Trust in Virtual Reality

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Abstract

The current era has seen unrestrained technological progress. New technologies are replacing common work practices and processes in several fields, such as industry, healthcare, and commerce. The main reasons for using these technologies is the reduction of time to develop products, increased quality of products and processes, and increases in security and communication.

This thesis focuses on Virtual Reality (VR). VR is currently replacing old systems and modifying practices and processes in fields such as automotive, healthcare, training and psychological therapies. However, when applying technologies, it is fundamental to study the interaction between the technology and the end users. This thesis takes into consideration one aspect of human-computer interaction: trust. Trust has been seen as fundamental in technologies such as e-commerce, e-marketing, autonomous systems and social networks. This is because trust has been found to be associated with the intention to use a technology, and lack of trust could deter users from adopting the technology. This concept is particularly important for VR, since it is only recently gaining widespread adoption. However, studies on users' trust in VR systems are limited in the literature and there is uncertainty regarding the factors which could influence end user trust.

This research aimed at developing a model to investigate trust in VR. The goal was to identify the factors which have a theoretical influence on trust in VR through an analysis of the literature on trust in VR and trust in technology in general. This permitted the creation of a framework with usability, technology acceptance and presence as possible predictors of trust in VR. In order to validate this framework, six user experiments were conducted. The experiments investigated the relationships among the factors identified in the literature and their influence on trust. The first study was designed to explore possible methodological issues. The next three studies, conducted in collaboration with researchers at the University of Nottingham, analysed further the relationship between usability and trust and between technology acceptance and presence with trust. The fifth experiment was conducted to specifically explore the influence of presence on trust. The last study looked at all factors, and validated the framework, demonstrating that technology acceptance and presence are predictors of trust in VR, and usability has an indirect effect on trust, as it is a strong predictor of technology acceptance. This research generated a model which includes well-studied factors in human computer interaction and human factors and could be applied to study trust in VR for different systems. This model increases the amount of information on VR, both on an academic and industrial point of view. In addition, guidelines based on the model were generated to inform the evaluation of existing VR systems and the design of new ones.

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Acronyms

- **AR**: Augmented reality
- **EDA**: Electro-Dermal Activity
- **EPM**: Extent of presence metaphor
- **EWK**: Extent of World Knowledge
- **HCI**: Human Computer Interaction
- **HF**: Human Factors
- **HMD**: Head Mounted Display
- **HRIS**: Human resources information system
- **ITC-SOPI**: ITC Sense Of Presence Inventory
- **MR**: Mixed reality
- **PI**: Place illusion
- **PQ**: Presence Questionnaire
- **PSI**: Plausibility illusion
- **RF**: Reproduction fidelity
- **S.U.S.**: Slater, Usoh and Steed questionnaire
- **SSQ**: Simulator Sickness Questionnaire
- **SUS**: System Usability Scale
- **TAM**: Technology acceptance Model
- **VA**: Virtual Assembly
- **VB**: Virtual Body
- **VE**: Virtual Environment
- **VR**: Virtual Reality

1. Introduction

1.1 Background

Studying the interaction between a person and a technology is fundamental for the correct use and adoption of the system (Corlett and Wilson, 1995; Chapter 1). In fact, there are examples in the literature of the misuse of technologies which have led to an enormous loss of money and time in best cases, and injuries and fatalities in the worst cases (For a review see: Proctor and Van Zandt, 2008; chapter 1). Human factors concerns the study of the interaction between people and technology and, among other aims, tries to improve the design of systems in order to be accepted and used properly by end users (Wilson and Sharples, 2015). The study of human factors in technology has been applied for decades and has seen promising results in the enhancement of wellbeing, performance, safety, job satisfaction, company image and the avoidance of errors (Wilson and Sharples, 2015). In this work, the focus is on Virtual Reality (VR). VR is a technology that has been rediscovered recently, thanks to a reduction in costs (Young et al.,2014) and it is currently being used in many fields, such as industry (for example: Lawson, Salanitri and Waterfield, 2016), healthcare (for a review: Ma et al., 2014), training (for example: Borsci et al., 2016) and education (for a review: de Faria et al., 2016). For example, in the automotive industry, VR is used in several processes, such as design, prototyping and ergonomic evaluation (Lawson, Salanitri and Waterfield, 2016). In all the fields where VR has been applied, the benefits of the use of this technology have been tangible. For example, VR applied to industrial processes has been seen to reduce cost and time of the development of a product, which are among the most important advantages in a competitive market (Lawson, Salanitri and Waterfield, 2016). In healthcare and training, VR has been applied thanks to its capacity to replicate real world situations and to distract the users in procedures such as pain reduction (Wismeijer and Vingerhoets, 2005), stroke rehabilitation (Lloréns et al., 2015), industrial training (Borsci et al., 2016) and surgeon training (Seymour et al, 2002).

However, in order to exploit the full potential of a technology, improve its efficacy, improve its safety and the probability that the technology will actually be used, the interaction between the user and the technology has to be taken into account. In the research conducted for this thesis, the study of trust that users have in VR systems was the primary focus. Trust has already been found to be fundamental in the interaction between a person and a technology (McKnight et al., 2011). The importance of this concept led to the introduction of a new type of trust, called "trust in technology", where the object of trust is not a person, but a system (Mayer, Davis and Shoorman, 1995; McKnight et al., 2011). Trust in technology has been studied in systems such as e-commerce and e-market, where privacy is important due to the sharing of sensitive data (such as bank details or personal information) (Ba, Whinston and Zhang, 1999; Gefen, Karahanna and Straub, 2003) or in automated systems, especially in supervisors' trust in machines they are responsible for (Muir and Moray, 1996). In these studies, it has been highlighted that trust could be one of the fundamental variables leading to the actual adoption of the technology. For example, talking about supervisors' trust in automated machines, Muir (1994) wrote: *"If we could not build automated systems that worked and could be trusted, we could not build supervisory control systems at all.*" (p.1906). Muir and Moray (1996) found that trust "determines" (p.454) the use of automated technologies. Regarding e-commerce, McKnight et al. (2002) stated that lack of trust could deter the use of e-commerce. However, even though the importance of trust has been demonstrated in various fields, the concept of trust in VR has not received the necessary attention. Trust in VR could be fundamental in the fields where VR is applied. For instance, in the design phase, which has been seen to be one of the most expensive and time-consuming processes in industry (Gomes de Sá and Zachmann, 1999) the belief that the system used is reliable and functional is critical for its correct application and to exploit the potential reduction in design cost and increase in quality that VR offers (Lawson, Salanitri and Waterfield, 2016). A lack of understanding of factors that influence trust in VR could lead to users refusing to use the technology and consequently decrease VR advantages over other technologies.

This PhD research aimed at developing a new model to investigate trust in VR. The aim was to understand if some of the factors known to enhance trust in other technologies (e.g. e-commerce, e-market, social network (Gefen, Karahanna and Straub, 2003, McKnight et al., 2002)) are also applicable to VR, and also to investigate additional factors, specific to VR systems (e.g. presence). The focus of the research was on VR in general, not a specific application. In fact, various systems (HMD, CAVE, desktop VR and flight simulator) were used. In addition, the type of environments and tasks were different in all the experiments. The model which will result from this thesis could be used to inform designers and VR experts about the main factors which will enhance trust in most VR systems. However, more in depth studies and research should be carried out for specific applications as the characteristics that each work context requires could be different and the factors could have a different weight in the development of trust. For example, some applications would require a high fidelity virtual environment and therefore may necessitate a higher sense of presence, but others may find this characteristic counterproductive. Nevertheless, the model created in this thesis offers a reference point of where to start and what aspects to consider when addressing trust in VR system design.

This was the main motivation behind the development of this PhD project. A collaboration between an academic institution, the University of Nottingham, and an industrial firm, Jaguar Land Rover, was created, in order to investigate the factors enhancing trust in VR.

1.2 Contributions

This PhD research had two contributions because of the different interests of the two partners involved in the PhD project.

1.2.1 Academic contribution

VR systems, despite being invented several decades ago, are currently receiving great attention in academia, mainly thanks to the decrease in price and increase of quality (Young et al., 2014). However, there are many aspects of the technology which lack sufficient analysis, such as trust. This PhD project was developed in order to fill this gap and identify the factors that influence trust in VR system and identify potential relationships between them.

1.2.2 Industrial Contribution

As stated in the previous section, VR is currently applied in many fields, including industry. This PhD project aimed at helping the design of new VR systems and guiding the modification of systems that are currently used. This is in order to enhance the trust end-users have in the system and, therefore, increase the likelihood that the system will be used, used properly and that the advantages VR has compared to other technology will be exploited. The model resulted from this PhD research will give guidelines to Jaguar Land Rover and other industries on how to evaluate and assess trust issue in their VR systems.

These contributions guided the creation of the aims of the project which will be explained in the next paragraph.

1.3 Aims

The aims of the project were as follows:

Aim 1: to identify the possible factors influencing trust in VR

The first step of the project was to identify the factors which have been seen to influence trust in VR derived from literature review. However, as stated before, there is a lack of studies investigating this aspect of VR systems. Therefore, it was useful to investigate, in literature, the factors which have been seen to enhance trust in other technologies and the factors which have already been seen as important for VR systems and combining the two to identify possible predictors of trust in VR.

Aim 2: to develop and validate a model of trust in VR systems

The combination of the literature on trust in other technologies and the literature on VR enabled the identification of the potential factors influencing trust. These factors were used to create a model to assess trust in VR. This PhD aimed at constructing and validating the model through a series of experiments.

Aim 3: to inform the evaluation and design of VR systems in order to enhance their trustworthiness.

