs GP2-VT1) and the interface as the within-participants factor (Gamepad vs VitruvianVR) were run to investigate differences in the dimensions of the experience between the two interfaces.

UX Enjoyment:

A main effect of the interface emerged ($F(1,46) = 82.32$, $p<0.01$, $\eta G^2 = 0.46$), with the scores of the participants using the VitruvianVR (M = 6.65, SD = 0.498) being higher compared to the scores of when they interacted with the Gamepad (M = 4.86, SD = 1.38) indicating higher perceived enjoyment while interacting with VitruvianVR. A main effect of the order of use was also statistically significant (F(1,46) = 5.52, *p* =.023, $\eta G^2 = 0.06$), in that scores of the participants who followed the order Gamepad-VitruvianVR (GP1-VT2) (M = 5.99, SD = 1.01) were statistically higher than their counterparts (GP2-VT1: M = 5.51, SD = 1.63) indicating that who interacted at first with the gamepad and then with the VitruvianVR perceived more fun from the general experience compared to who utilized the device in the opposite order (Figure 4.5a). The Order of Use x Interface interaction was statistically significant (F(1,46) = 7.78, *p*<0.01, $\eta G^2 = 0.075$). Independent samples post-hoc t-tests (Bonferroni correction) showed that the scores of the participants who interacted with the Gamepad as the first interface (M = 5.38, SD = 1.02) were statistically higher compared with those of participants who interacted with the Gamepad as the second interface (M = 4.35, SD = 1.52), t(40.32) = 2.75, *p* =.022, d = -1.03. Secondly, the scores of participants who interacted with VitruvianVR as the second interface (M = 6.61, SD = 0.498) were statistically higher compared with those of participants who interacted with the Gamepad as the second interface (M = 4.35, SD = 1.52), t(27.89) = 6.94, *p*<.001, d = 2.26. Thirdly, the scores of participants who interacted with the VitruvianVR as the first interface (M = 6.68, SD = 0.50) were statistically higher compared with those of participants who interacted with the Gamepad as the first interface (M = 5.38, SD = 1.02), t(33.61) = 5.60, *p*<.001, d = 1.30 (Figure 4.5).

UX Novelty:

A main effect of the interface emerged (F(1,46) = 315.47, *p*<0.01, $\eta G^2 = 0.80$) with the scores of participants for VitruvianVR (M = 6.52, SD = 0.54) being higher compared to the scores of when they interacted with the Gamepad (M = 3.06, SD = 1.19) indicating higher perceived novelty while interacting with the VitruvianVR (Figure 4.6). A main effect of the order of use was also statistically significant (F(1,46) = 6.05, *p* =.018, $\eta G^2 = 0.05$), in that scores of the participants who followed the order Gamepad-VitruvianVR

Figure 4.5: UX enjoyment dimension Order of Use x Interface scores (mean). *$p<0.05$

(GP1-VT2) (M = 4.99, SD = 2.13) were statistically higher than their counterparts (GP2-VT1: M = 4.58, SD = 2.13) indicating that who interacted at first with the gamepad and then with the VitruvianVR perceived more novelty from the general experience compared to who utilized the device in the opposite order (Figure 4.6). The two way Order of Use x Interface interaction was statistically significant ($F(1,46) = 5.54$, $p = 0.02$, $\eta G^2 = 0.065$). Independent samples post hoc t-test (Bonferroni correction) showed that the participants' scores of who interacted with the Gamepad as the first interface (M = 3.49, SD = 1.26) were higher compared with those of participants who interacted with the Gamepad as the second interface (M = 2.62, SD = 0.97), $t(43.15) = 2.75$, $p = .027$, d = -1.3. Secondly, the scores of participants who interacted with the VitruvianVR as the second interface (M = 6.49, SD = 0.513) were statistically higher compared with those of participants who interacted with the gamepad as the second interface (M = 2.62, SD = 0.97), $t(34.95) = 17.26$, $p<.001$, d = 3.87. Thirdly, the scores of participants who interacted with the VitruvianVR as the first interface (M = 6.54, SD = 5.79) were statistically higher compared with those of participants who interacted with Gamepad as the first interface (M = 3.49, SD = 1.26), $t(32.29) = 10.78$, $p<.001$, d = 3.05 (Figure 4.6).

UX Safety:

A main effect of the interface emerged ($F(1,46) = 13.02$, $p<0.01$, $\eta G^2= 0.10$) with the scores of participants for VitruvianVR (M = 6.14, SD = 0.73) being higher compared to

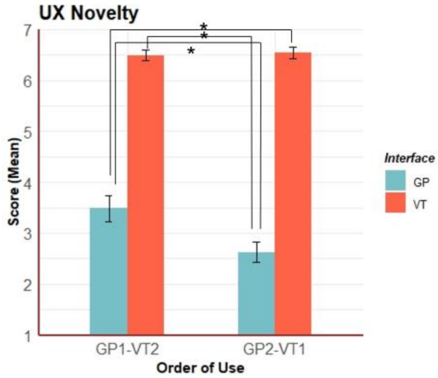


Figure 4.6: UX Novelty dimension Order of Use x Interface scores (mean).* $p<0.05$

the scores of when they interacted with the Gamepad (M = 5.49, SD = 1.19) indicating higher perceived safety while interacting with the VitruvianVR (Figure 4.7). No main effect of the order of use was found (F(1,46) = 3.29, $p = 0.08$, $\eta G^2 = 0.04$) nor interaction effect (F(1,46) = 0.48, $p = 0.49$, $\eta G^2 = .004$) (Figure 4.7).

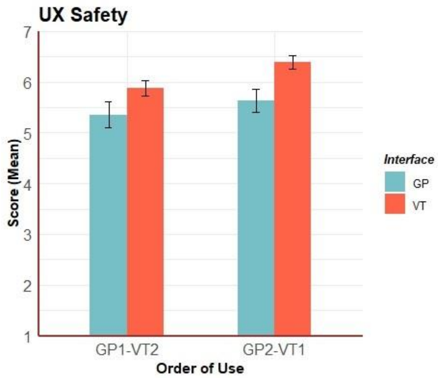


Figure 4.7: UX Safety dimension Order of Use x Interface scores (mean). * $p<.05$

UX Comfort:

No significant difference emerged for the UX comfort dimension for main effect (F(1,46) = 0.42, $p = 0.52$, $\eta G^2 = .004$), order effect (F(1,46) = 4.17, $p = 0.05$, $\eta G^2 = 0.05$) and interaction effect (F(1,46) = 0.35, $p = 0.56$, $\eta G^2 = .003$) as visible in Figure 4.8.

UX Overall Satisfaction:

A main effect of the interface emerged (F(1,46) = 13.02, $p<0.01$, $\eta G^2 = 0.10$) with the

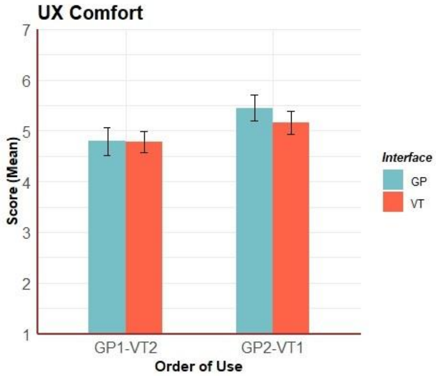


Figure 4.8: UX Comfort dimension Order of Use x Interface scores (mean).

scores of participants for VitruvianVR (M = 6.41, SD = 0.56) being higher compared to the scores of when they interacted with the Gamepad (M = 5.04, SD = 1.27) indicating higher overall satisfaction while interacting with the VitruvianVR (Figure 4.9). No main effect of the order of use was found (F(1,46) = 2.39, $p = 0.12$, $\eta G^2 = 0.02$) nor interaction effect (F(1,46) = 0.31, $p = 0.57$, $\eta G^2 = .003$) (Figure 4.9).

Figure 4.9: UX Overall Satisfaction dimension Order of Use x Interface scores (mean). $*p < 0.05$

UX Realism:

A main effect of the interface emerged (F(1,46) = 13.02, $p<0.01$, $\eta G^2 = 0.10$) with the scores of participants for VitruvianVR (M = 5.23, SD = 1.15) being higher compared to the scores of when they interacted with the Gamepad (M = 3.03, SD = 1.28) indicating higher perceived realism while interacting with the VitruvianVR (Figure 4.10). A main effect of the order of use was also statistically significant ($F(1,46) = 11.16$, p =.001, $\eta G^2 = 0.14$), in that scores of the participants who followed the order Gamepad-VitruvianVR (GP1-VT2) (M = 4.58, SD = 1.46) were statistically higher than their counterparts (GP2-VT1: M = 3.69, SD = 1.70) indicating that who interacted at first with the gamepad and then with the VitruvianVR perceived more realism from the general experience compared to who utilized the device in the opposite order (Figure 4.10). No interaction effect was found ($F(1,46) = 1.02$, $p = 0.32$, $\eta G^2 = .007$)

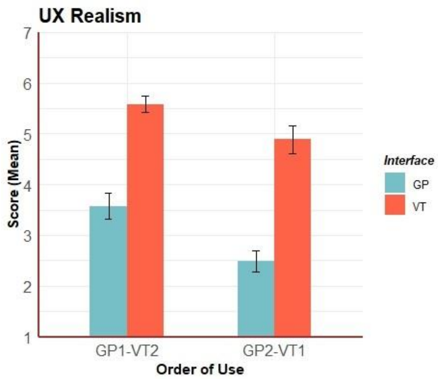


Figure 4.10: UX Realism dimension Order of Use x Interface scores (mean). *$p<0.05$

Summarizing the results it is possible to state that the VitruvianVR is consider as more enjoyable, novel, satisfying, safe and realistic compared to the traditional hand-held interface. Also, participants who used the VitruvianVR as the first interface tends to indicated lower scores for the devices used as second in the case of the enjoyment, novelty and realism dimensions.

Technology Acceptance Model

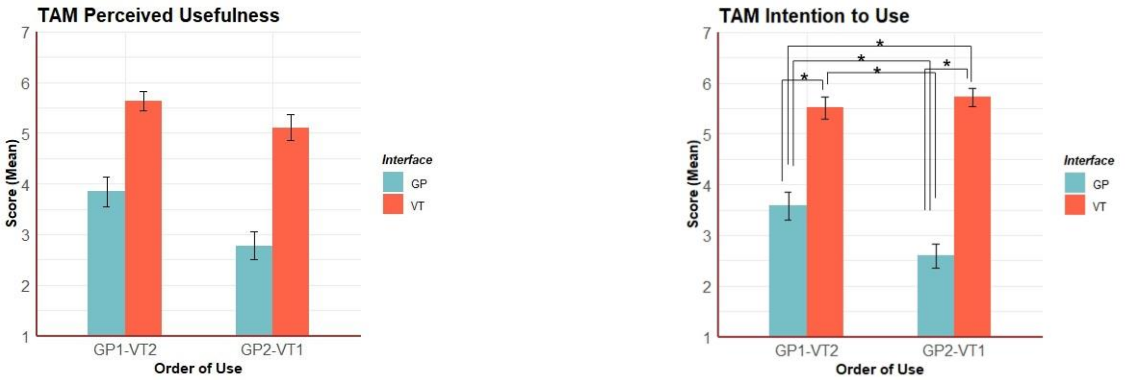
In this subsection the results coming from the Technology Acceptance Model (TAM) will be reported (i.e., perceived usefulness and behavioral intention). The data gathered with the UX ad hoc questionnaire regarding TAM dimensions were normally distributed according to Shapiro-Wilk's test. A series of mixed two-way ANOVAs with the order of use as the between-participants factor (GP1-VT2 vs GP2-VT1) and the interface as the within-participants factor (Gamepad vs VitruvianVR) were run.

Perceived Usefulness

The analyses showed that the main effect of the interface factor was statistically significant for perceived usefulness ($F(1,46) = 116.40$, $p<0.01$, $\eta G^2 = 0.42$) in that the scores of the participants for VitruvianVR ($M = 5.37$, $SD = 1.12$) were higher compared to the scores of when they interacted with the Gamepad ($M = 3.31$, $SD = 1.47$) indicating higher perceived usefulness for VitruvianVR. A main effect of the order of use factor was statistically significant ($F(1,46)=6.74$, $p = .013$, $\eta G^2 = 0.09$) in that scores of the participants for the order Gamepad-VitruvianVR (GP1-VT2) ($M = 4.74$, $SD = 1.49$) were statistically higher compared with those of participants who interacted with the opposite order of presentation (GP2-VT1: $M = 3.94$, $SD = 1.73$) (Figure 4.11a), indicating that who interacted at first with the gamepad and then with the VitruvianVR perceived more utility from the general experience compared to who utilized the device in the opposite order (Figure 4.11a). No latter effect was found ($F(1,46) = 2.13$, $p = 0.15$, $\eta G^2 = .013$).

Intention to Use

A main effect of the interface factor was statistically significant ($F(1,46) = 181.65$, $p<0.01$, $\eta G^2 = 0.57$) in that the scores of the participants for VitruvianVR ($M = 6.61$, $SD = 0.99$) were higher compared to the scores of when participants interacted with the Gamepad ($M = 3.09$, $SD = 1.33$) indicating higher intention to use. The two-way Order of Use x Interface interaction was statistically significant ($F(1,46) = 10.21$, $p = 0.003$, $\eta G^2 = 0.069$). Independent samples post-hoc t-tests (Bonferroni correction) showed that first the scores of the participants who interacted with the Gamepad as the first interface ($M = 3.58$, $SD = 1.34$) were statistically higher compared with those of participants who interacted with the Gamepad as the second interface ($M = 2.59$, $SD = 1.14$), $t(44.93) = 2.76$, $p =.013$, d=0,99. Secondly, the scores of participants who interacted with VitruvianVR as the second interface ($M = 5.51$, $SD = 1.08$) were statistically higher compared with those of participants who interacted with the Gamepad as the second interface (M = 2.59, SD = 1.14), t(45.86)=9.07, $p<.001$, d = 2.92). Thirdly, the scores of participants who interacted with VitruvianVR as the first interface (M = 5.72, SD = 0.90) were statistically higher compared with those of participants who interacted with the Gamepad as the first interface (M = 3.58, SD = 1.34), t(40.4) = 6.48, $p<.001$, d = 2.67 (Figure 4.11b).



(a) TAM Perceived Usefulness Order of Use x Interface scores (mean).

(b) TAM Intention to use dimension Order of Use x Interface scores (mean).

Figure 4.11: Technology Acceptance Model (TAM) ad hoc questionnaire Order of Use x Interface scores (mean). *$p<.05$

The results indicate an higher perceived usefulness and intention to use for the VitruvianVR as compared with the gamepad. Utilizing VitruvianVR as the first interface lowers the scores of the gamepad used after it if compared to when VitruvianVR is used as the second device, indicating higher scores for the GP1-VT2 sample over the GP2-VT1 sample. Also, utilizing VitruvianVR as the first interface lowers down the score of the behavioral intention for the gamepad if used after it. This effects leads to a statistical difference between the gamepad used as the first interface or when it is used as the second.

Simulator Sickness Questionnaire

The data collected were analyzed with parametric analyses according to Shapiro Wilk's test. On cybersickness data were run a series of ANOVAs with the order of use as the between-participants factor (GP1-VT2 vs GP2-VT1) and measurement time as the within-participants factor (0 vs 1 vs 2).