As stated in the background section, this PhD project had two contributions, one academic and one for industry. The third aim referred to industry and aimed at informing the design and evaluation VR system especially for industrial applications. This was achieved through the development of guidelines on which characteristics should be considered when developing or adopting a VR system. The guidelines are generic and were based on previous literature on the factors studied in this thesis.

1.4 Research approach

The research approach taken to achieve the aims cannot be explained without reference to the literature review. Therefore, this section will present a brief explanation of the framework developed.

1.4.1 The framework

In the framework, three factors were included as influencers of trust in VR: technology acceptance, presence and usability. The framework is depicted in the image below

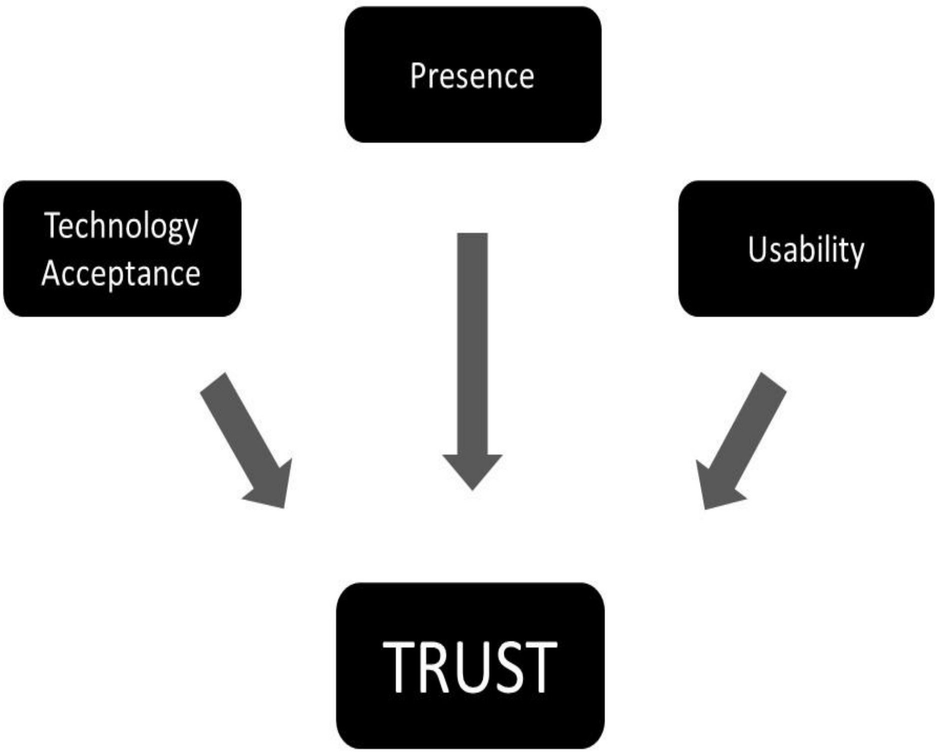

Figure 1.1 The framework to investigate trust in VR

The framework was created by combining the literature on trust in technology and the literature on VR. The results of this combination were three main factors: technology acceptance and usability, which were found to be related to trust in general technology and in other systems (Hernández-Ortega, 2011; Lippert and Swiercz, 2005), and presence, which has been seen as fundamental in the VR field (Witmer and Singer, 1998, Slater and Wilbur, 1997).

As can be seen from the image above, the framework theorises that the three factors have an equal and direct influence on trust. However, since it was the first time this framework was validated, there was the possibility that the three factors may have different impact on trust and that one, two or all the three factors may not have any effect on trust.

In order to validate the framework, empirical studies were designed to assess the relationship between the factors. This included assessing the individual factors and their relationship with trust, but also more generally an understanding of the overall nature of the model. This was particularly important in order to prioritise the series of interventions an industry could use to develop a VR system.

1.4.2 Experimental plan

In order to validate the framework described above, a series of experiments were designed in collaboration with other researchers working in the VR field. Data from six studies were used to validate the framework described above. Table 1.1 presents a summary of the six experiments with a brief explanation of the factors investigated, the aim and the methodology used.

Study	Factor(s)	Aim	Method	VR Technology
Study 1- Pilot Study	Usability/ Technology acceptance/ Presence	To investigate the reliability of the questionnaires chosen, to spot methodological and deign issues and to have a first set of data on the relationship between usability, technology acceptance and presence with trust	19 participants performing six assembly and disassembly tasks	CAVE
Study 2- Desktop VR	Usability	Investigate the relationship between usability and trust in a desktop VR	22 participants performing one task	Desktop VR
Study 3- Flight Simulator	Usability	Investigate the relationship between usability and trust in a flight simulator	8 participants performing three tasks	Flight Simulator
Study 4- Virtual Boot	Technology Acceptance/ Presence	Investigate the relationship between presence and Technology acceptance with Trust	22 participants looking at a virtual car model.	CAVE
Study 5- Presence	Presence	Investigate the relationship between presence and trust	50 participants divided in two groups, half with immersive VR and half with non-immersive VR	Head-Mounted Display and Desktop VR

Study 6-Final	Usability/ Technology acceptance/ Presence	Investigate the relationship between the three factors and trust and how the factors interact with each other.	40 participants interacting with eight different VE and performing a task	Head-Mounted Display

Table 1.1 list of all the experiments conducted, the aims and the method used.

A more detailed overview of each experiment will be given in the next section.

1.5 Thesis Overview

This paragraph will provide an overview of this thesis, with a brief explanation of each chapter.

1.5.1 Chapter 2 - Literature Review

The literature review chapter provides a description of the theories and studies taken into consideration for the development of the framework. The literature review was mostly from human factors and HCI fields, but also from computer science, psychology and engineering. In addition, the process of creating the framework is explained giving an in-depth explanation of all the factors taken into consideration and the reasons the factors were chosen depending on the previous literature.

1.5.2 Chapter 3 - Pilot Study

Chapter 3 first describes the measures used during the PhD research and then reports the pilot study designed to investigate the design, methodology and measures to be used in the subsequent experiments. The pilot study focused more on the practice of research than on the results. However, some data were collected and analysed, in order to have also the first glance at the validation of the model and the behaviour of the factors (Figure 1.2).

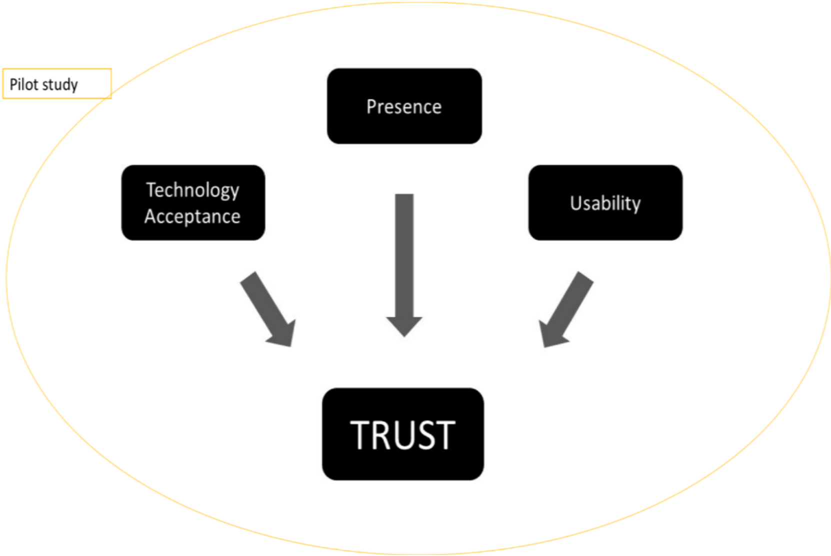

Figure 1.2 Pilot study shown on the framework of trust in VR

1.5.3 Chapter 4 - Single and paired factors studies.

Chapter 4 gives a description of the three studies where the factors were considered singularly or paired. This was to investigate the relationship between each factor (technology acceptance, usability and presence) and trust when taken alone or in pairs. The research described in this chapter is the results of three different collaborations. The first collaboration was with two different researchers, who were investigating the usability of VR systems and agreed to add the measure of trust in their experiments. Thus, two studies investigated the relationship between usability and trust. Consequentially, another collaboration was made to add measure of technology acceptance and presence in a VR experiment.

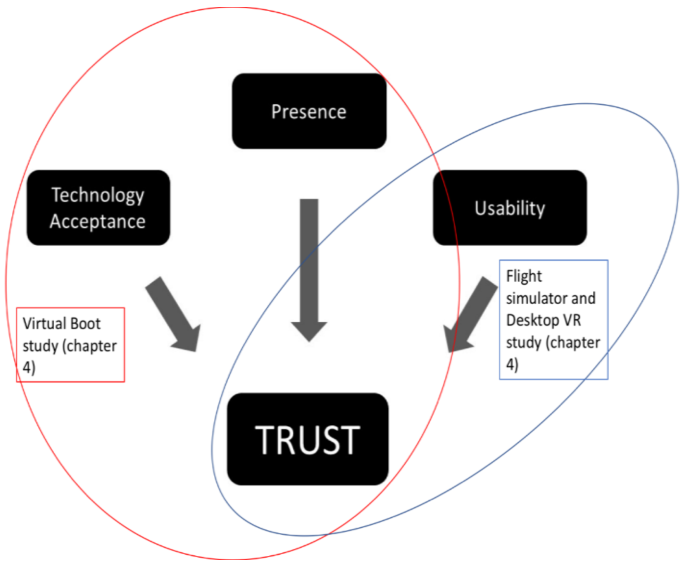

Figure 1.3 Studies 2,3,4 shown on the framework of trust in VR

1.5.4 Chapter 5 - Presence Study

Chapter 5 provides a detailed explanation of study 5, which focuses on the relationship between presence and trust.