SSQ Total Scale:

A main effect of the measurement times was found ($F(2,92) = 48.44$, $p<.001$, $\eta G^2 = 0.39$). Specifically, paired samples t-tests (Bonferroni correction) showed that the scores of the participants that used the Gamepad as the first interface and VitruvianVR as the second interface at measurement time 1 (M = 32.10, SD = 18.52) were statistically higher than they were at time 0 (M = 1.71, SD = 6.89) ($t(29.24) = 7.53$, $p<.001$) and at time 2 (M = 10.90, SD = 7.63) ($t(30.60) = 5.18$, $p<.001$). The scores at measurement time 2 was statistically higher than at time 0 ($t(45.52) = 4.38$, $p<.001$), indicating that the first session was perceived by the participants as the more capable of generating sickness discomfort. Also, they showed that the scores of the participants that used the Gamepad as the second interface and VitruvianVR as the first interface were statistically higher at measurement time 2 (M = 28.67, SD = 16.04) compared to time 1 (M = 8.73, SD = 6.59) ($t(30.54) = 5.63$, $p<.001$) and time 0 (M = 1.40, SD = 2.88) ($t(24.48) = 8.19$, $p<.001$). The scores at measurement time 1 was statistically higher than at time 0 ($t(31.47) = 4.99$, $p<.001$), confirming again that participants found the session with gamepad the one with higher perceived sickness. The two-way Order of Use x measurement times interaction for the SSQ Total scale was statistically significant ($F(2,92) = 44.88$, $p<.001$, $\eta G^2 = 0.37$). Independent samples post hoc t-tests (Bonferroni correction) showed no differences between time 2 of who interacted first with the Gamepad and then with VitruvianVR (GP1-VT2) compared with time 1 of their counterparts (GP2-VT1: $t(45.03) = 1.06$, $p = 0.29$). Also no difference emerged between the two groups respectively between time 1 and time 2 ($t(45.09) = 0.69$, $p= 0.50$). Same applies for time 0 in both groups ($t(30.80) = 0.20$, $p = 0.84$) (Figure 4.12a).

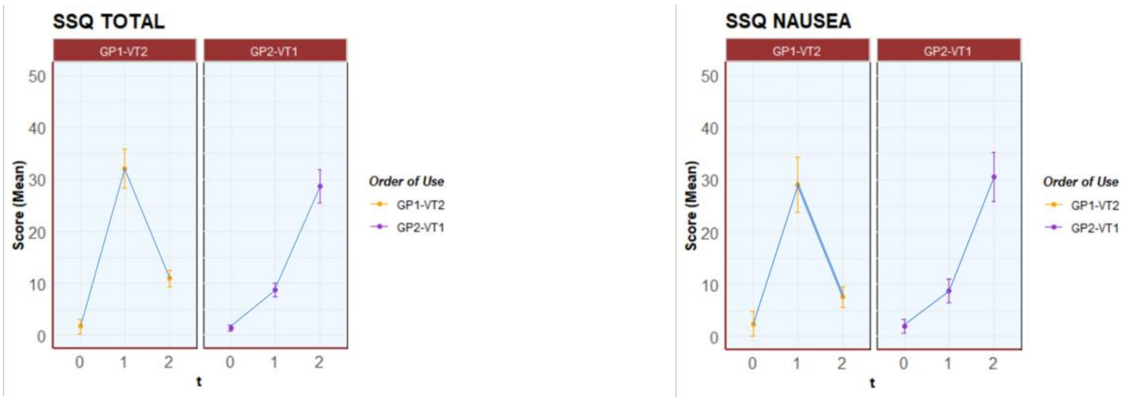
SSQ Nausea scale:

A main effect of the measurement times was found ($F(2,92) = 21.78$, $p<.001$, $\eta G^2 =$

0.20), in that participants who used the Gamepad as the first interface and the VitruvianVR as the second at measurement time 1 (M = 29.02, SD = 25.7) were statistically higher than measurement time 0 (M = 2.39, SD = 11.69) (t(32.12) = 4.62, $p<.001$) and measurement time 2 (M = 7.55, SD = 9.74) (t(29.47) = 3.83, $p<.001$). The scores at measurement time 2 and at time 0 showed no difference ($p = .05$). Also, they showed that the scores of the participants that used the Gamepad as the second interface and VitruvianVR as first interface were statistically higher at time 2 (M = 30.61, SD = 23.02) compared to time 1 (M= 8.75, SD = 10.87) (t(26.40) = 5.88, $p<.001$) and 0 (M = 1.99, SD = 6.28) (t(32.76) = 4.21, $p<.001$). The scores at measurement time 1 was statistically higher than at time 0 (t(36.82) = 2.64, $p=.02$). These results showed an higher perception of nausea while interacting with the gamepad. The two-way Order of Use x measurement times interaction was statistically significant (F(2,92) = 27.24, $p<.001$, $\eta G^2 = 0.24$). Post hoc t-test (Bonferroni correction) showed no difference between time 2 of participants interacted first with the Gamepad and then with VitruvianVR compared with time 1 of those who interacted with the Gamepad as the second interface and VitruvianVR as the first one (t(45.45) = -0.40, $p = 0.69$). Also no difference emerged between the two groups respectively between measurement time 1 and time 2 (t(45.45) = -0.23, $p = 0.82$). The same applies for measurement time 0 in both groups (t(35.25) = 0.15, $p = 0.88$) (Figure 4.12b).

SSQ Oculomotor Symptoms:

A main effect of the measurement time was found (F(2,92) = 22.76, $p<.001$, $\eta G^2 = 0.23$), in that participants who interacted with the Gamepad as the first interface and the VitruvianVR as the second interface at time 1 (M = 24.32, SD = 19.48) were statistically higher than at time 0 (M = 2.53, SD = 9.39) (t(33.15) = 4.93, $p<.001$) or at measurement time 2 (M = 9.48, SD = 7.82) (t(30.23) = 3.46, $p = .003$). The scores at measurement time 2 were statistically higher than at time 0 (t(44.54) = 2.78, $p = 0.01$). Also, they showed that the scores of the participants who interacted with reversed order of presentation were sta-



(a) SSQ Total sub-scale Order of Use x time adjusted scores (mean).

(b) SSQ Nausea symptoms sub-scale Order of Use x time adjusted scores (mean).

Figure 4.12: Simulator Sickness Questionnaire (SSQ) Order of Use x time adjusted mean scores for the total and the nausea symptoms sub-scale.

tistically higher at time 2 (M = 24.95, SD = 18.09) compared to measurement time at 1 (M = 8.84, SD = 8.56) (t(32.81) = 3.94, *p* =.001) and at time 0 (M = 2.53, SD = 4.83) (t(26.26) = 5.87, *p*<.001). Scores at time 1 were statistically higher than at time 0 (t(36.29) = 3.15, *p* =.009), indicating in both cases higher perception of oculomotor symptoms during the gamepad session. The two-way Order of Use x delta times interaction was statistically significant for both oculomotor symptoms (F(2,92) = 19.76, *p*<.001, ηG^2 = 0.20). Independent samples t-tests (Bonferroni correction) showed no difference in scores between time 2 of participants who interacted first with the Gamepad and then with VitruvianVR compared with scores at time 1 of those one that interacted with Gamepad as the second interface and the VitruvianVR as the first one for the oculomotor symptoms (t(45.63) = 0.27, *p* = 0.79). No differences emerged between the two groups respectively between time 1 and time 2 (t(45.75) = -0.12, *p* = 0.91). Same applies for time 0 in each group (t(34.36) = 0, *p* = 1) (Figure 4.13a), indicating no differences if considering just the effects of the measurement times for the interface used.

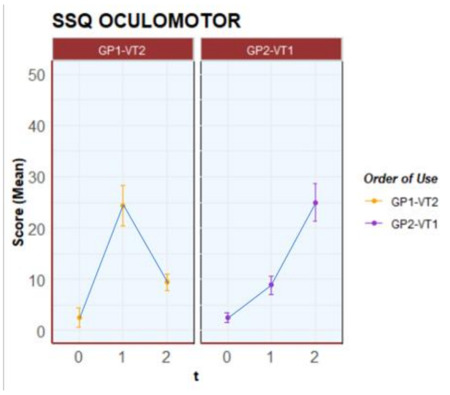
SSQ Disorientation scale

A main effect of the measurement times was found (F(2,92) = 51.72, *p*<.001, ηG^2 = 0.41). In that the scores of the participants who used the Gamepad as the first interface and

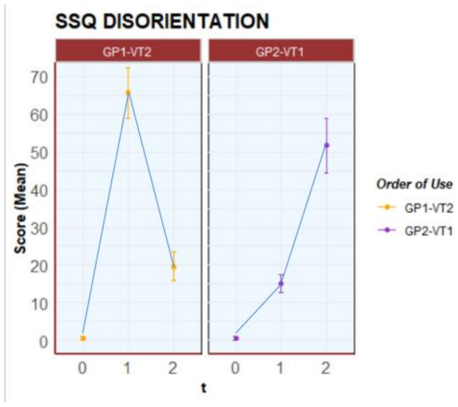
VitruvianVR as the second interface at time 1 (M = 65.54, SD = 32.96) were statistically higher than measurement time 0 (M = 0.58, SD = 2.84) (t(23.34) = 9.62, p<.001) and measurement time 2 (M = 19.72, SD = 18.77) (t(36.50) = 5.92, p<.001). The scores at measurement time 2 were statistically higher than at time 0 (t(24.05) = 4.94, p<.001). Also, they showed that the scores of the participants that interacted in the order sampes of GP2-VT1 were statistically higher at measurement time 2 (M = 51.62, SD = 35.42) compared to measurement time 1 (M = 15.08, SD = 11.55) (t(27.83) = 4.80, p<.001) and measurement time 0 (M = 0.58, SD = 2.84) (t(23.30) = 7.04, p<.001). The scores at measurement time 1 was statistically higher than time 0 (t(25.77) = 5.97, p<.001). These results indicates higher disorientation in participants who were interacting with gamepad compared to when they were interacting with VitruvianVR. The two way Order of Use x delta times interaction was statistically significant (F(2,92) = 47.25, p<.001, ηG^2 = 0.39). No differences in scores were found between time 2 of participants who interacted first with the Gamepad and then with VitruvianVR compared with scores at time 1 of those one that interacted with Gamepad as the second interface and the VitruvianVR as the first one (t(38.23) = 1.03, p = 0.30). No differences were also found between the two groups respectively between time 1 and time 2 (t(45.76) = 1.41, p = 0.17). Same applies for time 0 in both groups (t(46) = 0, p = 1) (Figure 4.13b).

"ΔSSQ Total Score:

In order to isolate the effects and to see the impact of the interfaces in depth we also run a mixed two-way ANOVA with the order of use as the between-participants factor (GP1-VT2 vs GP2-VT1) and the delta times as the within-participants factor (0-1 vs 1- 2 vs 0-2) on the SSQ Total scale. Main effects of the delta measurement times factor (F(2,92) = 27.70, p<.001, ηG^2 = 0.27) and the order of use (F(1,46) = 20.31, p<.001, ηG^2 = 0.14) were statistically significant. The effects highlights the ability of VitruvianVR to counter the effects of perceived cybersickness on users'. The two-way Order of Use x delta times interaction was statistically significant (F(2,92) = 59.78, p<.001, ηG^2 = 0.45).



(a) SSQ Oculomotor symptoms sub-scale Order of Use x time adjusted scores (mean).



(b) SSQ Disorientation symptoms sub-scale Order of Use x time adjusted scores (mean).

Figure 4.13: Simulator Sickness Questionnaire (SSQ) Order of Use x time adjusted mean scores for oculomotor symptoms and disorientation sub-scales.

A series of t-tests for paired samples with Bonferroni's correction method showed that the scores of the participants that used the Gamepad as the first interface and VitruvianVR as the second interface were statistically higher at delta time 0-1 compared to delta time 1-2 ($t(45.41) = 9.48$, $p<.001$) and 0-2 ($t(34.71) = 4.63$, $p<.001$). Also, they showed that the scores of the participants that interacted in the order of presentation of GP2-VT1 were statistically lower at delta measurement time 0-1 compared to delta measurement time 1-2 ($t(32.06) = -3.77$, $p = .001$) and 0-2 ($t(30.35) = -5.43$, $p<.001$). Furthermore, post-hoc t-tests (Bonferroni correction) showed that the scores of the participants who interacted with the Gamepad as the first interface and VitruvianVR as the second interface at delta measurement time 0-1 were statistically higher compared with those of participants who interacted with the reverse order of presentation for the same delta measurement time ($t(28.23) = 5.3787$, $p<.001$). Secondly, the scores of the participants who interacted in the order GP1-VT2 at delta measurement time 1-2 were statistically lower compared with those of participants who interacted with the order GP2-VT1 ($t(44.68) = -8.70$, $p<.001$). Thirdly, the scores of the participants who interacted with GP1-VT2 at delta measurement time 0-2 were statistically lower compared with those of participants who interacted with the order GP2-VT1 ($t(38.56) = -4.50$, $p<.001$) indicating a lower sickness at the end of the session for those who interacted with Vitruvian as second. The Mauchly's test for sphericity showed a violation of the assumption for the delta measurements time factor (W=0.28, p<.001) and the two-way order of use x delta measurements time interaction (W=0.28, p<.001). We report the results of the Greenhouse-Geisser's test correction for delta measurements time ($\varepsilon = 0.58$) and the two-way order of use x delta interaction ($\varepsilon = 0.58$). The results showed that the delta has a statistically significant influence on SSQ Total score $F(1.16,53.36) = 27.70$, $p < .001$, $\eta^2 = 0.27$, along with the two-way interaction, $F(1.16,53.36) = 59.78$, $p<.001$, $\eta^2 = 0.45$ (Figure 4.14).

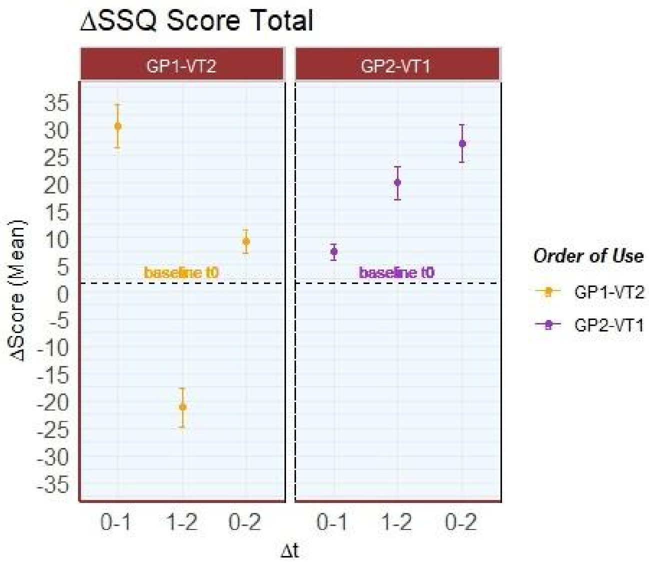


Figure 4.14: SSQ Order of Use x ″Δtime adjusted mean ″Δscores for SSQ Total scale.