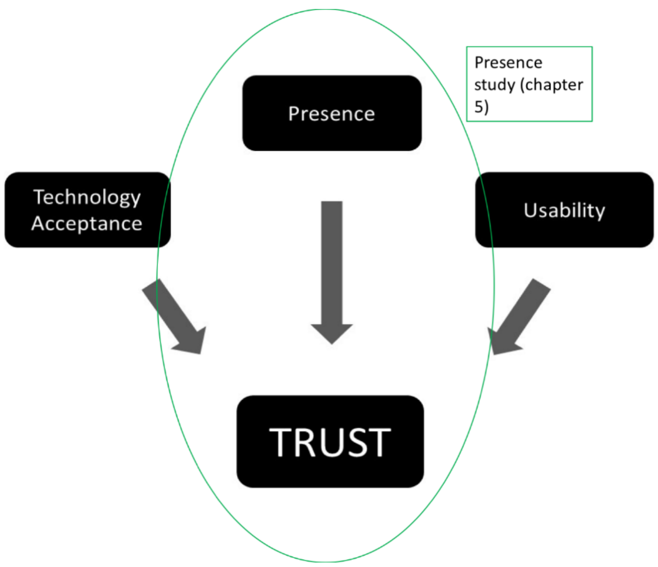

Figure 1.4 Study 5 shown on the framework of trust in VR

1.5.5 Chapter 6 – Final validation

Chapter 6 describes the last experiment conducted. The final study focused on the relationship between the three factors and trust. This study was particularly important in the plan because it not only investigated the relationship between the three factors and trust, but it also analysed the relationship within the framework. This study was the final validation of the model.

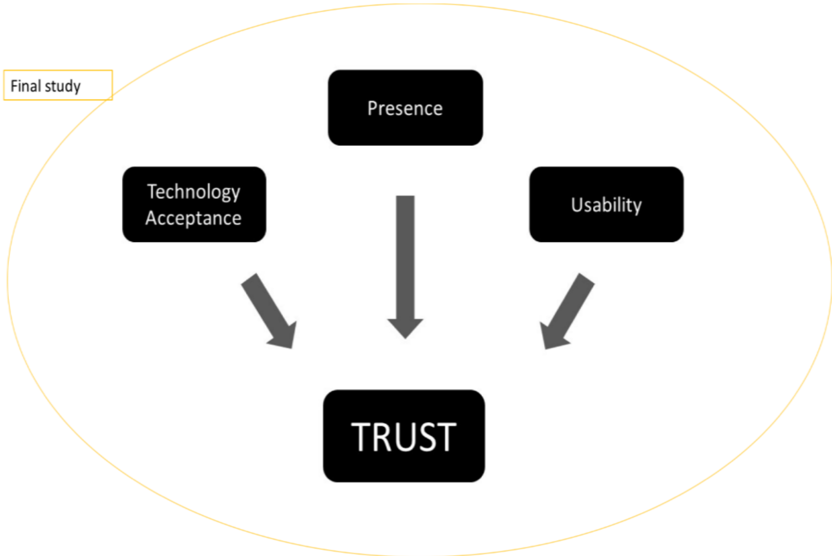

Figure 1.5 Final study shown on the framework of trust in VR

1.5.6 Chapter 7 – Discussion and Conclusion

The last chapter provides the discussion and conclusion of the PhD project. Moreover, it highlights the novelty and the achievements of the aims described in the first section of this chapter. Finally, it draws the final conclusion of the research work, including limitations and future steps.

2. Chapter 2 – Literature Review

2.1 Chapter Overview

This chapter describes the literature review that serves as a background to the experimental work conducted. The review includes the studies in the VR fields and the main factors relevant for the adoption and acceptance of this technology. Moreover, literature on trust in VR and trust in technology, was added. This identified three main factors as potential influencers of trust in VR: technology acceptance, usability and presence. In addition, the chapter describes the literature on each of the three factors and the reasons those were chosen to be included in the model to study trust. The chapter will then present a theorised framework for trust in VR.

2.2 VR

2.2.1 Definition

In one of its most used definitions, VR is a 3D virtual environment generated by a computer, where people can interact (Rheingold, 1991). This definition will also be the one chosen for this thesis. Defining VR as a 3D virtual environment, allows the inclusion of a broad range of systems, which are not the typical representation of VR systems, usually narrowed to Head-Mounted Displays (HMD) only. Coates (1992) stated: "*Virtual Reality is electronic simulations of environments experienced via head mounted eye goggles and wired clothing enabling the end user to interact in realistic three-dimensional situations.*" (In Steuer, 1992; p. 74). Greenbaum (1992) argued that: "*Virtual Reality is an alternate world filled with computer-generated images that respond to human movements. These simulated environments are usually visited with the aid of an expensive data suit which features stereophonic video* *goggles and fiber-optic data gloves.*" (In Steuer, 1992; p. 75). However, as Steuer (1992) pointed out, these definitions constrain the range of technology that could be defined as VR systems to a few sample (only HMDs). In this thesis, many systems were used in the experiments and only one respects the Coates (1992) and Greenbaum (1992) definitions, but all of them can be defined as VR systems following the Rheingold (1991) and Steuer (1992) ideas.

2.2.2 Terminology

VR is often called and defined by other names, such as virtual environments, virtual world and microworlds (Gigante, 1993), mainly to avoid the unrealistic expectations that the terms virtual reality gives (exact representation of the reality in the virtual) (Earnshaw, 2014). In this thesis, the most commonly used term will be adopted, that is VR.

It is useful to mention two other terms derived from VR: Augmented Reality (AR) and Mixed Reality (MR). MR includes all technology where real and virtual world are combined (Milgram and Kishino, 1994) which includes AR. AR is defined as a system which superimposes virtual objects on the real world (Azuma et al., 2001). Azuma and colleagues (2001) gave three main properties of AR (p.34):

- combines real and virtual objects in a real environment;
- runs interactively, and in real time;
- registers (aligns) real and virtual objects with each other.

Among the MR technologies, Milgram and Kishino (1994) also added a new term called Augmented Virtuality, that is when a completely virtual world is "augmented" with real objects. Milgram and Kishino (1994) developed a virtual continuum, from the real world to an entire virtual world. MR is whatever is in the middle, with AR being closer to the real world and augmented virtuality being closer to the virtual one. A representation of the continuum is shown in the image below.

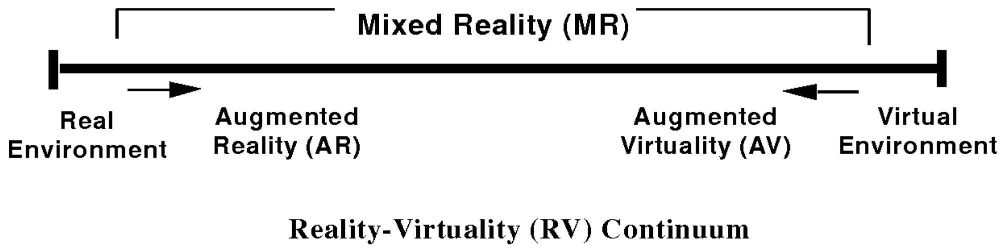

Figure 2.1 Reality continuum, from the real world to Virtual Reality (Source: Milgram and Kishino, 1999)

2.2.3 VR in industry

In the patent of one of the first VR technologies created (Sensorama), Heilig (1962) anticipated one of the major advantages of using VR in industry. The author wrote:

> *"Industry, on the other hand, is faced with a similar problem due to present day rapid rate of development of automatic machines. Here, too, it is desired to train a labor force without the accompanying risks."* (Heilig, 1962)

Even though this patent was written many years ago, it lists the major advantages that VR offers nowadays compared to other technologies: the capacity to replicate a real environment, but without the risks associated with it.

In recent years, the competitiveness of the market requires industries to implement new methods to improve the quality of products and, at the same time, reduce costs and time (Choi and Cheung, 2008). With this aim, VR has been implemented in several industry processes (Lawson, Salanitri and Waterfield, 2016) described below. The recent implementation of VR in industrial processes is mainly due to the decrease in VR cost. In fact, as Choi et al. (2015) stated, in the past, VR was only used for the design of premium products, due to the low return on investment (Choi et al., 2015). In recent years, however, the dramatic decrease of VR systems costs permitted the expansion of the use of VR in many industrial fields such as, among others, design, prototyping, manufacturing, assembly and training.

2.2.3.1 Design

Design is usually one of the most expensive and time-consuming phases of a product development (Gomes de Sá and Zachmann, 1999). It constitutes one of the biggest "bottlenecks" in the process of development, due to the cost and possible misunderstanding that, for example, building physical mock-ups could cause and the needs to revert and repeat processes several times before the final products reach the market (Fiorentino et al., 2002). Gomes de Sá and Zachmann (1999) estimated that 70% of the cost of the life cycle of a product is influenced by the decisions made in the early design stage. VR has been seen as potentially useful to solve these issues and make the process faster and more effective. Examples of how VR can help in the design process are: replacing physical mock-ups (Shao et al., 2012); avoiding the process of rebuilding a model in case of design errors (Kim et al., 2011); being used in early design stages (Lawson and Burnett, 2015); permitting 1:1 scale prototypes, which can add further information in the early phases (e.g. VR permits the users to sit in a 1:1 model of a car and see any possible visual constraint and issues in control accessibility) (Noon et al., 2012); and permitting collaborative design, where a multidisciplinary team, even based in different locations, can work together at the same time (Lehner and De Fanti, 1997; Mujber et al., 2004).

A good example of a successful application of VR in design can be found in Purschke, Shulze and Zimmermann (1998), who describe how VR was implemented at Volkswagen®. The authors described a possible issue with using Computer-Aided Design (CAD) in the design process, that is the obstacle in information flow between various department, especially the styling department. This is because the usual tools used in all the phases of design may not be suitable with the intuitive and creative work of stylists. The authors found that VR could solve this problem, providing an immersive environment and an improved human-computer interaction (Purschke, Shulze and Zimmermann, 1998)

2.2.3.2 Virtual Prototyping

The process of prototyping through VR is called virtual prototyping. Virtual prototyping is arguably the most used example of VR effectiveness in industry. This is due to the fact that in the case of prototyping VR has been seen to reduce the time and cost of the process of design, permitting the modification in real time of a model (Kulkarni et al., 2011). This avoid issues manifesting from errors in the early stages of design which are among the most common errors in design (Gomes de Sá and Zachmann, 1999).

2.2.3.3 Manufacturing and Assembly

The design of manufacturing systems in an industry were usually carried out following algorithms using operations research approaches (Vosniakos and Gogouvitis, 2015). However, this approach does not take into account fundamental factors such as ergonomics, machine collaboration and human factors. To obviate this issue, discrete simulations are used, but these do not allow the 3D representation of spaces, equipment and humans. VR has been suggested as the solution to all these issues, allowing the 3D simulation of processes such as material flow, collision risks and installation planning (digital factories, see section 2.2.3.3.1) (Vosniakos and Gogouvitis, 2015). This is particularly important as it has been seen that VR, permitting the representation of a virtual workspace, gives significant advantages in the process of design and tool implementation (Jayaram, Connacher and Lyons, 1997). In a review, Choi et al. (2015) found that VR is being applied widely to design reviews and assembly tests of products. In addition, there are studies which highlight the improvement in decision making, cost reduction (Mujber., 2004) and the enhancement of risk measures and control of manufacturing process (Lee et al., 2001).

2.2.3.3.1 Factory planning

One of the applications of VR in manufacturing concerns the process of "factory planning". Factory planning is a problem-dealing process, aiming at optimizing processes such as material flow, resource utilization and logistics. The digitalisation of factory planning is called "digital factory" (Kühn, 2006).

Menck et al. (2012), explained that factory planning is composed of six stages (for more details see Menck et al., 2012) and, even if they are consecutive in time, overlapping and parallelization are required. Moreover, the planning includes various departments working together and it has been seen that cooperation and communication are key factors for increasing efficiency and decreasing complexity (Menck et al., 2012). VR has been seen to be a technology that favourite this process, permitting the 3D simulation of the environments and the collaboration of various experts even remotely located.

2.2.3.3.2 Virtual assembly (VA)

Another aspect of virtual manufacturing is VA. This includes the possibility to perform assembly and disassembly tasks in VR. Jayaram et al. (1997), demonstrated that VA increases the product quality and decreases time-to-market, giving tangible advantages in the process of design and new tools implementations.

2.2.3.4 Training

Strictly connected with manufacturing, also the process of training has seen an adoption of VR systems. The main advantage that VR systems offers in training are the riskless situations in which workers can be trained, together with an immersive environment which has been seen to be more effective than standard training methods (Borsci et al., 2015). Stone (2001) showed that VR training improved the task completion (compared to training with real equipment) from the 50th to the 66th percentile. Borsci et al. (2015) tested the effectiveness of VR training for car maintenance against paper-based training and video training. The results showed that participants using a VR training performed better in the immediate and had better information retention after two and four weeks.

2.2.4 Influence on VR design on users' experience

As explained in the introduction section, VR has different characteristics compared to other technologies. Some of these characteristics can influence the users' experience, behaviour and perception of the systems and could be important in the development of trust. In this paragraph, five VR characteristics will be described: the "extent of world knowledge", "reproduction fidelity" and "extent of presence metaphor" (Milgram and Kishino, 1994), the "manipulation of plausibility illusion" (Slater 2009) and the "uncanny valley" (Mori, 1970).

2.2.4.1 Extent of world knowledge, reproduction fidelity and extent of presence metaphor

In section 2.2.2 of this thesis the Milgram and Kishino's (1994) real-virtual continuum was presented. However, the authors provide deeper explanation of the difference between real and virtual (and all the configurations in the middle of the continuum) adding three more possible "taxonomies for merging real and virtual worlds" (Milgram and Kishino, 1994; p.11): the "extent of world knowledge" (EWK) the "reproduction fidelity" (RF) and the "extent of presence metaphor" (EPM). The first one concerns the amount of knowledge that the computer holds about the objects being rendered (and displayed) in the VE. Figure 2.1 shows the comparison between the two continuums.

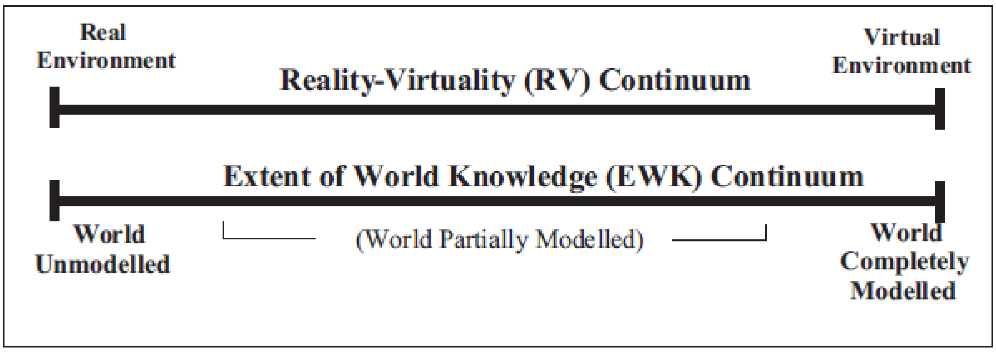

Figure 2.1 Real-virtual continuum (above) and EWK continuum. Source: Milgram and Colquhoun Jr., 1999).

By "world completely modelled" (right extreme), the authors mean that the computer knows exactly which object is being displayed and where it is being displayed. If, for example, a picture of a real-life situation was to be added to the environment, the environment would move from the right extreme of the continuum toward the middle (the position depends on the number of pictures displayed and the space taken in the VE). If a digitalised image was to be superimposed to a real-life picture the environment would lean from the middle towards the left extreme. Finally, if, for instance, the environment was a scan of a real-life image or a real-life situation itself, the environment would be in the left extreme. For what concerns this PhD work, the focus is on the right extreme of the two continuums, that is a completely virtual environment and a world completely modelled.

Another way to describe real-virtual difference is the taxonomy used by the authors for the RF. Figure 2.2, shows the RF continuum.

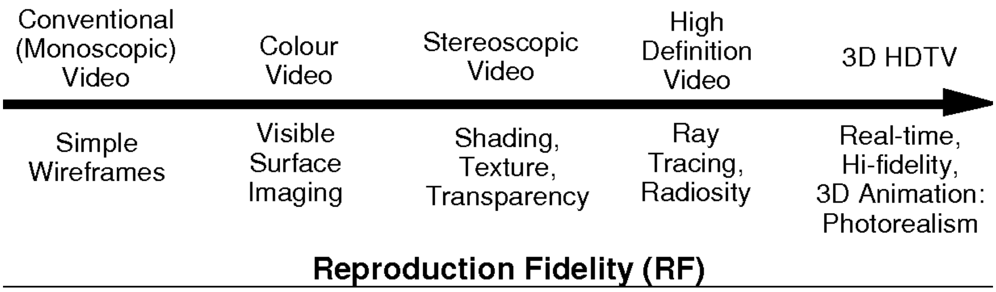

Figure 2.2 RF continuum for real objects (above) and virtual objects (below). Source: Milgram and Kishino, 1994.

This dimension has more to do with realism and specifically with the image quality (Milgram and Kishino, 1994). The goal of the authors is to switch the scope of previous taxonomies where presence (see section 2.5) is the ultimate goal. This is because, this taxonomy considers also VEs with good image quality but not aiming at making the user feel present, as well as environment with relatively poor image quality but able to immerse a person. RF applies both to the vision of real images (e.g. pictures, scan; left extreme of the EWK continuum) and virtual ones (digitalised object; right extreme of the EWK continuum). Referring to this, the authors mentioned an extremely important aspect of this continuum: "*Even though the simplest wireframe display of a virtual object and the lowest quality video image of a real object are quite distinct, the converse is not true for the upper extrema*" (Milgram and Kishino, 1994; p. 11). This means that concerning the right extreme of the continuum, the distinction between real and virtual could fade away and a digitalised image (in Figure 2.2 "Real-time, Hi-fidelity 3D animation") could be no different from a real life picture (in Figure 2.2 "3D HDTV") or even real-life objects. As the authors argued in their work, if the right extreme was to be achieved, there would be no way to distinguish between a picture or a scan image and an object virtually rendered.

The last dimension that the authors described in their paper concerns the sense of presence (see section 2.5), which is a factor included in the trust model described in this thesis. Figure 2.3 depicts the continuum.

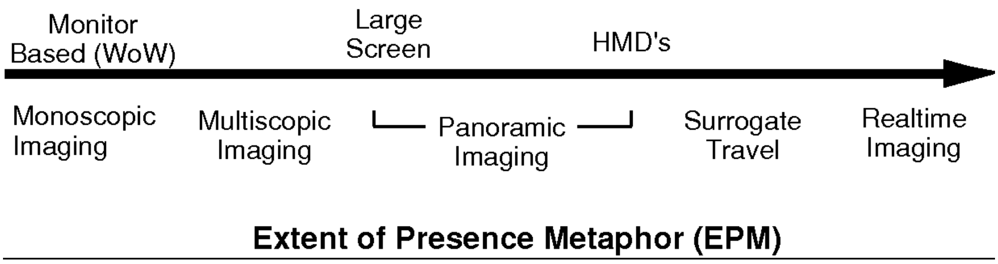

Figure 2.3 EPM continuum (below) and progress of display media (below). Source: Milgram and Kishino, 1994.