Usability

The results coming from the Usability ad hoc questionnaire (i.e., ease of learning, ease of use, and perceived controller intuitiveness) were analyzed through a series a mixed two-way ANOVAs. The results of the Shapiro-Wilk's test indicated a normal distribution of the dimensions, allowing us to apply parametric analyses.

Ease of learning:

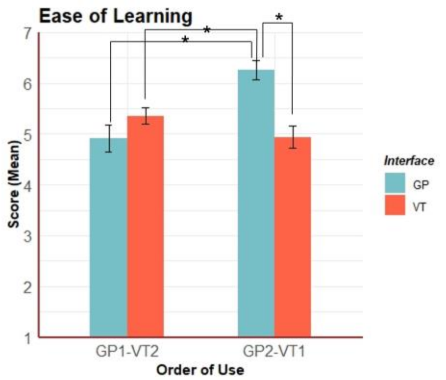
A main effect of the interface factor was present ($F(1,46) = 5.81$, $p = 0.01$, $\eta G^2 = 0.046$) in that the overall scores of the participants for VitruvianVR (M = 5.14, SD = 0.94) were lower compared to the scores of when they interacted with the Gamepad (M = 5.59, SD = 1.29) indicating higher ease of learning for the Gamepad. The interaction effect was statistically significant ($F(1,46) = 22.97$, $p<0.001$, $\eta G^2 = 0.16$). Independant samples post-hoc t-tests (Bonferroni correction) showed that the scores of the participants who interacted with the Gamepad as the first interface (M = 4.92, SD = 1.29) were statistically lower compared with those of participants who interacted with the Gamepad as the second interface (M = 6.26, SD = 0.91), $t(41.37) = -4.16$, $p<.001$, d = -1.19. Secondly, the scores of participants who interacted with VitruvianVR as the second interface (M = 5.36, SD = 0.80) were statistically lower compared with those of participants who interacted with Gamepad as the second interface (M = 6.26, SD = 0.91), $t(45.271) = -3.65$, $p =.002$, d = -1.07 (Figure 4.15a). These results indicates that utilizing the gamepad as the second interface is consider easier to learn compared to when it is utilized as first, and also in general.

Ease of use:

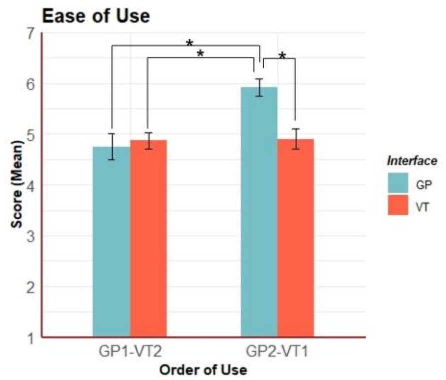
A main effect of the interface factor was found to be statistically significant ($F(1,46) = 6.60$, $p = 0.014$, $\eta G^2 = 0.05$). The scores of the participants for the interaction with the VitruvianVR (M = 4.89, SD = 0.87) were lower compared to the scores of when they interacted with the Gamepad (M = 5.33, SD = 1.21) indicating higher ease of use for the traditional handheld device. The two-way Order of Use x Interface effect also was found to be significant ($F(1,46) = 10.79$, $p = 0.002$, $\eta G^2 = 0.082$). Independent samples post-hoc t-tests (Bonferroni's correction) showed that the scores of the participants who interacted with the Gamepad as the first interface (M = 4.74, SD = 1.25) were statistically lower compared with those of participants who interacted with the Gamepad as the second interface (M = 5.93, SD = 0.84), $t(40.29) = -3.83$, $p<.001$, d = -1.19. Finally, the scores of participants who interacted with VitruvianVR as the second interface (M = 4.86, SD =

0.81) were statistically lower compared with those of participants who interacted with the Gamepad as the second interface (M = 5 .93, SD = 0.84), t(40.29) = -3.82, p<.001, d = -1.07 (Figure 4.15b).

The results showed that participants found the gamepad easier to learn and use if compared to the VitruvianVR. Also, if the VitruvianVR is used as the first interface, scores for gamepad as a second for both dimensions are higher than when it is used as first and also higher compared to every session.



(a) Usability ad hoc Questionnaire Order of use x Interface mean score Ease of Learning dimension.



(b)Usability ad hoc Questionnaire Order of use x Interface mean score Ease of Use dimension.

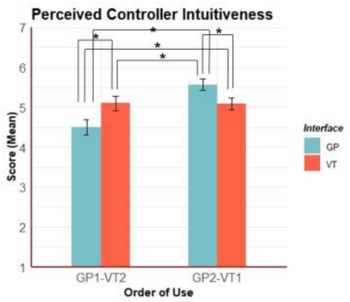
Figure 4.15: Usability ad hoc Questionnaire Order of use x Interface mean scores for Ease of Learning and Ease of use dimensions. *p<.05

Perceived intuitiveness of controllers:

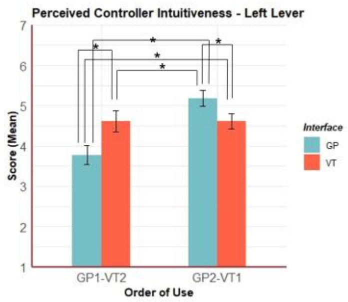
When taking in consideration both left and right levers results is possible to see a main effect of the order of use factor (F(1,46) = 5.89, p = .002, ηG^2 = 0.095) in that scores for the order of GP1-VT2 (M = 4.79, SD = 0.97) were statistically lower compared to GP2-VT1 (M = 5.32, SD = 0.75), indicating that who interacted at first with the gamepad and then with the VitruvianVR perceived less intuitiveness of controllers from the general experience compared to who utilized the device in the opposite order. The two-way Order of Use x Interface interaction was also statistically significant (F(1,46) = 28.90, p<.001, ηG^2 = 0.10). A series of independent samples post-hoc t-tests (Bonferroni correction) showed that the scores of the participants who interacted with the Gamepad as the first interface (M = 4.49, SD = 0.94) were statistically lower compared with those of participants who interacted with Gamepad as the second interface (M=5.55, SD = 0.70), t(42.47) = -4.49, *p*<.001, d = -1,06 (Figure 4.16a).

Taking into consideration only the right lever results did not show any difference between participants (F(1,46) = 0.75, *p* = 0.39, ηG^2 = .009) nor within them (F(1,46) = 0.44, *p* = 0.51, ηG^2 = .004). No latter effect was found (F(1,46) = 2.12, *p* = 0.15, ηG^2 = 0.02) (Figure 4.16c). While, considering the left lever, results were consistent with the findings of considering the effects of both levers showing a main effect of the order of use factor (F(1,46) = 6.47, *p* =.01, ηG^2 = 0.10). Specifically, scores for the order of GP1-VT2 (M = 4.25, SD = 1.27) were statistically lower compared to GP2-VT1 (M = 4.90, SD = 0.98) indicating that utilizing the VitruvianVR as the first interface and the gamepad as the second led to a higher intuition of the left lever. Also, that the left lever is the one leading to a difference when the levers are considered altogether. Furthermore, the two-way Order of Use x Interface interaction was statistically significant (F(1,46) = 24.07, *p*<.001, ηG^2 = 0.10). Independent samples Post-hoc t-tests (Bonferroni correction) method showed that the scores of the participants who interacted with the Gamepad as the first interface (M = 3.77, SD = 1.15) were statistically lower compared with those of participants who interacted with the Gamepad as the second interface (M = 4.61, SD = 1.26), t(44.87) = -4.56, *p*<.001, d = -0.84. Secondly, the scores of the participants who interacted with the VitruvianVR as the first interface (M = 4.62, SD = 0.91) were higher compared with the scores of the participants who interacted with the Gamepad as the first interface (M = 3.77, SD = 1.15) t(43.64) = 2.83, *p* =.02, d = 0.85.

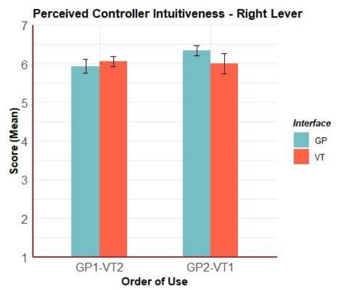
In summary we can state that the participants scores for the perceived intuitiveness of the left lever was the one influencing the general result. Also, the order of use that consisted of GP2-VT1 is considered as more intuitive compared to the opposite order of presentation. Also, the second interface used is considered as more intuitive compared to



(a) Usability ad hoc Questionnaire Order of use x Interface mean scores for Perceived controller intuitiveness dimensions considering both levers effects in conjunction.



(b) Usability ad hoc Questionnaire Order of use x Interface mean scores for Perceived controller intuitiveness dimension considering the left lever.



(c) Usability ad hoc Questionnaire Order of use x Interface mean scores for Perceived controller intuitiveness dimension considering the right lever.

Figure 4.16: Usability ad hoc Questionnaire Order of use x Interface mean scores for perceived controller intuitiveness. *$p<.05$

when is used as the first one during each session and for each interface.

Mental Workload

Results from the NASA TLX Questionnaire are shown in this subsection concerning all of its sub-scales. After running a series of Shapiro-Wilk tests, we applied parametric analyses since the data were normally distributed. A series of mixed two-way ANOVAs with the order of use as the between-participants factor (GP1-VT2 vs GP2-VT1) and the interface as the within-participants factor (Gamepad vs VitruvianVR) were run.

NASA TLX Mental Demand:

A main effect of the interface emerged (F(1,46) = 2.01, p<.001, ηG^2 = 0.15). The participants for VitruvianVR (M = 57.40, SD = 19.21) were higher compared to the scores of when they interacted with the Gamepad (M = 39.06, SD = 25.82) indicating higher Mental Demand for VitruvianVR. The two-way Order of Use x Interface interaction was statistically significant (F(1,46) = 7.30, p =.009, ηG^2 = 0.06). Independent samples post-hoc t-tests (Bonferroni correction) showed that the scores of participants who interacted with VitruvianVR as the second interface (M = 52.08, SD = 21.72) were higher compared with those of participants who interacted with the Gamepad as the second interface (M = 33.33, SD = 26.65), t(44.20) = 2.67, p =.003, d = -1.07. Secondly, the scores of participants who interacted with the VitruvianVR as the first interface (M = 62.71, SD = 14.96) were statistically higher compared with those of participants who interacted with the Gamepad as the first interface (M = 44.79, SD = 24.16), t(38.38) = 3.1, p =.01, d = 17.91 (Figure 4.17a) indicating that utilizing VitruvianVR as first requires more mental effort, especially when not preceded by other devices (Figure 4.17a).

NASA TLX Physical Demand:

A main effect of the interface emerged (F(1,46) = 7.92, p =.007, $\eta G^2 = 0.05$), with the scores of the participants for VitruvianVR (M = 29.90, SD = 19.5) being higher compared to the scores of when they interacted with the Gamepad (M = 21.14, SD = 18.94) indicating higher Physical Demand for VitruvianVR (Figure 4.17b). No main effect of the order of use (F(1,46) = 1.65, p = 0.21, $\eta G^2 = 0.02$) was found. No interaction effect was found (F(1,46) = 1.98, p = 0.16, ηG2 = 0.01) (Figure 4.17b).

NASA TLX Temporal Demand:

A main effect of the interface emerged ((F(1,46) = 5.58, p =.002, $\eta G^2 = 0.04$). In that the scores of the participants using VitruvianVR (M = 42.4, SD = 21.66) were higher compared to the scores of when they interacted with the Gamepad (M = 33.5, SD = 23.72) indicating higher Temporal Demand for VitruvianVR (Figure 4.17d). No main effect of the order of use (F(1,46) = 0.24, p = 0.63, $\eta G^2 = .003$) was found. No interaction effect was found (F(1,46) = 3.47, p = 0.69, $\eta G^2 = 0.02$) (Figure 4.17d).

NASA TLX Performance:

The NASA TLX Performance scale (in which 100 is consider as a poor and 0 as a good) showed a main effect of the interface (F(1,46) = 14.15, p<.001, $\eta G^2 = 0.07$). The scores for VitruvianVR (M = 39.69, SD = 21.39) were higher compared to the scores of when they interacted with the Gamepad (M = 27.18, SD = 24.90) indicating lower perceived Performance when interacting with the VitruvianVR.The two way Order of Use x Interface interaction was statistically significant (F(1,46) = 11.46, p =.001, $\eta G^2 = 0.06$). Independent samples post-hoc t-tests (Bonferroni correction) showed that the scores of participant who interacted with the Gamepad as the first interface (M = 36.04, SD = 28.44) were statistically higher compared to those who interacted with the Gamepad as the second interface (M = 18.3, SD = 17.17), t(37.8) = 2.61, p =.04, d = 17.74. The scores for participants who interacted with VitruvianVR as the second interface (M = 37.29, SD = 20.21) were statistically higher compared with those of participants who interacted with the Gamepad as the second interface (M = 18.3, SD = 17.17), t(44.83) = 3.5, p =.003, d = 18.99 indicating lower perceived performance for the gamepad used as first (Figure 4.17f).

NASA TLX Effort:

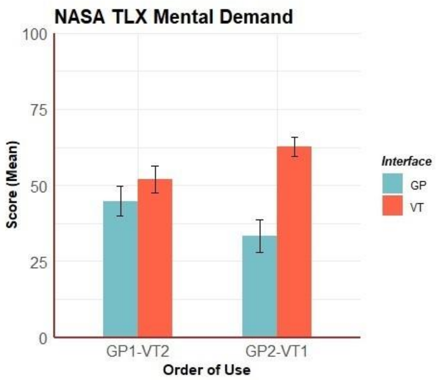
A main effect of the interface emerged (F(1,46) = 13.65, p<.001, $\eta G^2 = 0.07$) in that the scores of the participants interacting with VitruvianVR (M = 74.58, SD = 22.40) were higher compared to the scores of when they interacted with the Gamepad (M = 60.63, SD = 29.67) indicating that the VitruvianVR required more effort. An interaction effect also emerged (F(1,46) = 14.06, p<.001, $\eta G^2 = 0.075$) (Figure 4.17c).

NASA TLX Frustration:

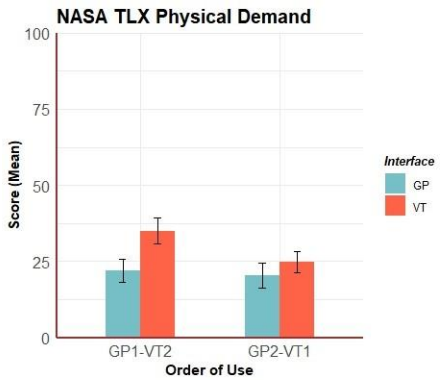
No main effects were found neither for the interface (F(1,46) = 0.38, p = 0.54, ηG^2 = .002) or the order of use (F(1,46) = 0.30, p = 0.58, ηG^2 = .005). An interaction effect emerged (F(1,46) = 10.90, p =.002, $\eta G^2 = 0.06$), indicating that the second interface is always consider as less frustrating compared to the one used as first.

Microsoft Desirability Toolkit

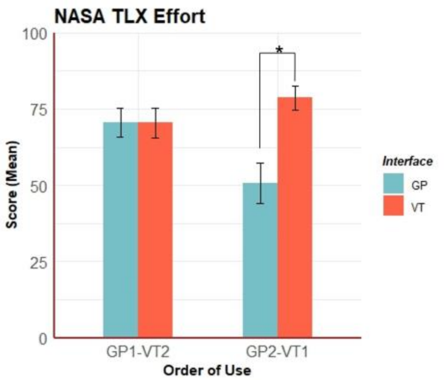
At the end of the two sessions participants were asked to choose between 30 adjective the one that better describes their experience with both the Gamepad and VitruvianVR. Results shown in Figure 4.18 indicates the 5 most chose adjective for the Gamepad and the 5 most chose for VitruvianVR. We would like to point out the differences also in the term ”nauseating” which was reported and chosen from 18.75% of participants, while for Vit-



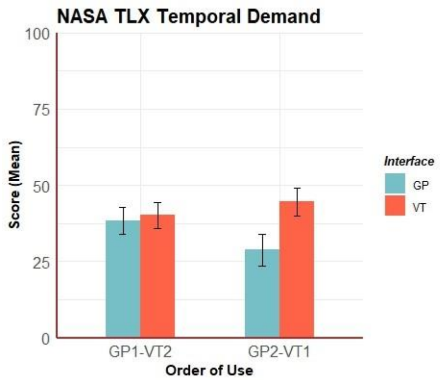
(a) Nasa TLX Mental Demand Order of Use x Interface scores (mean).



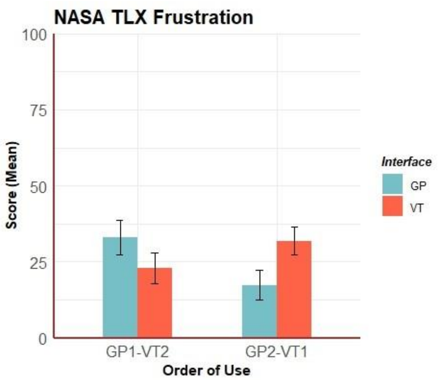
(b) NASA TLX Physical Demand Order of Use x Interface scores (mean).



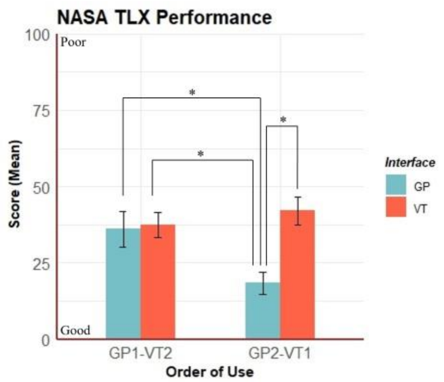
(c) Nasa TLX Effort Order of Use x Interface scores (mean).



(d) Nasa TLX Temporal Demand Order of Use x Interface scores (mean).



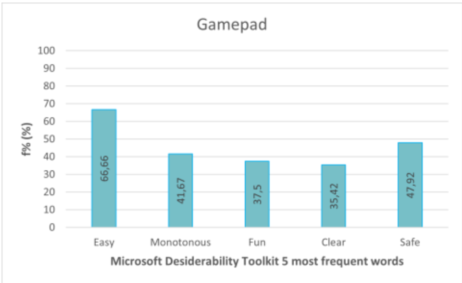
(e) Nasa TLX Frustration Order of Use x Interface scores (mean).



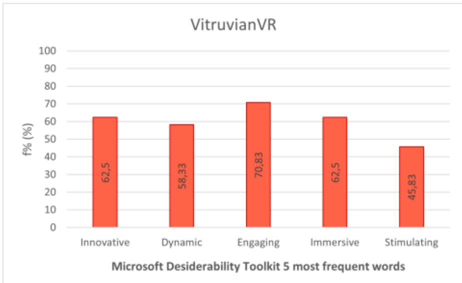
(f) Nasa TLX Performance Order of Use x Interface scores (mean) where 100 indicates a poor perceived performance and 0 a good perceived performance.

Figure 4.17: Nasa TLX Order of use x Interface scores (mean) for each sub-scale. $*p<.05$

ruvianVR was never chosen. Also, ”immersive” and ”engaging” were chosen just 6.25% and 10.42% of the time from participants for the gamepad which was lower if compared to the 62.5% and 70.83% of the time reported for VitruvianVR. Also, Vitruvian (f%=56.25%) was reported as fun with higher frequency compared to the gamepad (f%=14.58%) (AppendixI).



(a) Microsoft Desirability Toolkit's 5 most frequent terms chosen for the Gamepad.



(b) Microsoft Desirability Toolkit's 5 most frequent terms chosen for the VitruvianVR.

Figure 4.18: Microsoft Desirability Toolkit's 5 most frequent terms chosen for Gamepad and VitruvianVR.

Interview

In order to investigate possible preferences and differences between the experiences carried out with the two interfaces, participants were asked if there was an interface between the two that they preferred, and if yes, which one. Most of the preferences were given to the experience carried out with VitruvianVR (95.83%).

To get more information and opinions from participants', they were also asked to indicate the reason behind their choice.

From the table in Figure 4.19a it is possible to see that participants reported that they liked more the experience with VitruvianVR due to a reduced sense of sickness symptoms (20.83%). Also, the immersion (33.33%), engagement (25%) and realism (41.67%) play a role in impacting the preference of an experience. VitruvianVR's controllers were also a motivation for the preference in that they were consider as more intuitive in most cases

(16.66%). While for the gamepad, the preferences were based just on the intuitiveness of the controllers (2.08%) and a reduced sense of sickness (2.08%).

Thematic Analysis – Reasons of the preference - VITRUVIANVR

Category	Codes	Definition	f%	F
Perceived effects on Controllers	Learning	The user reported to have found controllers more comprehensable	*4.16%*	*2*
	Control	The user reported to have had more control on the movements	*6.25%*	*3*
	Intuition	The user reported the controllers to be more intuitive and leads the preference	*16.66%*	*8*
User's affective state	Movements	The user reported to have preferred the interface liked due to the movements	*12.5%*	*6*
	Safety	The user reported to have preferred the interface liked due to had been feeling safe.	*4.16%*	*2*
	Effort	The user reported to have preferred the interface liked due to a higher request of effort and concentration	*4.16%*	*3*
	Satifaction	The user reported to have preferred the interface liked due to satifsaction o attractiveness	*6.25%*	*2*
	Sickness	The user reported to have preferred the interface liked due to less perceived sickness (e.g. headache, nausea, instability, disorientation)	*20.83%*	*10*
Perceived effects on the experience	Engagement	The user reported to have preferred the interface due to the engagement in the experience	*25%*	*12*
	Immersion	The user reported to have preferred the interface due to the immersion in the experience	*33.33%*	*16*
	Enjoyment	The user reported to have preferred the interface due to the enjoyment perceived in the experience	*10.42%*	*5*
	Realism	The user reported to have preferred the interface liked due to the perceived realism of the experience	*41.67%*	*20*
	Novelty	The user reported to have preferred the interface liked due to the novelty of the experience	*14.58%*	*7*
	Complete	The user reported to have preferer the interface due to its ability to provide a complete experience	*2.08%*	*1*

(a) Thematic analysis on reasons of the preferences for VitruvianVR.

Thematic Analysis – Reasons of the preference - GAMEPAD

Category	Codes	Definition	f%	F
Perceived effects on Controllers	Intuition	Users reported the controllers to be more intuitive and leads the preference	*2.08%*	*1*
User's affective state	Sickness	Users reported to have preferred the interface liked due to less perceived sickness (e.g. headache, nausea, instability, disorientation)	*2.08%*	*1*

(b) Thematic analysis on reasons of the preferences for the gamepad.

Figure 4.19: Thematic analyses of the reasons that led to users' interface preference choice.

The second question was referred instead to the impact of the bodily rotation on the experience, asking its effect and if perceived as positive or negative. As visible in the table summarizing the results in Figure 4.20, participants reported that the bodily rotation had an impact on the control make it hard to use (20.83%) even though it enabled a better comprehensions of the movements (33.33%) and increased ability to control the hang-glider thanks to the feedback provided by the motion (12.5%). Rotating controls were

Thematic Analysis – Body rotation impact on the experience				
Category	Codes	Definition	f%	F
Perceived effects on Controllers	Comprehension	The users understood how to use the controllers better due to rotation.	33.33%	16
	Difficulty	The users considered the experience to be harder to due higher difficulty of the controllers because of rotation	20.83%	10
	Control	The users felt more/less in control of the hang-glider thanks to rotation	12.5%	6
	Naturalness	The users found that rotation made use of the controller feel more natural	6.25%	3
User's affective state	Sickness	The users reported low levels of sickness thanks to rotation	18.75%	9
	Concentration	The users reported rotation to have either a positive or negative impact on concentration.	18.75%	9
	Loss of Orientation	The users reported low levels of sense of orientation due to rotation	14.58%	7
	Motivation	The users felt a change in motivatation thanks to rotation	8.33%	4
	Fear	The users felt scared due to rotation	6.25%	3
	Pain	The users reported the interface to be painful due to rotation	8.33%	4
	Safety	The users felt safe due to rotation	4.16%	2
Perceived effects on the experience	Engagement	The users found rotation to be engaging	18.75%	10
	Immersion	The users found rotation to be immersive	54.16%	26
	Stimulating	The users found rotation to be stimulating	18.75%	9
	Realism	The users found rotation to increase realism	25%	12
	Novelty	The users found rotation to be innovative	4.16%	2
	Complete	The users found that rotation made the experience feel more complete	2.08%	1

Figure 4.20: Thematic analysis of the body rotation impact on the experience.

also perceived as natural movements (6.25%). Regarding safety, participants' reported that they have felt safe on the machine, thanks to the high level of immersion it provides (4.16%). Other participants reported bodily movements to be scary (6.25%) and painful because of the VitruvianVR's mechanical structure (8.33%). Bodily rotation impacted positively on the users reducing the perceived cybersickness (18.75%). However, some participants reported a loss of orientation and spatial position of their body in the physical world (14.58%), finding it hard to get back to the starting position. That impacted also on controls since in the moment in which that happened, they were not able to get back to the original position, preventing a precise control of the hang-glider. Also, the impact of body movement required more concentration (18.75%) that could have influenced the experience in a positive way with more immersion, or de-concentrating from the controls. In most of the cases participants found the body rotation to be more immersive (54.16%), realistic (25%), engaging (18.75%) and stimulating (18.75%).

5 Discussion

This chapter presents the discussion of the results reported in the previous chapter. It is structured with a brief discussion of the results found following the hypothesis stated in Section 3.3.

5.1 Effects on the experience

5.1.1 Sense Of Presence

The results from the Presence Questionnaire (PQ) (Witmer et al., 2005) shows that utilizing the VitruvianVR for a Virtual Reality (VR) flight simulation leads to higher perceived sense of presence compared to a traditional hand-held interface such as the gamepad. Furthermore, utilizing the VitruvianVR as the first interface leads to higher perceived scores of adaptation and sensory fidelity for the following interface as well, i.e., gamepad. The results confirm hypothesis H1: utilizing this novel prototype leads to an increased sense of presence. Furthermore, results are in line with previous research (Hashemian et al., 2020). While, considering the interaction effects, we contribute to extend previous findings, in which Bektaş et al. (2021) did not find any impact on utilizing a leaning-based interface that allows a rotation on two axes. On the contrary we found that for integrating an additional axe of rotation along with a more naturalistic interaction for a flight experience with an hang-glider led to a stronger effect that last also on following session with other devices increasing the perceived sense of presence even with them. This result may be explainable considering that involving the whole body during the session with VitruvianVR may have a strong impact on the experience which then influences following sessions inside a Virtual Environment (VE). In Virtual Reality (VR) experiences the impact of the sense of presence is so important that it can be seen as part of the definition of VR itself (Coelho, Tichon, Hine, Wallis, & Riva, 2006). From the results it is possible to state that VitruvianVR impacts users' perceived sense of presence by increasing it. This ability can be useful for VR flight experience training (De Leo, Diggs, Radici, & Mastaglio, 2014) and for User eXperience (UX) enhancement (Narciso, Bessa, Melo, Coelho, & Vasconcelos-Raposo, 2019).

5.1.2 User Experience

The results from the User Experience ad hoc questionnaire showed different results based on the dimensions taken in consideration. Utilizing the VitruvianVR was found to be more enjoyable and innovative when compared to the gamepad. Also, using VitruvianVR as the first interface significantly lowered the score of the gamepad used after it. This findings are consistent with H1 and also with previous research (Hashemian et al., 2020; Marchal et al., 2011). The latter effect can be explained by the fact that participants preferred interacting with the VitruvianVR, in that utilizing the gamepad as the second interface may be affected by the impact of the VitruvianVR, resulting in lower scores.

These results extend previous findings on motion cuing interfaces found in the work of Kitson et al. (2017) that compared different kind of leaning based interfaces. Regarding the comfort dimension, no differences were found between the two interfaces, indicating the same level of comfort with both interfaces, in contrast with H1. It is important to state that in both conditions participants were standing for a total amount of 11 minutes, but in the case of VitruvianVR the users were tied to harnesses. Nonetheless both scores were high. For the safety and overall satisfaction with the experience results showed that utilizing VitruvianVR leads to a higher perception of a sensation of safety and satisfaction. The former can be explained due to the higher immersion and sense of presence in the virtual environment, alongside with the safety measures provided by VitruvianVR. The latter effect instead is consistent with other works found in the literature in which overall satisfaction was found to be higher if associated with a higher level of immersion and presence (Abbas et al., 2023). Realism was found to be higher during the interaction with VitruvianVR in any conditions. Also in this case utilizing the gamepad after VitruvianVR leads to lower scores if compared to its use as the first interface since probably participants preferred VitruvianVR realism over the experience provided by the hand-held device. In the literature high scores of realism are predictors of high levels of immersion and sense of presence, consistently with what we have found in our research (Hvass et al., 2017). In light of that, VitruvianVR improves users' perceived UX to carry out VR experiences.

5.1.3 Technology Acceptance Model

Results from the Technology Acceptance Model, more specifically analyses on perceived usefulness, behavioral intention and ease of use, showed that VitruvianVR is perceived as more useful, leading to higher scores of the intention to use it in the future if compared to the gamepad, consistently with H1. On the other hand, the gamepad was found to be easier to use compared with VitruvianVR, in line with H4. These results are in line with previous research on the topic that showed higher behavioral intentions for experiences that offer higher immersion (Abbas et al., 2023) and that perceived usefulness is the strongest predictor of intention to use (King & He, 2006).

5.2 Effects on the performance

5.2.1 Task Accuracy

Participants were more accurate with the gamepad compared to the VitruvianVR. There was no statistically significant difference in the number of failures for each interface, even though with the gamepad it happened with more frequency. In addition it was possible to see a learning effect for both interfaces. These results are consistent with our H2 and also with what was already found in the literature, in which embodied interfaces do not provide better performances in accuracy compared to traditional devices (Bektaş et al., 2021). This effect can be explained considering that the gamepad required less mental demand and effort as cited in the previous section, and low levels of mental workload are usually associated with good performances (Jeffri & Rambli, 2021). Also, participants tend to have more familiarity with that device compared to VitruvianVR which was something new and never used or seen before

5.2.2 Bird report Accuracy

The results coming from the detection task of spawning birds in the environment with a talking a-loud technique showed no differences between the two interfaces. In addition, it was possible to see a learning effect from the order of the scenario. Also, the number of false alarms as defined in the signal detection theory (Green et al., 1966; Domes & Zimmer, 2019) was found to be the same with both interfaces implying that the effect is due to the visual characteristics of the VE itself.