As can be seen from the figure, the continuum goes from monoscopic imaging, where the user sees the virtual world from the outside through a single view point, to a realtime imaging, where, in theory, there should be no difference between mediated reality (i.e. virtual reality) and unmediated reality (i.e. real life). The continuum progresses from the left extreme to the right, improving the immersion (i.e. being on the outside with the monoscopic imaging versus being on the inside with the rest of the systems), the view point (i.e. single view point of the monoscopic imaging versus wider field of view of the multiscopic or panoramic imaging) and capacity of movement in the VE (no movement at all with the monoscopic and multiscopic imaging versus head movement with the panoramic imaging versus full body movement with surrogate travel and realtime imaging).

The taxonomies described above are particularly important for this thesis. In particular, the RF continuum highlight that the sense of presence could strongly depend on the type of VE but also on the type of task presented. This is one of the justifications of the generalisation of the model presented in this thesis. In fact, people may trust an environment that is high quality but not immersive or an environment that is low quality but highly immersive depending on the context in which VR is used. Interestingly, the fact that, if the

EPM right extreme was to be achieved there would not be any discernible difference between real and virtual, could mean that users would feel the same sense of presence they feel in the real world. Therefore, if presence influences trust, it can be assumed that people would trust a system in the right extreme of the EPM continuum as they would trust a real-world object.

2.2.4.2 Self-avatar and plausibility illusion (PSI)

The concept of Plausibility Illusion (PSI) was introduced by Slater (2009) as one of the two dimensions composing presence. Following the author's idea, Place Illusion (PI) and PSI are two orthogonal dimensions of presence. PI correspond to the classic definition of "the sensation of being there" (for a deeper description of the presence definition(s) see section 2.5) while PSI refers to the illusion that what is happening in the VE is actually happening, even though the users know that it is not (Slater, 2009). Skarbez et al. (2017) argued that if immersion is the main factor of PI, coherence is the main factor of PSI. The authors defined coherence as *"the set of reasonable circumstances that can be demonstrated by the scenario without introducing unreasonable circumstances, and a reasonable circumstance as a state of affairs in a virtual scenario that is self-evident given prior knowledge"* (Skarbez et al., 2017; p. 1369). That is the degree of how much the VE matches the users' expectations. In the same research, the authors found that one of the most important characteristics of coherence is the representation of the users' virtual bodies (VBs). In their experiment, the researchers found that the vast majority of participants rated the presence of a VB as the most important factor for PSI.

This particular aspect is very important for this thesis as the presence of a VB (or self-avatar) has been found related to trust in shared virtual environments (SVE) (Pan and Steed, 2017), net-based collaborations (Bente et al., 2008) and robot-mediated communication (Rae, Takayama and Mutlu, 2013). Therefore, an aspect that has been found to influence presence (PSI) also influences trust. Even though the authors investigated trust users have in another avatar or actor involved in the scenario (that is more related to trust in people) it is still important and can be applied to users trust in VR systems.

In addition, Skarbez et al. (2017) also found that the second most important aspect in the perception of coherence was the appropriateness of the virtual environment to the situation presented. Participants preferred an environment matching the scenario they were in (in this case, a bar) rather than an abstract or mismatched environment. Finally, Skarbez et al. (2017) study revealed that participants gave importance to the behaviour of a virtual object (in this case a ball) when using it extensively, rather than when rarely using it or not using it at all.

If presence is a factor of trust, as hypothesised in this thesis, these aspects could be very important. Indeed, they can be considered as possible additions in a system in order to enhance presence and, therefore, trust.

2.2.4.3 The "uncanny valley"

Another VR characteristic related to user experience and trust is the phenomenon of the "uncanny valley". This concept was first described by Mori (1970) in relation to robotic appearance and movement. The author found that while it is true that familiarity increases when the human likeness increases (e.g. a humanoid robot is perceived as more familiar than an industrial robot), when an object is close to a real-life appearance but not exactly the same there is a reduction in familiarity and believability and the users can become uneasy and uncomfortable. Figure 2.4 depicts the concept of uncanny valley with some examples.

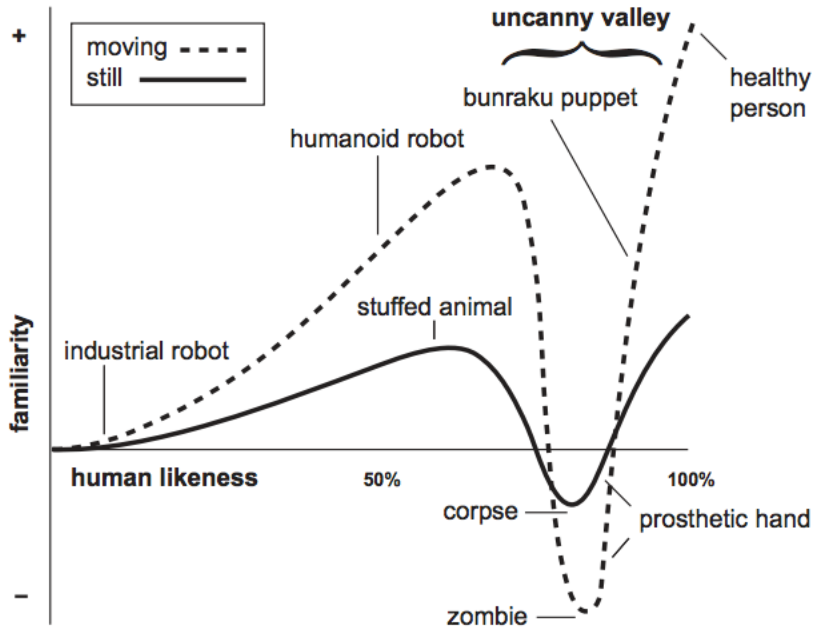

Figure 2.4 The simplified representation of the uncanny valley. Source: Mori, 1970 (translation by MacDorman and Minato).

Even though the uncanny valley was first theorised in the field of robotic, the current technological progress and the development of more realistic renderings has seen the phenomenon also in computer graphic (Bartneck et al., 2009) and VR (Vinayagamoorthy, Steed and Slater, 2005). In their review, Vinayagamoorthy, Steed and Slater (2005) found that the uncanny valley phenomenon affects the modelling of virtual characters. The authors found that the enhancement of realism and behavioural complexity is not enough to build convincing virtual characters and a much more important factor is the consistency of behavioural fidelity (Vinayagamoorthy, Steed and Slater, 2005). In their review, McMahan, Lai and Pal (2016) analysed case studies applying the uncanny valley theory to fidelity interaction in VEs (The authors defined interaction fidelity as the exactness of real-world actions reproduction in an interactive system) (McMahan, Lai and Pai, 2016) and found that mid-fidelity interaction is worse than high-fidelity interaction and even than low-fidelity interaction. Furthemore, they found that mid-fidelity is worse than high-fidelity in manipulation tasks (faster completion time of a manipulative task) and in search tasks (faster completion time of non-present targets). Mid-fidelity interaction was also worse than low-fidelity in steering tasks (faster driving time and fewer mistakes) and navigation tasks (faster travel times). According to the researchers, a possible cause of the uncanny valley phenomenon in fidelity interaction could be the familiarity of the controller. In fact, they argued that in high-fidelity interaction the controller is similar to real life, hence the familiarity is high. In the low-fidelity interaction, controllers are usually vastly used tools, such as the keyboard and mouse combination, therefore the users are already familiar with them. However, in mid-fidelity interaction the controllers are something in the middle and the users will have to adjust to them.

Even though the uncanny valley in interaction fidelity can be applied to this thesis, the phenomenon is usually explored regarding avatars in VE. Therefore, the application in this work is limited. However, the fact that the system design can influence the familiarity and believability of a VE aspect, is strongly connected to the aim of this work.

2.2.5 Conclusion

As it has been described in the previous sections, VR has been implemented in various fields within industry and has been seen as more effective and less risky than other methods. However, the issue of trust in VR has arisen in the various research, such as the uncanny valley phenomenon and the PSI. The VR characteristics described in this section showed how the design of VR systems and VE can influence the users' experience and interaction. However, some of these well-known theories only partially apply to this work. For instance, the Milgram and Kishino (1994) taxonomy is more related to AR than to VR. The manipulation of PSI and the uncanny valley are more related to the exploration of social interaction between different actors in VE and strongly refer to avatars and VBs. Therefore, there is a need for a new model for trust in VR, having trust in VR systems as the main focus.

2.3 Trust

2.3.1 Introduction

Trust is a psychological and social concept that has been investigated for many decades. Searching for a unique definition would be a hard, if not impossible, task (Hernández-Ortega, 2011). Indeed, the definition of trust depends widely on the actors included in the relationship and in the situation where trust is investigated (Husted, 1998). As Husted (1998) argued, the actors both receiving or giving trust could be very different, and, depending on the situations and the actors, trust could be also a negative concept. For example, decisions based on trust and not on strictly economic rules can lead to misallocation of capital.

Regarding the aim of this work, the concept of trust is referred to as the interaction between users and technology. Therefore, this work will not focus of the concept of trust in people, even though, for completeness, the difference between trust in people and trust in technologies will be described.