5.3 Cybersickness

Regarding cybersickness, results showed that the experience conducted with VitruvianVR generates a lower perception of sickness in participants compared to traditional hand held devices, indicating that adding bodily motion while carrying out experiences reduces cybersickness symptoms. Even though in the work of Bektaş et al. (2021) participants did not report lower perceived sickness with a leaning-based interface with 2 axes of rotation compared to a gamepad, VitruvianVR (with 3 axes) was actually able to contrast perceptions of sickness. This confirms H3 and is in line with the sensory mismatch theory on cybersickness (Reason & Brand, 1975; Ng et al., 2020). Furthermore, scores for VitruvianVR in each scales are considered as minimal ($5<x<10$) as described in the work of Stanney, Kennedy, and Drexler. This ability of VitruvianVR to fully involve and immerse the users with minimal motion sickness in the virtual environments could be a key property to reduce the gap of users' willingness to use VR (M. Zhang et al., 2022), indicating its beneficial effects for future experience and training (Sagnier et al., 2020; Impellizzeri et al., 2022).

5.4 Usability

The evaluation of usability firstly showed that the gamepad was found to be easier to learn and easier to use compared to VitruvianVR. This effect is in line with H4, and can be explained by the high level of ergonomic interaction provided by the traditional handheld devices, consistently with the work of Kitson et al. (2017). It is important to highlight that in this dissertation participants had little experience in the use of traditional devices, still they could have tried it before. Nonetheless, VitruvianVR in general is considered easy to learn and to use as well. An interesting effect found was that utilizing VitruvianVR as the first interface increases scores for the gamepad for both dimensions. Different assumptions could explain this effect. First of all, as also reported in the interviews, participants found VitruvianVR controllers to be hard to use, and this may have also impacted their perception of learnability, thereby making the interaction with the gamepad easier. Another explanation could be that interacting with VitruvianVR and its body movements/rotations allowed for better comprehension of the movements in the Virtual Environment (VE) that lasted in the following session with the gamepad. Regarding perceived intuitiveness of the controllers results show that the second interface is always perceived as more intuitive compared to the one used at first. These results could be explained by the learning effect (Biskup, 2008), participants got used to the controllers and the movements to the point in which the second session was always more intuitive than the first one. In general, utilizing VitruvianVR as the first interface and the gamepad as the second lead to higher scores compared to the opposite order of presentation. This effect is in line with the improved comprehension associated with VitruvianVR and reported in the interviews, then affected by the learning effect for the following session. More specifically, by isolating the left and the right levers of both interfaces, perception of intuitiveness for the right lever that allowed just one input was found to be the same for both interfaces in both conditions with high scores. The results of general intuitiveness were mainly influenced by the left lever that controlled two movements, indicating that it is better to isolate inputs for the axes of rotations to provide the user a more natural and intuitive interaction. Previous studies on the intuitiveness and mapping of controls showed similar results, in that over- riding participants with one command to control more outputs can lead to more mistakes and confusion, especially when the action allowed is complex or counter-intuitive as in the case of the rotation on the roll axe in which visual output mismatched with the mo- tion input provided by the participants (Reeves et al., 2004; McGloin et al., 2011; Nealen, Saltsman, & Boxerman, 2011).

5.5 Mental Workload

Results from the Nasa TLX Questionnaire confirmed hypothesis (H5), in that VitruvianVR was found to lead to higher mental workload compared to traditional hand held devices. From the analysis on single items, it emerged that VitruvianVR required higher mental demand, physical demand, temporal demand and effort, alongside with lower perceived performance compared to the gamepad. For the item of mental demand, participants who interacted with the gamepad as the first interface reported lower scores for VitruvianVR compared to when the gamepad was utilized as the second interface, indicating a lower mental demand for the interface if preceded by some traditional trials. In addition, for the perceived performance, when the gamepad was used as the second interface it gained higher scores compared to when it was used as the first one. This effect could be due to the difficulty of the experience that requires higher mental and physical demand when interacting with the VitruvianVR. Another explanation can be that VitruvianVR helps to comprehend the experience better, facilitating its understanding and improving the performance in following sessions with other interfaces. The item assessing frustration that stated *"How irritated, stressed, and annoyed versus content, relaxed, and complacent did you feel during the task?"* participants reported that they have felt less frustrated with the second interface used compared to the first one. This effect can be explained with the learning effect. From this result we can conclude that VitruvianVR is a device that requires higher mental demand due to the characteristic of the device it- self: more effort in understanding movements, rotation and its functions; more temporal demand due to the dynamicity allowed with the rotation on the axes and more physical demand since the whole body is engaged in the experience. In light of that, it is important to consider those aspects when building VR experience to conduct with VitruvianVR. As a matter of fact, considering the cognitive demands it is fundamental to build a good training experience that does not overload the mental capacity of the users (Leung et al., 2010).

5.6 Microsoft desirability toolkit

The Microsoft desirability toolkit showed that the majority of participants, when choosing 5 adjectives for the experience with the gamepad, described it as easy, safe, monotonous, nice, and clear. As visible, 4 out of 5 adjectives have a positive valance, while one of them negative. Regarding the experience with VitruvianVR, all the adjectives have a positive value, as it is described as innovative, dynamic, engaging, immersive and stimulating. Moreover, the adjectives chosen for the two interfaces showed two different participants' focuses: in the case of VitruvianVR the focus was more on the experience, while for the gamepad it was more on the usability.

5.7 Interview

When directly asked to express a preference for one of the two interfaced used, the majority of the participants reported to favor the VitruvianVR. The reasons behind the choice were different, and can be summarized in 3 big categories: perceived effects on controllers, user's affective state and perceived effects of the experience. The first category refers to the extent to which an experience was preferred due to the ability of the interface to make the users perceive the controller as more comprehensible and intuitive leading to an higher control of the experience. The second one refers instead to the users' affecting state that was affected and led to the preference. Among them it was reported a feeling of safety, satisfaction, appreciation of the movements and a reduce sensation of sickness as reasons that led prefer VitruvianVR. Few people preferred gamepad highlighting intuition of control e reduced sickness as reasons for that. Regarding the question *"Did the bodily rotations on different axes allowed by VitruvianVR during the VR experience, compared to* *the standing situations with controller/joystick have an impact on your experience? If so, What was the impact? And how?"* we were able to identify the same category indicating the high role of 3-axes rotations also on the users preferences. The first category about controls refers to the extent to which the rotation impacted the perception of controllers by making it more understandable, natural and with the ability to increase the hang-glider control even though it make them be more difficult to use in some occasions since the rotation on the roll axe was not intuitive or commands were not that responding. Also, users reported to have perceived less sickness, higher concentration, motivation and a sensation of being safe due to the movement and the immersion it provided. On the other hand, rotation also had an impact of fear, pain and in many occasion a loss of orientation of the position of their physical body in the physical world, considered as a bad effects that also could have had an impact on controllers. The impact of rotation also was felt in the VR experience since it made it be more engaging, immersive, stimulating, realistic, complete and felt as something innovative and new.

5.8 Limitations and future directions

Limitations of the dissertation include the drawback that the study did not feature physiological measures to assess constructs such as sense of presence, cybersickness and mental workload in an objective way. Furthermore, utilizing a within-participant design could have led to the presence of the learning effect. The presence of the familiarity with the traditional handheld device has to be taken also in consideration as a limitation of the study. Future research can attempt to overcome these limitations by adding physiological measurements such as pupil dilatation (Nenna et al., 2022), eye movements (E. Chang, Kim, & Yoo, 2021), Heart Rate Variability (HRV), galvanic skin conductance and event related potential (Narciso et al., 2022; Riva, Davide, & IJsselsteijn, 2003). Also, future experiments could feature a between-participants design in order to eliminate possible learning effects as well as testing the interface in a wider variety of VR scenarios and with different VR devices less familiar than the gamepad (Kitson et al., 2017).

Conclusion

The advancements of Virtual Reality (VR) technologies nowadays require the design of effective and easy-to-use locomotion interfaces to convey a convincing feeling of self-motion in the absence of actual motion. Introducing and analysing the effects of new embodied interfaces can result as extremely important to fill in the discrepancy between the level of immersion induced by a VR system and the users' actual felt experience. Many locomotion interfaces with different degrees of embodiment were introduced in the literature about VR flying experiences. However, not one of them took into consideration a standing position that allows a rotation on three different axes (i.e., pitch, roll and yaw) featuring a full body experience. In this dissertation we investigated a novel interface for interacting with VR flight experiences, in that we utilized an experimental design that compared it with a traditional handheld device, the gamepad. We evaluated the differences between the experiences with the two devices taking into account the following aspects: sense of presence, user experience, cybersickness, usability, acceptance, mental workload and performance. The trial and task consisted of a VR flight experience with a hang-glider in which participants were asked to pass through as many rings as possible while reporting birds spawning in the environment in 3 different scenarios. Results from the study showed how VitruvianVR affected users' perception of the experience by increasing the sense of presence and acceptance, along with different dimensions of user experience in comparison with the traditional handheld device. In addition, it can contrast the perception of cybersickness symptoms. On the other hand, VitruvianVR was found to require higher levels of perceived mental workload thus reducing performance. However, this result may also be due to VitruvianVR's lower usability compared to the traditional handheld device.

Although the study found positive results, it is necessary to deepen our understanding on the interface usability in order to render it easier to use and to reduce its cognitive demand. Moreover, from the results of the study it is possible to state that it would be necessary to isolate the inputs of the three rotations along with matching the visual output with the physical-motor command in order to achieve that aim. In addition, adding a solution for the users' perceived loss of orientation could improve the ease of use of the device, such as implementing a motor that generates a counter-force that resets the users to the original position.

In conclusion, this dissertation in the field of embodied interfaces represents a step forward in the design of effective locomotion devices, in that we can affirm how utilizing VitruvianVR to conduct VR flight experiences can offer advantages such as stronger sense of presence alongside an ability to contrast the perception of cybersickness when compared to the traditional handheld device. These findings are promising for the development of VR given that it may reduce the gap between users and the effective willingness to carry out a VR experience. Finally, it was possible to demonstrate how utilizing VitruvianVR can be perceived as more useful in performing flight training exercises, given a possibility for the development of these kind of training for users with more expertise.

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A Personal Data Questionnaire

Età 2. Età

▼ 18 ... 30

Genere 3. Genere biologico alla nascita

- ○ Maschio
- ○ Femmina
- ○ Non Binario
- ○ Preferisco non specificare

Mano dominante 4. Mano dominante

- ○ Destra
- ○ Sinistra
- ○ Ambidestra

Professione 5. Professione

- ○ Studente/ssa
- ○ Operaio/a
- ○ Dipendente
- ○ Insegnante/ricercatore/ricercatrice
- ○ Libero/a professionista
- ○ Disoccupato
- ○ Altro (specificare):

Esperienze Deltaplano 6. Hai mai avuto esperienze pregresse di volo tramite Deltaplano?

- Sì
- No

Esperienze simulatori 7. Hai mai avuto esperienze con dei simulatori di volo o di guida?

- Sì
- No

Esperienza Gamepad 8. Con che frequenza fai utilizzo di Controller/Joystick (es. Xbox 360, Xbox One, PS4 etc...)

- Ogni giorno
- 2-3 volte a settimana
- Una volta a settimana
- Una volta al mese
- Meno di una volta al mese
- Meno di una volta all'anno
- Una sola volta
- Mai

Esperienza IVR 9. Hai mai utilizzato un visore di realtà virtuale? (Oculus quest, HTC Vive, Google etc...)

- Ogni giorno
- 2-3 volte a settimana
- Una volta a settimana
- Una volta al mese
- Meno di una volta al mese
- Meno di una volta all'anno
- Una sola volta
- Mai

End of Block: Block 1

Start of Block: SSQ

B Immersive Tendencies Questionnaire

ITQ IMMERSIVE TENDENCIES QUESTIONNAIRE

Indica la risposta che più ti rappresenta selezionando l'apposita casella di risposta su una scala a 7 punti. Ad esempio, se la tua risposta è una o due volte, il secondo punto dalla sinistra deve essere contrassegnato. Se la tua risposta è più volte ma non sempre, allora la sesta casella da sinistra (o la seconda da destra) è quella da selezionare. Rispondi alle domande autonomamente e nell'ordine in cui sono scritte. Non saltare domande e non ritornare a una domanda precedente per cambiare risposta.

ITQ1 1. Durante la visione di film o tv drama ti coinvolgi facilmente?

- ○ 1 (Mai)
- ○ 2
- ○ 3
- ○ 4 (Occasionalmente)
- ○ 5
- ○ 6
- ○ 7 (Sempre)

ITQ2 2. Durante la visione di un programma televisivo o mentre leggi un libro, ti coinvolgi al punto che le persone attorno hanno bisogno di chiamarti più volte per richiamare la tua attenzione?

- ○ 1 (Mai)
- ○ 2
- ○ 3
- ○ 4 (Occasionalmente)
- ○ 5
- ○ 6
- ○ 7 (Sempre)

ITQ3 3. Quanto ti senti vigile in questo momento?

- 1 (Non vigile)
- 2
- 3
- 4 (Moderatamente vigile)
- 5
- 6
- 7 (Completamente vigile)

ITQ4 4. Durante la visione di un film, sei mai così coinvolto da non renderti conto delle cose che accadono attorno a te?

- 1 (Mai)
- 2
- 3
- 4 (Occasionalmente)
- 5
- 6
- 7 (Sempre)

ITQ5 5. Quanto frequentemente tendi a identificarti con i personaggi presenti in un racconto?

- 1 (Mai)
- 2
- 3
- 4 (Occasionalmente)
- 5
- 6
- 7 (Sempre)

ITQ6 6. Giocando ad un un videogioco, sei mai così coinvolto da agire come se fossi all'interno dello stesso piuttosto che muovere il joystick e guardare lo schermo?

- 1 (Mai)
- 2
- 3
- 4 (Occasionalmente)
- 5
- 6
- 7 (Sempre)

ITQ7 7. Quanto ti senti fisicamente in forma oggi?

- 1 (Non in forma)
- 2
- 3
- 4 (Moderatamente in forma)
- 5
- 6
- 7 (Completamente in forma)

ITQ8 8. Quanto sei bravo a ignorare distrazioni esterne mentre sei coinvolto in qualche attività?

- 1 (Per nulla bravo)
- 2
- 3
- 4 (Alquanto bravo)
- 5
- 6
- 7 (Del tutto bravo)

ITQ9 9. Durante la visione di un evento sportivo, sei mai così coinvolto dall'incontro da reagire come se fossi uno dei giocatori di una delle squadre?

- ◯ 1 (Mai)
- ◯ 2
- ◯ 3
- ◯ 4 (Occasionalmente)
- ◯ 5
- ◯ 6
- ◯ 7 (Sempre)

ITQ10 10. Sei mai così coinvolto durante un sogno ad occhi aperti da non renderti conto di ciò che ti accade attorno?

- ◯ 1 (Mai)
- ◯ 2
- ◯ 3
- ◯ 4 (Occasionalmente)
- ◯ 5
- ◯ 6
- ◯ 7 (Sempre)

ITQ11 11. Hai mai dei sogni che sembrano così veri da farti sentire disorientato una volta sveglio?