2.3.2 Definitions: Trust in people versus Trust in technologies.

Trust is a complicated and vast concept, present and fundamental in every aspect of a person's life (e.g. inter-personal, intra-personal, management, leadership). Rousseau et al. (1998) stated that trust is the willingness to rely upon another person. Mayer, Davis and Shoorman (1995) stated that trust is: *"the willingness of a party to be vulnerable to the actions of another party based on the expectation that the other will perform a particular action important to the trustor, irrespective of the ability to monitor or control that other party."* (p. 712). These two definitions, among the most used in the literature, could seem similar in the form, but are extremely different for the purpose of this work. In fact, this thesis is focused on trust in VR, which is a technology, not a person. However, the Mayer, Davis and Shoorman (1995) definition does not specify that the trustee has to be a person, using the word "party". Thus, is it possible to trust an object? The answer, unfortunately, is far from simple. There is no agreement in the literature on the answer to this question. For example, Friedman, Khan and Howe (2000) stated that *"People trust people, not technology"* (p. 36), because trust requires entities to be capable of *"experience good will, extend good will toward others, feel vulnerable, and experience betrayal"* (Ibidem), which is impossible for technologies. The authors, however, also stated that people can rely on technology (but not trust them). On the contrary, McKnight and colleagues (2011) revised the definition of trust, stating that: *"Trust situations arise when one has to make oneself vulnerable by relying on another person or object, regardless of the trust object's will or volition"* (p. 3). This definition, more similar to the Mayer, Davis and Shoorman (1995) one, clearly states that the object of trust does not have to be a person. In this work, the McKnight et al. (2011) definition will be considered. In fact, technologies are an integral part of everyday communications and connections and, therefore, it is important to understand how people interact with them. People use technologies for almost everything, such as communications, work and entertainment, and most of these actions require trust. For example, when paying online, a person trusts the system of payment (being a phone app, software, ATM…) (Luo et al., 2010).

However, even if both trust in people and trust in technology can exist, there are some differences between the two.

Lippert and Swiercz (2005), gave four differences and similarities between trust in technology and trust in people:

- There is an asymmetry between the two actors. The trust toward a system is characterised by the impossibility for the technology to trust in return.
- There are different measures to evaluate the trust toward a person or toward a system.
- Both types of trust are assessed after the interaction with the other actor.
- Both types of trust are perceptions about the object of trust.

Going deeper regarding the differences between people trust and technology trust, McKnight et al. (2011) compared the two types of trust, taking into account three characteristics: contextual condition, object of dependence and nature of the trustor’s expectations. Table 2.1 describes the differences.

	Trust in People	**Trust in Technology**
Contextual Condition	Risk, Uncertainty, Lack of total control	Risk, Uncertainty, Lack of total user control
Object of Dependence	People—in terms of moral agency and both volitional and non-volitional factors	Technologies—in terms of amoral and non-volitional factors only
Nature of the Trustor’s Expectations (regarding the Object of Dependence)	1. Do things for you in a competent way. (Ability (Mayer, Davis, & Schoorman, 1995))	1. Demonstrate possession of the needed functionality to do a required task.
	2. Are caring and considerate of you; are benevolent towards you; possess the will and moral agency to help you when needed. (Benevolence (Mayer, Davis and Shoorman, 1995))	2. Are able to provide you effective help when needed (e.g., through a help menu).
	3. Are consistent in 1.-2 above. (Predictability [McKnight, Cummings and Chervany, 1998])	3. Operate reliably or consistently without failing.

Table 2.1 Difference between trust in people and trust in technology. Source: McKnight et al., 2011

To investigate further the concept of trust[1], its characteristics and determinant will be described in the next paragraph.

[1] As stated earlier, this work will focus on the concept of trust in technology. Therefore, from now thereof, the term “trust” will refer to the concept of trust in technology

2.3.3 Characteristics of trust

Trust is a multidimensional concept (Rempel, Holmes, & Zanna, 1985; McKnight et al., 2011). A good review of the various dimensions of trust is contained in the work of McKnight et al. (2011). In this section, two studies are reviewed on the dimensions of trust: Lippert and Swiercz (2005) and McKnight et al. (2011).

Lippert and Swiercz (2005) gave three dimensions of trust: Predictability, Reliability and Utility. *Technology Predictability* is based on the individual's ability to predict that the technology will fulfil the previous expectations on performance. *Technology reliability* is based on the perception that the technology is reliable enough in a dependence situation and *technology utility* is built on the perceived usefulness of the technology.

McKnight et al. (2011) depicted a more complete picture of the dimensions of trust in a specific technology. The authors explained that trust in technology is reflected in three beliefs: functionality, helpfulness and reliability. Functionality refers to the capability of a technology to perform a specific task. Helpfulness is based on the belief that the technology will be helpful for the users and reliability refers to the perception that a technology works properly.

2.3.4 Determinants

Regarding the factors influencing trust Lippert and Swiercz (2005) depicted a model (Figure 2.5) which includes several factors.

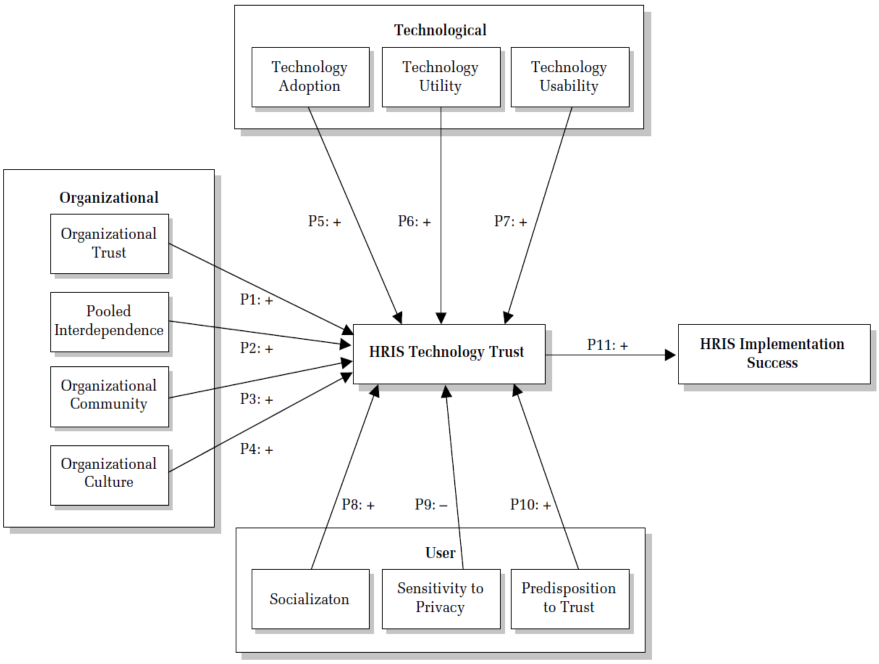

Figure 2.5 Model of trust in technology. Source: Lippert and Swiercz, 2005

As can be seen in the model, the authors divided the factors influencing trust in three categories: Technological, Organisational and User. As the name suggests, technological factors regard the characteristics of the technology used. It is divided into technology adoption, which is present when the user is constantly satisfied with the interaction with the system, technology utility, which refers to the system potential to fulfil expectations and technology usability, which is influenced by the users' experience of the system. The users' factors are divided into socialisation, that is how a new organisation member is introduced to the system, sensitivity to privacy and predisposition to trust. The organisational determinants all refer to the trust toward the company (Lippert and Swiercz, 2005). For the purpose of this work, the organisational factors and socialisation will not be taken into consideration, since the studies will not be conducted in a particular company and the systems used are not always implemented in a firm.

McKnight et al. (2011)'s model of trust explains that trust in technology is given, in general, by three factors: trust in a specific technology (functionality, reliability and helpfulness), propensity to trust and institution-based trust. *Propensity to trust* is defined as the tendency to trust technology in general. The general propensity to trust is developed regardless of the context and the technology used. This kind of trust is composed by two concepts: faith in general technology and trusting stance. The first relies on trust in the attributes of technology in general; the second is based on the beliefs that technology will develop positive outcomes. *Institution-based trust,* as McKnight et al. (2011) stated: *"focuses on the belief that success is likely because of supportive situations and structures tied to a specific context or a class of trustee"* (p. 8). The institution-based trust is composed by two factors: the situation normality, which refers to the fact that within a normal and well-defined setting, it is right to trust a new type of technology and the structural assurance, which takes into account the adequacy of the support and the infrastructure of the company. The relationship between the various attributes of trust is depicted in Figure 2.6.

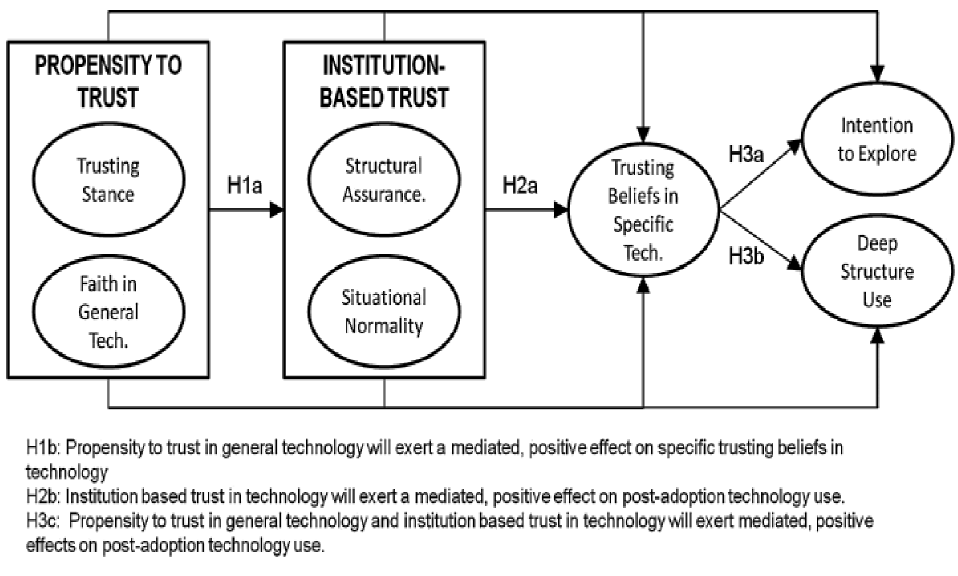

Figure 2.6. Model of trust. Source: McKnight et al., 2011

To summarise the work of McKnight and colleagues, trust is a multidimensional concept. Both users and technology characteristics can influence the final trust in the system. Propensity to trust and Institution-based trust are considered as personal factors and the level of these two types of trust is not influenced by the use of the specific technology. Propensity to trust is a calculus-based trust, with which people decide to make themselves vulnerable. In other words, to trust without previous knowledge. Institution-based trust is a knowledge-based trust, where people have enough information on, for example VR in general, to decide to trust the system. Both these types of trust are developed before the actual interaction with the technology. In this work, they will be called: *pre-interaction trust*. The trust in specific technology, instead, is developed after the use of the technology. It can be influenced also by the personal factors, but it depends on the system characteristics.

2.3.5 Trust application

Trust in technology has been seen as fundamental in several technological fields, such as e-commerce, social network, web sites and information systems. For example, Ba, Whinston and Zhang (1999) found that the enhancement of trust in e-markets (e.g. eBay) through online feedback mechanisms, could mitigate the information asymmetry (i.e. the seller has more information than the buyer), decrease perceived risk and increase the price the buyer is willing to pay. Another example of trust applied to e-commerce is given in Gefen, Karahanna and Straub (2003). The authors explained that while trust is very important in any economic interaction, due to the possibility of undesirable opportunistic behaviour, it has even more impact in online commerce. In fact, in online interactions, it is easier for the seller to take advantage of the buyer thanks to anonymity. An example of opportunistic behaviour could be: *"unfair pricing, conveying inaccurate information, violations of privacy, unauthorized use of credit card information, and unauthorized tracking of transaction"* (Gefen, Karahanna and Straub, 2003, p 55). However, trust is seen to mediate the perceived risk of opportunistic behaviour and increase the intention to use. Lankton and McKnight (2011) investigated the dimension of trust in Facebook and found that the popular social network is trusted both as a technology and a "quasi-person". Another example of trust applied to technology is the one already cited in the paragraphs above about the Human Resources Information System (HRIS) (Lipper and Swiercz, 2005) which was also studied by Ngoc Duc, Siengthai and Page (2013), who found that trust is one of the main factors influencing the decision of implementing HRIS. Another review of studies on trust in e-commerce can be found in Grabner-Krauter and Kaluscha (2003), which not only highlighted the importance of trust, but confirmed what was anticipated in the previous chapters: there is a need for a framework since the research on trust is: "*in the stage of borrowing different constructs from other theories"* (p. 803) and that there is no agreement on the determinants of trust.

It is important to note that none of the articles on trust cited above treated VR as the system studied. Even though some of the characteristics are applied in this thesis, VR is a particular technology and could have other factors influencing trust. Unfortunately, there is a lack of literature regarding trust in VR, therefore one of the steps taken in this project was to develop a framework to investigate the factors influencing trust in VR. After a review on the literature on trust in technology and on VR, the factors taken into consideration are: technology acceptance, since it has been seen already related to trust in technology (see section 2.4.3 and 2.6.5), presence, because of its importance in the VR field and usability, since it was already theorised by other authors that usability could be a determinant of trust (e.g. Lippert and Swiercz, 2005). The next sections will explain the factors in detail.

2.4 Technology acceptance.

This section will describe the first factor taken into consideration: technology acceptance. This factor has already been seen as related to trust in various studies (Gefen, Karahanna and Straub, 2003; Wu et al., 2011; Hernández-

Ortega, 2011) demonstrating its importance in the development of trust. Moreover, some of the attributes of technology acceptance are very closely related to some of the dimensions of trust, as will be demonstrated in this section.

The next sub-sections will describe the concept of technology acceptance, its main model, the Technology Acceptance Model (TAM) (Davis, 1985) the application of technology acceptance in the literature and studies on its relationship with trust.

2.4.1 The technology acceptance model

Technology acceptance has been described in the work of Davis (1985) in which the author developed the Technology Acceptance Model (TAM). Technology acceptance is fundamental in the process of implementation of a new system, since it has been seen to explain 40% of the users' intention to use the system (Venkatesh and Davis, 2000).

The technology acceptance model was built with two main aims: (1) to understand the process of acceptance of a technology and (2) to implement a new user acceptance test. According to Davis (1985) there are two main factors composing technology acceptance: perceived usefulness and perceived ease of use.

Perceived usefulness is defined as the user belief that the technology will enhance their performance. Perceived ease of use refers to the belief that the use of the technology will be effortless (Davis, 1985). Between the two factors, perceived usefulness has been seen as the most important and to have the highest impact on the intention to use the system. In fact, in the Venkatesh and Davis (2000) enhanced TAM, called TAM2, other than adding new factors, ease of use was placed also as a factor of perceived usefulness. The TAM is still the central model influencing the intention to use. However, some other factors have been added to the original model. These are listed below.

- Subjective Norms: defined as: "*person's perception that most people who are important to him think he should or should not perform the behaviour* *in question.*" (Fishbein & Ajzen, 1975, p. 302, cited in Venkatesh and Davis, 2000). There are still questions about whether this factor is significant in the landscape of TAM, since some researchers found it statistically significant and others did not (Mathieson, 1991; Taylor & Todd, 1995).

- Voluntariness and social compliance: it has been found that subjective norm is a significant factor in the mandatory situations but not in the voluntary ones (Hartwick & Barki, 1994). So, voluntariness is a variable that mediates the subjective norm influence. Thus, the authors hypothesize that subjective norms will have a positive effect on the intention to use the technology when this is mandatory.
- Image: Kelman (1958) argued that people can behave in a certain way to maintain a positive image within a group. Consequently, subjective norms influence image, and image influences the perceived usefulness.
- Cognitive processes: the cognitive processes described in the article are: job relevance, output quality, demonstrable results, and perceived ease of use.
- Job relevance: the degree to which a person perceives that the system he has to use is linked to the job he is doing. Defined as a cognitive judgement that exerts a direct influence on perceived usefulness.
- Output quality: how well a system performs a task.
- Demonstrable results: "*tangibility of the results of using the innovation"* (Moore & Benbasat, 1991, p. 203). People have more usefulness perception if the covariation between usage and positive results is easy discernible. On the contrary if an innovation produces positive results, but the user has difficulties in seeing them the perception of usefulness will decrease.
- Perceived ease of use: is the one described in the previous paragraph.

With the new factors the TAM2 is able to explain the 60% of variance of the users' final usage (Venkatesh and Davis, 2000).

Another enhancement of the TAM was performed by Venkatesh and Bala (2008). The new proposed model, called TAM3 considered the factors of perceived ease of use. The model resulted from this, is much more intricate than the original one. Figure 2.7 shows the model as depicted by Venkatesh in his work.

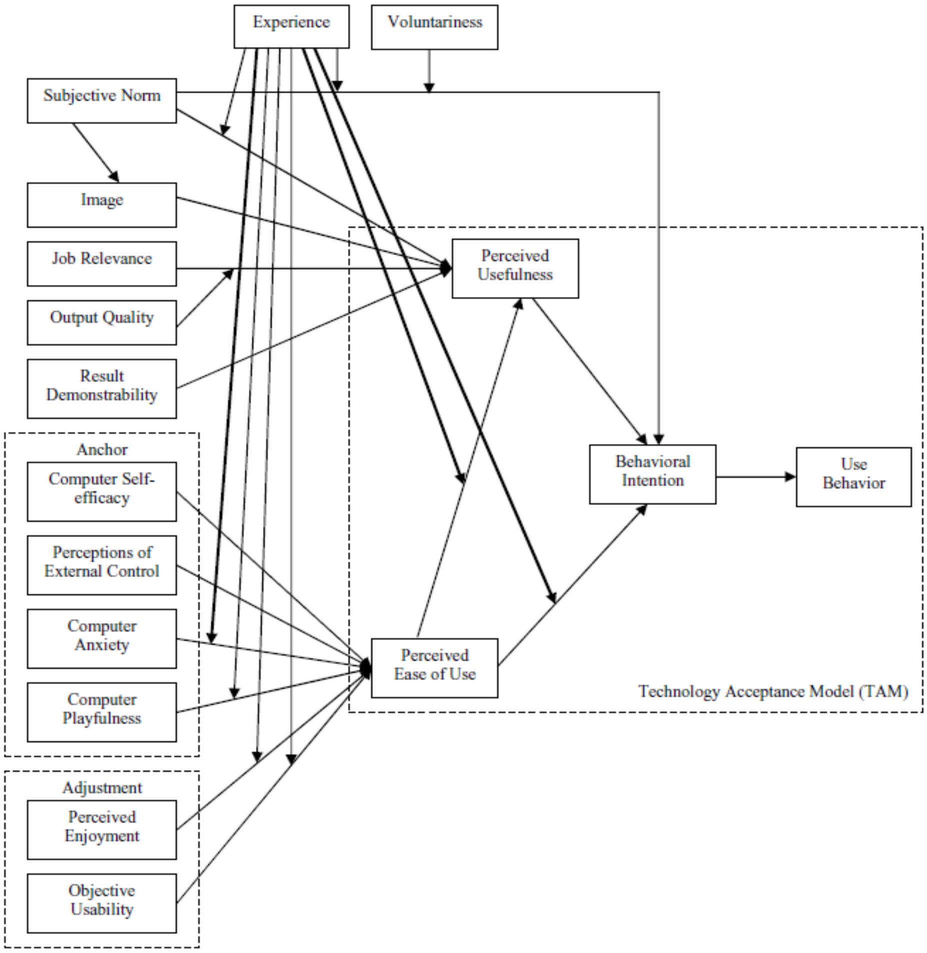

Figure 2.7 Scheme of the TAM3. Source: Venkatesh and Bala, 2008.