- 1 (Mai)
- 2
- 3
- 4 (Occasionalmente)
- 5
- 6
- 7 (Sempre)

ITQ12 12. Mentre giochi a qualche sport, sei mai così coinvolto da perdere traccia del tempo?

- 1 (Mai)
- 2
- 3
- 4 (Occasionalmente)
- 5
- 6
- 7 (Sempre)

ITQ13 13. Quanto bene riesci a concentrarti durante lo svolgimento di attività da te ritenute divertenti?

- 1 (Non riesco)
- 2
- 3
- 4 (Moderatamente bene)
- 5
- 6
- 7 (Riesco sempre)

ITQ14 14. Quanto spesso giochi ai videogiochi? (Sempre significa ogni giorno o ogni due giorni, di media)

- 1 (Mai)
- 2
- 3
- 4 (Occasionalmente)
- 5
- 6
- 7 (Sempre)

ITQ15 15. Ti capita mai di sentirti eccitato durante una scena di lotta o di inseguimento in TV o in un film?

- ◯ 1 (Mai)
- ◯ 2
- ◯ 3
- ◯ 4 (Occasionalmente)
- ◯ 5
- ◯ 6
- ◯ 7 (Sempre)

ITQ16 16. Ti capita mai di spaventarti di qualche evento successo in un programma TV o in un film?

- ◯ 1 (Mai)
- ◯ 2
- ◯ 3
- ◯ 4 (Occasionalmente)
- ◯ 5
- ◯ 6
- ◯ 7 (Sempre)

ITQ17 17. Sei mai rimasto impaurito o in tensione per tanto tempo dopo aver visto un film di paura?

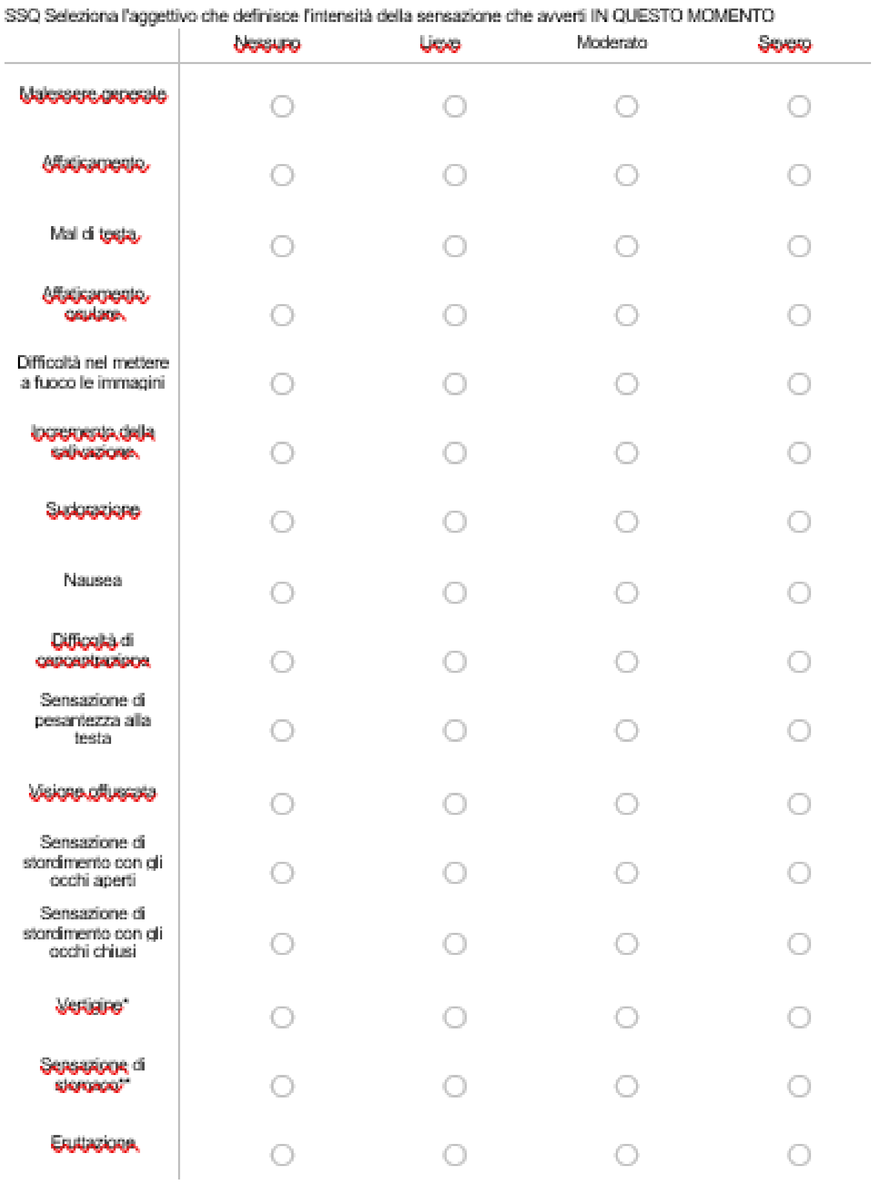
- 1 (Mai)
- 2
- 3
- 4 (Occasionalmente)
- 5
- 6
- 7 (Sempre)

ITQ18 18. Sei mai stato così coinvolto nel fare qualcosa da perdere completamente traccia del tempo?

- 1 (Mai)
- 2
- 3
- 4 (Occasionalmente)
- 5
- 6
- 7 (Sempre)

End of Block: Block 3

C Simulator Sickness Questionnaire



SSQ Seleziona l'aggettivo che definisce l'intensità della sensazione che avverti IN QUESTO MOMENTO

	Nessuno	Lieve	Moderato	Severo
Malessere generale	○	○	○	○
Affaticamento	○	○	○	○
Mal di testa	○	○	○	○
Affaticamento oculare	○	○	○	○
Difficoltà nel mettere a fuoco le immagini	○	○	○	○
Incremento della salivazione	○	○	○	○
Sudorazione	○	○	○	○
Nausea	○	○	○	○
Difficoltà di concentrazione	○	○	○	○
Sensazione di pesantezza alla testa	○	○	○	○
Visione offuscata	○	○	○	○
Sensazione di stordimento con gli occhi aperti	○	○	○	○
Sensazione di stordimento con gli occhi chiusi	○	○	○	○
Vertigine*	○	○	○	○
Sensazione di stomaco**	○	○	○	○
Eruttazione	○	○	○	○

SSQ La vertigine è avvertita come una perdita di orientamento correlata alla posizione eretta
** Il termine sensazione di stomaco è solitamente usato per indicare una sensazione di fastidio allo stomaco vicina alla nausea

D Presence Questionnaire

PRESENCE QUESTIONNAIRE
Descrivi la tua esperienza nell'ambiente virtuale cliccando sull'opzione adeguata tra le 7 opzioni disponibili. Ti chiediamo gentilmente di rispondere alle domande autonomamente e nell'ordine in cui sono scritte. Non saltare domande e non ritornare a una domanda precedente per cambiare risposta.

PQ IN BASE ALLA TUA ESPERIENZA NELL' AMBIENTE VIRTUALE...

PQ_1 1. Eri in grado di controllare gli eventi?

- 1 (Per niente)
- 2
- 3
- 4 (Moderatamente)
- 5
- 6
- 7 (Completamente)

PQ_2 2. Quanto era reattivo *lo strumento*(inserire rispettivamente Gamepad o VitruvianVR sulla base della condizione) rispetto alle azioni da te compiute?

- 1 (Per niente)
- 2
- 3
- 4 (Moderatamente)
- 5
- 6
- 7 (Completamente)

PQ_3 3. Quanto ti sembravano naturali le tue interazioni con l'ambiente tramite *lo strumento*?

- 1 (Estremamente fittizie)
- 2
- 3
- 4 (Al limite)
- 5
- 6
- 7 (Completamente naturali)

PQ_4 4. Quanto sei stato coinvolto dagli aspetti visivi della simulazione?

- 1 (Per niente)
- 2
- 3
- 4 (Moderatamente)
- 5
- 6
- 7 (Completamente)

PQ_5 5. Quanto gli aspetti uditivi dell'ambiente ti hanno coinvolto durante l'esperienza?

- 1 (Per niente)
- 2
- 3
- 4 (Moderatamente)
- 5
- 6
- 7 (Completamente)

PQ_6 6. Quanto ti sembrava naturale/fluido il meccanismo che controllava il movimento all'interno dell'ambiente?

- 1 (Estremamente fittizio)
- 2
- 3
- 4 (Al limite)
- 5
- 6
- 7 (Completamente naturale)

PQ_7 7. Quanto era convincente la sensazione di reale movimento degli oggetti nello spazio?

- 1 (Per niente)
- 2
- 3
- 4 (Moderatamente)
- 5
- 6
- 7 (Completamente)

PQ_8 8. Le tue esperienze all'interno dell'ambiente virtuale ti sembravano in linea con quanto si verifica nella realtà?

- 1 (Per niente)
- 2
- 3
- 4 (Moderatamente)
- 5
- 6
- 7 (Completamente)

PQ_9 9. Eri in grado di prevedere cosa sarebbe successo in risposta alle azioni da te compiute?

- 1 (Per niente)
- 2
- 3
- 4 (Moderatamente)
- 5
- 6
- 7 (Completamente)

PQ_10 10. Quanto ti sentivi in grado di monitorare e di esplorare visivamente quanto accadeva nell'ambiente?

- 1 (Per niente)
- 2
- 3
- 4 (Moderatamente)
- 5
- 6
- 7 (Completamente)

PQ_11 11. Con che accuratezza eri in grado di identificare i suoni?

- 1 (Per niente)
- 2
- 3
- 4 (Moderatamente)
- 5
- 6
- 7 (Completamente)

PQ_12 12. Con che accuratezza eri in grado di localizzare i suoni?

- 1 (Per niente)
- 2
- 3
- 4 (Moderatamente)
- 5
- 6
- 7 (Completamente)

PQ_14 13. Quanto era convincente la sensazione di movimento all'interno dell'ambiente virtuale tramite strumento?

- 1 (Per niente)
- 2
- 3
- 4 (Moderatamente)
- 5
- 6
- 7 (Completamente)

PQ_15 14. Quanto da vicino riuscivi a osservare gli oggetti?

- 1 (Per niente)
- 2
- 3
- 4 (Moderatamente)
- 5
- 6
- 7 (Completamente)

PQ_16 15. Riuscivi a osservare bene gli oggetti da diversi punti di vista?

- 1 (Per niente)
- 2
- 3
- 4 (Moderatamente)
- 5
- 6
- 7 (Completamente)

PQ_18 16. Quanto ti sentivi coinvolto dall'esperienza all'interno dell'ambiente virtuale?

- ○ 1 (Per niente)
- ○ 2
- ○ 3
- ○ 4 (Moderatamente)
- ○ 5
- ○ 6
- ○ 7 (Completamente)

PQ_19 17. Quanto ritardo c'era tra le tue azioni e il risultato di tali azioni?

- ○ 1 (Totalmente in ritardo)
- ○ 2
- ○ 3
- ○ 4 (Ritardo moderato)
- ○ 5
- ○ 6
- ○ 7 (Nessun ritardo)

PQ_20 18. Dopo quanto tempo ti sei adattato all'ambiente virtuale?

- 1 (Non mi sono adattato)
- 2
- 3
- 4 (Adattamento Lento)
- 5
- 6
- 7 (Meno di un minuto)

PQ_21 19. Alla fine dell'esperienza quanta padronanza sentivi di aver acquisito nel muoverti e nell'interagire nell'ambiente virtuale tramite il VitruvianVR?

- 1 (Nessuna padronanza)
- 2
- 3
- 4 (Moderatamente)
- 5
- 6
- 7 (Padronanza completa)

PQ_22* 20. Quanto credi che la qualità grafica del display abbia interferito o ti abbia distratto dallo svolgimento dei compito e delle attività richiesti?

- 1 (Per niente)
- 2
- 3
- 4 (Moderatamente)
- 5
- 6
- 7 (Completamente)

PQ_23* 21. Quanto credi che *lo strumento* abbia influenzato la tua prestazione nello svolgere il compito che ti era stato chiesto?

- 1 (Per niente)
- 2
- 3
- 4 (Moderatamente)
- 5
- 6
- 7 (Completamente)

PQ_24 22. Riuscivi a concentrarti bene sui compiti e sulle attività assegnati piuttosto che sui meccanismi messi in atto per compiere tali compiti o attività?

- 1 (Per niente)
- 2
- 3
- 4 (Moderatamente)
- 5
- 6
- 7 (Completamente)

PQ_25 23. Quanto erano coinvolti i tuoi sensi durante l'esperienza di realtà virtuale?

- 1 (Per niente)
- 2
- 3
- 4 (Moderatamente)
- 5
- 6
- 7 (Completamente)

PQ_29 24. Quanto è stato facile identificare gli oggetti attraverso un'interazione fisica come il toccare un oggetto, il camminare su una superficie o l'urtare un muro o un oggetto?

- 1 (Per niente)
- 2
- 3
- 4 (Moderatamente)
- 5
- 6
- 7 (Completamente)

PQ_30 25. C'erano momenti durante l'esperienza virtuale in cui ti sei sentito completamente concentrato sul compito o sull'ambiente?

- 1 (Per niente presenti)
- 2
- 3
- 4 (Moderatamente presenti)
- 5
- 6
- 7 (Completamente presenti)

PQ_31 26. Quanto è stato facile per te adattarti ai comandi utilizzati per interagire con l'ambiente virtuale?

- ○ 1 (Per niente)
- ○ 2
- ○ 3
- ○ 4 (Moderatamente)
- ○ 5
- ○ 6
- ○ 7 (Completamente)

PQ_32 27. Le informazioni fornite dai diversi sensi (es. vista, udito, tatto) all'interno dell'ambiente virtuale erano tra loro coerenti?

- ○ 1 (Per niente coerenti)
- ○ 2
- ○ 3
- ○ 4 (Moderatamente coerenti)
- ○ 5
- ○ 6
- ○ 7 (Completamente coerenti)

E UX ad HOC questionnaire

USER EXPERIENCE

Ti chiediamo ora di indicare il tuo grado di accordo con le affermazioni riportate di seguito relative all'esperienza appena conclusa con *lo strumento*, dove 1 indica "completamente in disaccordo" e 7 completamente in accordo. Non ci sono risposte giuste o sbagliate, ciò che ci interessa è la tua opinione. 1

= Completamente in disaccordo 2 = In disaccordo 3= Parzialmente in disaccordo 4 = Né in accordo né in disaccordo 5 = Parzialmente in accordo 6 = In accordo 7 = Completamente in accordo

---

UX_Enjoyment1 1. Mi è piaciuto interagire nella simulazione di volo in realtà virtuale tramite *lo strumento*

- 1 (Completamente in disaccordo)
- 2 (In disaccordo)
- 3 (Parzialmente in disaccordo)
- 4 (Né in accordo né in disaccordo)
- 5 (Parzialmente in accordo)
- 6 (In accordo)
- 7 (Completamente in accordo)

UX_Enjoyment2 2. Mi sono divertito/a durante l'esperienza

- 1 (Completamente in disaccordo)
- 2 (In disaccordo)
- 3 (Parzialmente in disaccordo)
- 4 (Né in accordo né in disaccordo)
- 5 (Parzialmente in accordo)
- 6 (In accordo)
- 7 (Completamente in accordo)

UX_Enjoyment3* 3. Ho trovato l'esperienza in realtà virtuale tramite *lo strumento* per certi versi noiosa

- 1 (Completamente in disaccordo)
- 2 (In disaccordo)
- 3 (Parzialmente in disaccordo)
- 4 (Né in accordo né in disaccordo)
- 5 (Parzialmente in accordo)
- 6 (In accordo)
- 7 (Completamente in accordo)

UX_Novelty1 4. Ritengo originale *lo strumento* per svolgere l'esperienza

- 1 (Completamente in disaccordo)
- 2 (In disaccordo)
- 3 (Parzialmente in disaccordo)
- 4 (Né in accordo né in disaccordo)
- 5 (Parzialmente in accordo)
- 6 (In accordo)
- 7 (Completamente in accordo)

UX_Novelty2 5. Ritengo innovativo *lo strumento* per svolgere l'esperienza

- 1 (Completamente in disaccordo)
- 2 (In disaccordo)
- 3 (Parzialmente in disaccordo)
- 4 (Né in accordo né in disaccordo)
- 5 (Parzialmente in accordo)
- 6 (In accordo)
- 7 (Completamente in accordo)

UX_Novelty3 6. Ritengo creativo *lo strumento* appena utilizzato per svolgere l'esperienza

- 1 (Completamente in disaccordo)
- 2 (In disaccordo)
- 3 (Parzialmente in disaccordo)
- 4 (Né in accordo né in disaccordo)
- 5 (Parzialmente in accordo)
- 6 (In accordo)
- 7 (Completamente in accordo)

UX_Novelty4 7. Ritengo che *lo strumento* sia tecnologicamente avanzato

- 1 (Completamente in disaccordo)
- 2 (In disaccordo)
- 3 (Parzialmente in disaccordo)
- 4 (Né in accordo né in disaccordo)
- 5 (Parzialmente in accordo)
- 6 (In accordo)
- 7 (Completamente in accordo)

UX_Safety1 8. Mi sentivo sicuro mentre utilizzavo *lo strumento*

- 1 (Completamente in disaccordo)
- 2 (In disaccordo)
- 3 (Parzialmente in disaccordo)
- 4 (Né in accordo né in disaccordo)
- 5 (Parzialmente in accordo)
- 6 (In accordo)
- 7 (Completamente in accordo)

UX_Safety2 9. Ritengo che il sentirmi sicuro abbia influito sulla mia prestazione all'interno dell'ambiente virtuale

- 1 (Completamente in disaccordo)
- 2 (In disaccordo)
- 3 (Parzialmente in disaccordo)
- 4 (Né in accordo né in disaccordo)
- 5 (Parzialmente in accordo)
- 6 (In accordo)
- 7 (Completamente in accordo)

UX_Comfort1 10. Mi sentivo comodo mentre utilizzavo *lo strumento*

- 1 (Completamente in disaccordo)
- 2 (In disaccordo)
- 3 (Parzialmente in disaccordo)
- 4 (Né in accordo né in disaccordo)
- 5 (Parzialmente in accordo)
- 6 (In accordo)
- 7 (Completamente in accordo)

UX_Comfort2 11. Mi sentivo rilassato mentre utilizzavo *lo strumento*

- 1 (Completamente in disaccordo)
- 2 (In disaccordo)
- 3 (Parzialmente in disaccordo)
- 4 (Né in accordo né in disaccordo)
- 5 (Parzialmente in accordo)
- 6 (In accordo)
- 7 (Completamente in accordo)

UX_Comfort3* 12. Mi sentivo teso mentre utilizzavo *lo strumento*

- 1 (Completamente in disaccordo)
- 2 (In disaccordo)
- 3 (Parzialmente in disaccordo)
- 4 (Né in accordo né in disaccordo)
- 5 (Parzialmente in accordo)
- 6 (In accordo)
- 7 (Completamente in accordo)

UX_OverallSat1 13. Nel complesso, sono soddisfatto del *lo strumento*

1 (Completamente in disaccordo)

2 (In disaccordo)

3 (Parzialmente in disaccordo)

4 (Né in accordo né in disaccordo)

5 (Parzialmente in accordo)

6 (In accordo)

7 (Completamente in accordo)

UX_OverallSat2 14. Nel complesso, mi sono sentito a mio agio mentre utilizzavo *lo strumento*

1 (Completamente in disaccordo)

2 (In disaccordo)

3 (Parzialmente in disaccordo)

4 (Né in accordo né in disaccordo)

5 (Parzialmente in accordo)

6 (In accordo)

7 (Completamente in accordo)

PUSF1 15. Penso che l'esperienza di simulazione di volo appena conclusa sia utile per affrontare un'esperienza di volo nel mondo fisico

- 1 (Completamente in disaccordo)
- 2 (In disaccordo)
- 3 (Parzialmente in disaccordo)
- 4 (Né in accordo né in disaccordo)
- 5 (Parzialmente in accordo)
- 6 (In accordo)
- 7 (Completamente in accordo)

X→

PUSF2 16. Penso che fare simulazioni in realtà virtuale con l'utilizzo del *lo strumento* migliorerebbe le mia esperienza con i training di volo

- 1 (Completamente in disaccordo)
- 2 (In disaccordo)
- 3 (Parzialmente in disaccordo)
- 4 (Né in accordo né in disaccordo)
- 5 (Parzialmente in accordo)
- 6 (In accordo)
- 7 (Completamente in accordo)

X→

PUSF3 17. Penso che utilizzare *lo strumento* migliorerebbe le mie performance nei training di volo

- 1 (Completamente in disaccordo)
- 2 (In disaccordo)
- 3 (Parzialmente in disaccordo)
- 4 (Né in accordo né in disaccordo)
- 5 (Parzialmente in accordo)
- 6 (In accordo)
- 7 (Completamente in accordo)

ITU1 18. Se reso disponibile e accessibile, ho intenzione di utilizzare *lo strumento* in un futuro per training di volo

- 1 (Completamente in disaccordo)
- 2 (In disaccordo)
- 3 (Parzialmente in disaccordo)
- 4 (Né in accordo né in disaccordo)
- 5 (Parzialmente in accordo)
- 6 (In accordo)
- 7 (Completamente in accordo)

ITU2 19. Se reso disponibile e accessibile, consiglierei vivamente agli altri di utilizzare *lo strumento* per training e scenari di volo

- 1 (Completamente in disaccordo)
- 2 (In disaccordo)
- 3 (Parzialmente in disaccordo)
- 4 (Né in accordo né in disaccordo)
- 5 (Parzialmente in accordo)
- 6 (In accordo)
- 7 (Completamente in accordo)

ITU3 20. Se reso disponibile e accessibile, continuerei a utilizzare *lo strumento* in un futuro per training e scenari di volo

- 1 (Completamente in disaccordo)
- 2 (In disaccordo)
- 3 (Parzialmente in disaccordo)
- 4 (Né in accordo né in disaccordo)
- 5 (Parzialmente in accordo)
- 6 (In accordo)
- 7 (Completamente in accordo)

ITU4 21. Se resa disponibile e accessibile, sarei disposto a pagare dei soldi per avere ancora un'esperienza *lo strumento* per altre simulazioni in realtà virtuale

- 1 (Completamente in disaccordo)
- 2 (In disaccordo)
- 3 (Parzialmente in disaccordo)
- 4 (Né in accordo né in disaccordo)
- 5 (Parzialmente in accordo)
- 6 (In accordo)
- 7 (Completamente in accordo)

UX_Realism1 22. Mi è sembrato di essere realmente su un deltaplano mentre svolgevo l'esperienza

- 1 (Completamente in disaccordo)
- 2 (In disaccordo)
- 3 (Parzialmente in disaccordo)
- 4 (Né in accordo né in disaccordo)
- 5 (Parzialmente in accordo)
- 6 (In accordo)
- 7 (Completamente in accordo)

UX_Realism2 23. Ho trovato tutte le sensazioni che provavo mentre svolgevo la simulazione di volo in realtà virtuale tramite *lo strumento* simili a quelle che proverei a fare l'esperienza nel mondo reale

- 1 (Completamente in disaccordo)
- 2 (In disaccordo)
- 3 (Parzialmente in disaccordo)
- 4 (Né in accordo né in disaccordo)
- 5 (Parzialmente in accordo)
- 6 (In accordo)
- 7 (Completamente in accordo)

UX_Realism3 24. Le caratteristiche del *lo strumento*) (es. Rotazione del corpo tramite macchinario/avere movimenti liberi decisi da me stando in piedi etc..) hanno influenzato in maniera positiva il grado di realisticità che ho provato durante la simulazione di volo in realtà virtuale

- 1 (Completamente in disaccordo)
- 2 (In disaccordo)
- 3 (Parzialmente in disaccordo)
- 4 (Né in accordo né in disaccordo)
- 5 (Parzialmente in accordo)
- 6 (In accordo)
- 7 (Completamente in accordo)

UX_Realism4 25. Mi è sembrato di essere effettivamente un deltaplanista mente svolgevo l'esperienza

- 1 (Completamente in disaccordo)
- 2 (In disaccordo)
- 3 (Parzialmente in disaccordo)
- 4 (Né in accordo né in disaccordo)
- 5 (Parzialmente in accordo)
- 6 (In accordo)
- 7 (Completamente in accordo)

F Usability questionnaire

USABILITA'

Ti chiediamo ora di indicare il tuo grado di accordo con le affermazioni riportate di seguito relative all'esperienza appena conclusa con *lo strumento*, dove 1 indica "completamente in disaccordo" e 7 completamente in accordo. Non ci sono risposte giuste o sbagliate, ciò che ci interessa è la tua opinione. 1 = Completamente in disaccordo 2 = In disaccordo 3= Parzialmente in disaccordo 4 = Né in accordo né in disaccordo 5 = Parzialmente in accordo 6 = In accordo 7 = Completamente in accordo

---

Usability_EOL1 1. Ho imparato ad utilizzare *lo strumento* velocemente

- 1 (Completamente in disaccordo)
- 2 (In disaccordo)
- 3 (Parzialmente in disaccordo)
- 4 (Né in accordo né in disaccordo)
- 5 (Parzialmente in accordo)
- 6 (In accordo)
- 7 (Completamente in accordo)

Usability_EOL2 2. Mi ricordo facilmente come utilizzare *lo strumento*

- 1 (Completamente in disaccordo)
- 2 (In disaccordo)
- 3 (Parzialmente in disaccordo)
- 4 (Né in accordo né in disaccordo)
- 5 (Parzialmente in accordo)
- 6 (In accordo)
- 7 (Completamente in accordo)

Usability_EOL3 3. E' facile imparare come si utilizza *lo strumento*

- 1 (Completamente in disaccordo)
- 2 (In disaccordo)
- 3 (Parzialmente in disaccordo)
- 4 (Né in accordo né in disaccordo)
- 5 (Parzialmente in accordo)
- 6 (In accordo)
- 7 (Completamente in accordo)

Usability_EOL4 4. Sono diventato abile con *lo strumento* velocemente

- 1 (Completamente in disaccordo)
- 2 (In disaccordo)
- 3 (Parzialmente in disaccordo)
- 4 (Né in accordo né in disaccordo)
- 5 (Parzialmente in accordo)
- 6 (In accordo)
- 7 (Completamente in accordo)

Usability_EOU1 5. *Lo strumento* è facile da usare

- 1 (Completamente in disaccordo)
- 2 (In disaccordo)
- 3 (Parzialmente in disaccordo)
- 4 (Né in accordo né in disaccordo)
- 5 (Parzialmente in accordo)
- 6 (In accordo)
- 7 (Completamente in accordo)

Usability_EOU2 6. *Lo strumento* è semplice da comprendere

- 1 (Completamente in disaccordo)
- 2 (In disaccordo)
- 3 (Parzialmente in disaccordo)
- 4 (Né in accordo né in disaccordo)
- 5 (Parzialmente in accordo)
- 6 (In accordo)
- 7 (Completamente in accordo)

Usability_EOU3 7. *Lo strumento* è pratico da usare

- 1 (Completamente in disaccordo)
- 2 (In disaccordo)
- 3 (Parzialmente in disaccordo)
- 4 (Né in accordo né in disaccordo)
- 5 (Parzialmente in accordo)
- 6 (In accordo)
- 7 (Completamente in accordo)

Usability_EOU4 8. Posso utilizzare *Lo strumento* senza bisogno di istruzioni

- 1 (Completamente in disaccordo)
- 2 (In disaccordo)
- 3 (Parzialmente in disaccordo)
- 4 (Né in accordo né in disaccordo)
- 5 (Parzialmente in accordo)
- 6 (In accordo)
- 7 (Completamente in accordo)

Usability_EOU5 9. Posso recuperare da eventuali errori commessi con il *Lo strumento* in modo intuitivo

- 1 (Completamente in disaccordo)
- 2 (In disaccordo)
- 3 (Parzialmente in disaccordo)
- 4 (Né in accordo né in disaccordo)
- 5 (Parzialmente in accordo)
- 6 (In accordo)
- 7 (Completamente in accordo)

Usability_EOU6 10. Potrei utilizzare *Lo strumento* ottenendo ogni volta buoni risultati

- 1 (Completamente in disaccordo)
- 2 (In disaccordo)
- 3 (Parzialmente in disaccordo)
- 4 (Né in accordo né in disaccordo)
- 5 (Parzialmente in accordo)
- 6 (In accordo)
- 7 (Completamente in accordo)

Usability_Intuitiveness1 11. La leva di destra del *Lo strumento* mi permetteva di fare azioni con il deltaplano coerenti con le mie intenzioni

- 1 (Completamente in disaccordo)
- 2 (In disaccordo)
- 3 (Parzialmente in disaccordo)
- 4 (Né in accordo né in disaccordo)
- 5 (Parzialmente in accordo)
- 6 (In accordo)
- 7 (Completamente in accordo)

Usability_Intuitiveness2 12. Ritengo intuitive a livello pratico le azioni permesse dalla leva di destra del *lo strumento*

- 1 (Completamente in disaccordo)
- 2 (In disaccordo)
- 3 (Parzialmente in disaccordo)
- 4 (Né in accordo né in disaccordo)
- 5 (Parzialmente in accordo)
- 6 (In accordo)
- 7 (Completamente in accordo)

Usability_Intuitiveness3* 13. Ho trovato la leva di destra del *Lo strumento* difficile da utilizzare per controllare il deltaplano

- 1 (Completamente in disaccordo)
- 2 (In disaccordo)
- 3 (Parzialmente in disaccordo)
- 4 (Né in accordo né in disaccordo)
- 5 (Parzialmente in accordo)
- 6 (In accordo)
- 7 (Completamente in accordo)

Usability_Intuitiveness4 14. La leva di sinistra del *lo strumento* mi permetteva di fare azioni di movimento di discesa e di risalita con il deltaplano coerenti con le mie intenzioni

- 1 (Completamente in disaccordo)
- 2 (In disaccordo)
- 3 (Parzialmente in disaccordo)
- 4 (Né in accordo né in disaccordo)
- 5 (Parzialmente in accordo)
- 6 (In accordo)
- 7 (Completamente in accordo)

UsabilityIntuitiveness5 15. La leva di sinistra del *Lo strumento* mi permetteva di fare azioni di rotazione corporea a destra e sinistra coerenti con le mie intenzioni

- 1 (Completamente in disaccordo)
- 2 (In disaccordo)
- 3 (Parzialmente in disaccordo)
- 4 (Né in accordo né in disaccordo)
- 5 (Parzialmente in accordo)
- 6 (In accordo)
- 7 (Completamente in accordo)

Usability_Intutiveness6 16. Ritengo intuitive a livello pratico l'azione di discesa e di risalita del deltaplano permessa dalla leva di sinistra del *lo strumento*

- 1 (Completamente in disaccordo)
- 2 (In disaccordo)
- 3 (Parzialmente in disaccordo)
- 4 (Né in accordo né in disaccordo)
- 5 (Parzialmente in accordo)
- 6 (In accordo)
- 7 (Completamente in accordo)

Usability_Intutiveness7 17. Ritengo intuitivo a livello pratico l'azione di rotazione corporea permessa dalla leva di sinistra del *lo strumento*

- 1 (Completamente in disaccordo)
- 2 (In disaccordo)
- 3 (Parzialmente in disaccordo)
- 4 (Né in accordo né in disaccordo)
- 5 (Parzialmente in accordo)
- 6 (In accordo)
- 7 (Completamente in accordo)

Usability_Intuitiveness8* 18. Ho trovato la leva di sinistra del *lo strumento* difficile da utilizzare per controllare il deltaplano

- 1 (Completamente in disaccordo)
- 2 (In disaccordo)
- 3 (Parzialmente in disaccordo)
- 4 (Né in accordo né in disaccordo)
- 5 (Parzialmente in accordo)
- 6 (In accordo)
- 7 (Completamente in accordo)

Usability_Intuitiveness9* 19. Ho trovato la leva di sinistra del *lo strumento* difficile da utilizzare per controllare la rotazione del mio personaggio nell'ambiente virtuale

- ○ 1 (Completamente in disaccordo)
- ○ 2 (In disaccordo)
- ○ 3 (Parzialmente in disaccordo)
- ○ 4 (Né in accordo né in disaccordo)
- ○ 5 (Parzialmente in accordo)
- ○ 6 (In accordo)
- ○ 7 (Completamente in accordo)

G NASA TLX

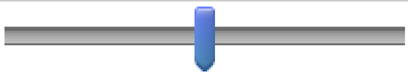
NASA TLX

Ti preghiamo di valutare il tuo carico di lavoro muovendo il pallino nella posizione che ritiene più opportuna in ciascuna delle 6 scale di valutazione nel punto che meglio riflette la tua esperienza. Ogni scala presenta 2 etichette agli estremi. Poni attenzione alla scala "Prestazione" che va da "Molto buona" a sinistra a "Molto scarsa" a destra questo ordine può creare confusione. Ti preghiamo di riflettere attentamente sulle risposte e di considerare ogni scala singolarmente.

Nasa_RichiestaMental 1. Quanto impegnativo mentalmente è stato il compito?

Molto Bassa Molto Alta

0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100

RICHIESTA MENTALE	

Nasa_RichiestaFisic 2. Quanto impegnativo fisicamente è stato il compito?

Molto Bassa Molto Alta

0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100

RICHIESTA FISICA	

Nasa_RichiestaTempor 3. Quanto rapido e frenetico è stato il ritmo del compito?

	Molto Bassa															Molto Alta					
	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
RICHIESTA TEMPORALE																					

Nasa_Prestazione 4. Che livello di successo ritieni di aver ottenuto nell'esecuzione del compito?

	Molto Buona															Molto Scarsa					
	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
PRESTAZIONE																					

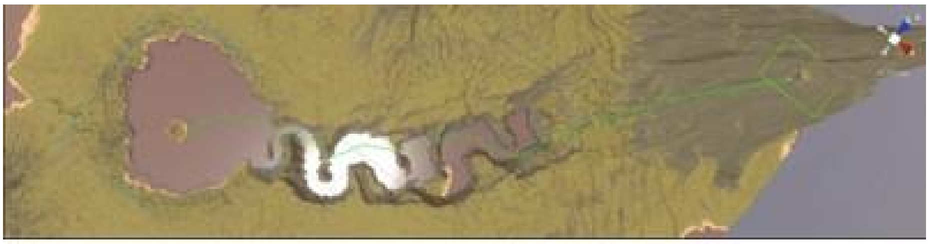
Nasa_Sforzo 5. Quanto ti sei impegnato per raggiungere il tuo livello di prestazione?

	Molto Basso															Molto Alto					
	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
SFORZO																					

Q42 6. Quanto ti sei sentito incerto, scoraggiato, irritato, stressato e infastidito durante il compito?

	Molto Bassa															Molto Alta					
	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
FRUSTRAZIONE																					

H Virtual reality scenarios



Flight scenario 1

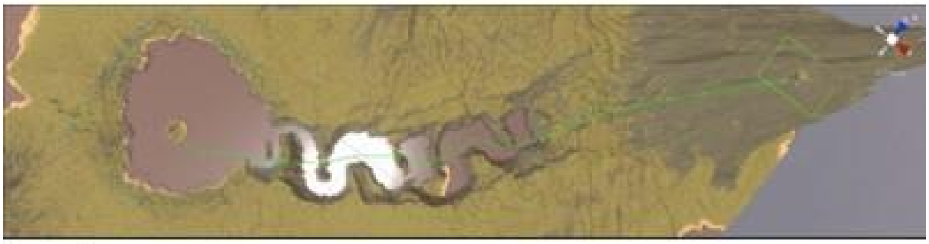
POI start: A

POI end: B

Trial duration: 195s

Number of rings: 19

Total amount of birds spawned: 4



Flyscene2

POI partenza: A

POI arrivo: B

Durata Percorso: 195s

Numero anelli: 19

Numero aeroplani: 5

FlyScene3

POI partenza: A

POI arrivo: B

Durata Percorso:

Numero anelli: 19

Numero aeroplani: 5

I Microsoft desirability toolkit

Q1 Seleziona 5 aggettivi tra la lista proposta qua di sotto per descrivere la tua esperienza di simulazione di volo tramite Controller

Palmare

- [ ] Semplice
- [ ] Macchinosa
- [ ] Lenta
- [ ] Nauseante
- [ ] Noiosa
- [ ] Monotona
- [ ] Esplorativa
- [ ] Soddisfacente
- [ ] Banale
- [ ] Carina
- [ ] Divertente
- [ ] Scomoda
- [ ] Complicata
- [ ] Paurosa
- [ ] Innovativa
- [ ] Dinamica
- [ ] Entusiasmante

- [ ] Coinvolgente
- [ ] Immersiva
- [ ] Difficile
- [ ] Stimolante
- [ ] Attraente
- [ ] Chiara
- [ ] Efficiente
- [ ] Veloce
- [ ] Incomprensibile
- [ ] Sicura
- [ ] Utile
- [ ] Stressante
- [ ] Sofisticata

*

Q4 Seleziona 5 aggettivi tra la lista proposta qua di sotto per descrivere la tua esperienza di simulazione di volo tramite VitruvianVR

- ☐ Semplice
- ☐ Macchinosa
- ☐ Lenta
- ☐ Nauseante
- ☐ Noiosa
- ☐ Monotona
- ☐ Esplorativa
- ☐ Soddisfacente
- ☐ Banale
- ☐ Carina
- ☐ Divertente
- ☐ Scomoda
- ☐ Complicata
- ☐ Paurosa
- ☐ Innovativa
- ☐ Dinamica
- ☐ Entusiasmante

- [ ] Coinvolgente
- [ ] Immersiva
- [ ] Difficile
- [ ] Stimolante
- [ ] Attraente
- [ ] Chiara
- [ ] Efficiente
- [ ] Veloce
- [ ] Incomprensibile
- [ ] Sicura
- [ ] Utile
- [ ] Stressante
- [ ] Sofisticata

Microsoft Desiderability Toolkit				
	Gamepad		VitruvianVR	
	F	%	F	%
Easy	32	66.66%	2	4.17%
Cumbersome	13	27.08%	5	10.42%
Slow	10	20.83%	0	0%
Nauseating	9	18.75%	0	0%
Boring	7	14.58%	1	2.08%
Monotonous	20	41.67%	0	0
Exploratory	6	12.5%	11	22.92%
Satisfying	10	20.83	6	12.5%
Banal	12	25%	0	0%
Nice	18	37.5%	1	2.08%
Fun	7	14.58%	27	56.25%
Uncomfortable	5	10.42%	1	2.08%
Complex	5	10.42%	1	2.08%
Fearful	0	0%	0	0%
Innovative	1	2.08%	30	62.5%
Dynamic	6	12.5%	28	58.33%
Exciting	1	2.08%	16	33.33%
Engaging	5	10.42%	34	70.83%
Immersive	3	6.25%	30	62.5%
Hard	2	4.17%	1	2.08%
Stimulating	4	8.33%	22	45.83%
Charming	2	4.17%	8	16.67%
Clear	17	35.42%	1	2.08%
Efficient	7	14.58%	1	2.08%
Fast	7	14.58%	2	4.16%
Incomprehensible	0	0%	0	0%
Safe	23	47.92%	5	10.42%
Useful	5	10.42%	3	6.25%
Stressful	3	6.25%	2	4.17%
Sofisticated	0	0%	2	4.17%
TOT	240	100%	240	100%

Table Appendix. Microsoft desirability toolkit general results with F and f% for each interface.

J Short summary of the study in ITALIAN

I recenti sviluppi delle tecnologie in Realtà Virtuale (RV) richiedono sempre più la creazione di dispositivi di locomozione efficienti e facili da usare che trasmettano una sensazione di movimento anche in assenza di uno spostamento fisico reale (Riecke & Jordan, 2015; Williams et al., 2007). Analizzare gli effetti delle così dette *”embodied interface”* può rappresentare un avanzamento sostanzioso nel cercare di eliminare il divario presente tra il livello di immersione fornito dal sistema in RV e ciò che effettivamente prova e percepisce l’utente che interagisce all’interno dell’ambiente virtuale stesso. In letteratura sono diverse le interfacce di locomozione che sono state proposte, ciascuna con un differente grado di *embodiment* nel suo funzionamento e controllo (Bektaş et al., 2021; Hashemian et al., 2020; Marchal et al., 2011; Rheiner, 2014), nessuna di queste però fornisce una situazione in cui l'utente è in piedi e, attraverso dei comandi, è in grado di ruotare su 3 differenti assi di rotazione (i.e., inclinazione, rollio, imbardata; che rappresentano una rotazione sugli assi X, Y e Z). garantendo così una rotazione completa che coinvolge tutto il corpo in qualsiasi sua direzione. In questa tesi l'obbiettivo era quello di introdurre una nuova interfaccia con la quale poter interagire all'interno di ambienti virtuali di volo: il VitruvianVR. Per raggiungere questo obbiettivo abbiamo comparato il VitruvianVR con un interfaccia palmare classica per il controllo delle esperienze di volo, ovvero il gamepad, andando a valutare aspetti come il senso di presenza, l'esperienza dell'utente in differenti costrutti, il malessere derivante dal visore, l'usabilità, l'accettazione, il sovraccarico mentale e la prestazione. Ciò che veniva richiesto al participante era di sottoporsi ad una esperienza in RV rappresentata da una serie di 3 prove di volo attraverso un deltaplano. Il partecipante doveva cercare di passare all'interno di più anelli possibili su un totale di 19 per scenario, nel mentre gli veniva richiesto anche di mantenere l'attenzione sull'ambiente in quanto avrebbe dovuto stare in allerta rispetto alla presenza di uccelli nell'ambiente, riportandoli al ricercatore quando venivano avvistati. I risultati hanno mostrato come il VitruvianVR influenza la percezione dell'utente rispetto all'esperienza: ne aumenta il senso di presenza percepito, l'accettazione e diversi aspetti dell'esperienza dell'utente se comparato con interfacce tradizionali di utilizzo. Inoltre, il VitruvianVR risulterebbe ridurre in maniera significativa il malessere generato dall'utilizzo dei visori. Tali risultati risultano essere generalmente in linea con altri studi condotti sugli stessi argomenti (Bektaş et al., 2021; Kitson et al., 2015; Abbas et al., 2023; Ng et al., 2020), amplificando in realtà gli effetti di percezione degli utenti e ottenendo risultati convergenti anche solo tramite l'utilizzo di misure *self-report* derivanti dalla percezione degli utenti. D'altro canto però è necessario sottolineare come il VitruvianVR richieda un carico mentale maggiore, e tale aspetto potrebbe aver impattato anche sulla performance degli utenti. Un ulteriore elemento che può aver impattato sulla prestazione può essere anche l'usabilità dello strumento che è risultata essere minore se comparato alle interfacce palmare classiche, tenendo però in considerazione anche la familiarità dei partecipanti con tali dispositivi.

Lo studio presenta ovviamente dei limiti tra cui, come citato precedentemente, l'assenza di misure fisiologiche per rilevare aspetti dell'esperienza come il senso di presenza, il malessere e il carico mentale. Inoltre, utilizzare un disegno sperimentale entro i soggetti può aver portato alla presenza di possibili effetti di apprendimento tra le varie interfacce. Ricerche future dovrebbero considerare questi aspetti inserendo all'interno del disegno sperimentale misurazioni di tipo fisiologico quali la dilatazione pupillare (Nenna et al., 2022), i movimento oculari (E. Chang et al., 2021), la variabilità della frequenza cardiaca, la conduttanza cutanea e i potenziali evento relati (Narciso et al., 2022; Riva et al., 2003); inoltre, tale disegno potrebbe sperimentale potrebbe essere sviluppato con una logica tra i soggetti, con campioni ben distinti.

Nonostante lo studio abbia prodotto risultati positivi, sarebbe necessario anche esplorare più nello specifico aspetti di usabilità dell'interfaccia in modo tale da renderla più facile da usare e abbassando i livelli richiesti di carico mentale. Tra alcuni dei suggerimenti che possono essere forniti per il raggiungimento di tale obbiettivo ritroviamo la necessità di isolare gli input che permettono la rotazione del macchinario, cercando di far corrispondere l'input motorio di movimento con l'output fornito alla vista tramite il visore. Inoltre, l'aggiunta di motori che generano una resistenza durante il movimento e che resetanno la persona alla posizione di partenza potrebbe risolvere il problema della perdita di orientamento spaziale nel mondo fisico.

Per concludere, questa tesi rispetto al campo delle interfacce *embodied* rappresenta un avanzamento nel design di interfacce di locomozione, di fatti possiamo affermare che l'utilizzo del VitruvianVR per condurre prove di volo in RV può fornire dei forti vantaggi rispetto al senso di presenza e al malessere provenienti dai visori, in aggiunta ad aspetti di esperienza in sé, se comparati con le interfacce più tradizionali. Tali risultati promettono bene in quanto possono essere d'aiuto nello sviluppo della realtà virtuale dato sì che il manipolare tali aspetti può risultare fondamentale nel ridurre la discrepanza esistente tra l'utente e la sua effettiva volontà di utilizzo della realtà virtuale (M. Zhang et al., 2022). Infine, è possibile affermare che il VitruvianVR è stato percepito anche come più utile per condurre esperienze di volo in realtà virtuale, fornendo prospettive future verso la realizzazione di veri e propri training di volo in realtà virtuale attraverso lo strumento.