The factors added in TAM3 are:

- Computer self-efficacy is the users perceived ability to perform a task via computer
- Perception of external control refers to the support of the external figures in the company
- Computer anxiety is the anxiety perceived when using a computer
- Computer playfulness refers to the spontaneity in using computers
- Perceived enjoyment refers to the enjoyment the user has while using a computer, regardless of the performance in the task
- Objective usability is the perceived effort required to perform a job.

As can be seen, some of the factors in TAM2 and TAM3 are not relevant to this project, because they refer to the user environment, especially to the user company, which cannot be investigated in this research, since most of the studies will be conducted in a university environment. Therefore, those will not be taken into consideration.

Venkatesh and Bala (2008) developed a model grouping all the factors added in the various versions of the TAM. The model is depicted in Figure 2.8.

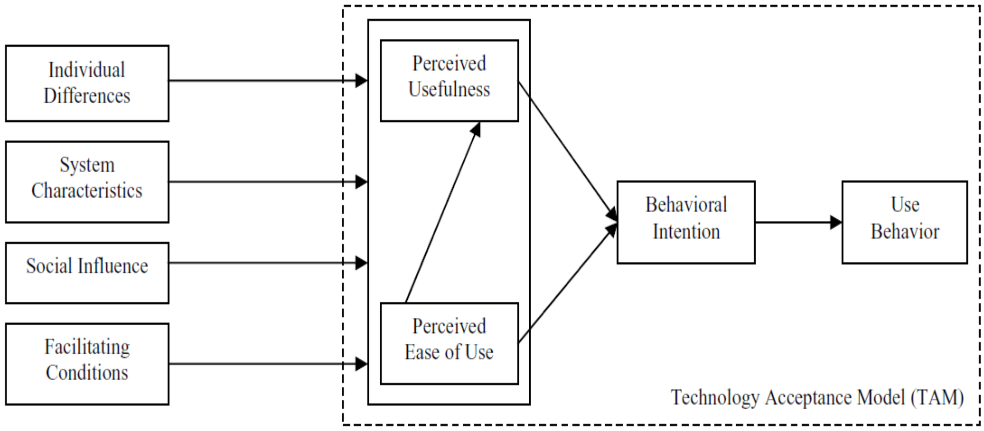

Figure 2.8 Model of TAM grouping all the factors. Source: Venkatesh and Bala, 2008

2.4.2 Technology acceptance application

The TAM has been widely applied in different fields. In a meta-analysis of the TAM application, King and He (2006) explored 88 studies where the TAM was used. There were several fields and studies gathered in four different categories: job-related, office, general (email and telecom) and Internet/e-commerce. The conclusions of the meta-analysis are listed below:

- The measures provided by the TAM are highly reliable and can be applied in various scenarios.
- There is an influence on the intention of use of some external factors, such as the experience of the users.
- The influence of perceived usefulness is stronger than the other factors.
- Students can be used as substitutes for professional users but not as substitutes for general users.

- Task applications and office applications can be studied in the same way.

Other applications of technology acceptance can be found in electronic communication (Straub, Keil and Brenner, 1997), and executive information systems (Rai and Bajwa, 1997).

2.4.3 Technology acceptance and VR

As can be assumed from section 2.4.2, whilst technology acceptance has been applied in various scenarios and for several technologies, there is not as much attention on VR applications. Only a few studies applied the TAM with VR technology. For example, Camilleri and Montebello (2011) and Fetscherin and Lattemann (2008) used the TAM to test the acceptance of a virtual world for educational and marketing purposes. However, applying the TAM to virtual world is different to applying it to VR systems. In virtual worlds, the user is often represented by an avatar in an online interaction. Bertrand and Bouchard (2008) applied the TAM to understand the users' acceptance of VR for clinical use. The authors found that technology acceptance influences the intention to use VR, but only perceived usefulness was found to have a direct influence on the final acceptance, with perceived ease of use being a perceived usefulness predictor (Bertrand and Bouchard, 2008)

2.4.4 Technology acceptance and Trust

The relationship between technology acceptance and trust has been investigated in the literature. Trust has been seen as related to technology acceptance in online purchasing (Gefen, Karahanna and Straub, 2003), online gaming (Wu et al., 2011) and e-banking (Suh and Han, 2003). In a meta-analysis on the relationship between trust and technology acceptance, Wu et al. (2011) found that trust is positively correlated with perceived usefulness, and perceived ease of use, the two main factors of the TAM. Interestingly, the authors also found correlation between trust and attitude toward a technology and behaviour intention and stated that trust, alone, is fundamental for the final adoption and use of a technology. Hernández-Ortega (2011) investigated technology acceptance as a determinant of post-use trust. The author demonstrated that perceived ease of use is one of the factors influencing trust (Hernández-Ortega, 2011).

However, the studies considered in the Wu et al. (2011) meta-analysis, and the aims of the review itself are different from those of this research. The aim of the meta-analysis was to analyse trust as a factor of the TAM. The work conducted for this PhD aims at demonstrating the opposite. Moreover, none of the studies analysed was using VR systems.

2.4.5 Why technology acceptance?

As seen in the last section, the TAM is a well-established model in the literature and has been seen as a good predictor for the final use of a technology. The decision to include technology acceptance as a possible factor of trust was taken for three main reasons, two from previous studies and definitions of the factors, and one from a conceptual point of view:

- **Technology acceptance and trust has already been seen to be relevant in various studies**. As explained in the last section, both trust and technology acceptance are seen as fundamental for the final use of the technology and were found related in various studies.
- **Perceived usefulness could be closely related to the dimensions of trust**. The concept of perceived usefulness, the most important in the construction of technology acceptance, has a very similar definition of functionality, that is one of the dimensions of trust. In fact, perceived usefulness refers to the perception that the system will enhance the performance and functionality refers to the belief that the system will be useful to perform a task.
- On a conceptual view, **it is fair to assume that if a user trusts a technology, they will probably accept it and use it.** But it is equally fair to assume that if users accept a technology, they will probably trust it and use it.

For these three reasons, technology acceptance was the first factor included in the framework to investigate the factors influencing trust in VR.

2.5 Presence

The choice of presence as a potential factor influencing trust in VR was due to the importance this concept has in the VR field. In fact, presence is one of the most studied and important factors in VR (Slater and Wilbur, 1997; Witmer and Singer, 1998). However, there is a gap in the literature relating presence to other factors, therefore the theorised relationship with trust is a relatively new line of research.

Even considering the number of studies conducted to understand presence, there is still controversy on the most important parts of this concept, such as the definition, the characteristics and the best way to measure it. This section will describe the attributes of presence, starting from the terminology and definitions, investigating the determinants and the measures and, finally, understanding its potential relation with trust.

2.5.1 Terminology

Before explaining the debate on the definition of presence, it is important to cast away some doubts on the term “presence”. In fact, the original definition, is not actually related to Virtual Reality, since the term presence refers to the perception of an environment by the users (Steuer, 1992). In real life, presence could be taken for granted. A person in an environment will perceive that environment and feel present in that environment. However, this cannot be said when the environment is shown to the person using a medium such as a VR system. In this case, will the person feel present in the real environment or the displayed environment? Minsky (1980) tried to avoid misunderstanding between presence in real life and presence in mediated environment coining the term “telepresence”. At the beginning, telepresence was used for teleoperators and it has since been applied to VR. To avoid confusion, in this thesis, the term presence will be used, in line with the most recent literature, but it will refer to the definition of telepresence, thus it will always take into consideration a mediated environment.

2.5.2 Definitions

One of the most used definitions of presence is the sensation of being in a place, while situated in another (Witmer and Singer, 1998). This means that if a VE induces enough presence, the users will believe that they actually are in the VE instead of the "real" one. Other definitions can be found in the literature. Draper, Kaber and Usher (1998) gave three definitions of presence ("telepresence" in their work): the simple telepresence, the cybernetic telepresence and the experiential telepresence. The simple definition of telepresence is the use of a computer-mediated environment. The cybernetic definition refers to the capability of a technology to replicate a real-world scenario and the experiential telepresence is a psychological state, which permit people to perceive themselves in a remote environment. The main difference between cybernetic and experiential telepresence is, as the authors stated in their paper: "*cybernetic telepresence is the projection of human capability into a computer-mediated environment; experiential telepresence is the projection of human consciousness into a computer-mediated environment*" (p. 356). As can be assumed, the experiential definition is the closest to the "sensation of being there". The experiential definition is believed to be the most important among the three by the authors. Another expansion of the definition of presence was given by Slater (2009). The author divided the concept of presence into two orthogonal concepts called PI and PSI. PI correspond to the sensation of being there. That is the classic definition. PSI is the illusion that what it is happening in the virtual world, is actually happening. There are different factors influencing the two concepts. These will be discussed in the next section.

As can be seen, the definition of presence is not unique, even if most of the authors agree that "the sensation of being there" defines all (Steuer, 1992; Witmer and Singer, 1998) or part (Draper, Kuber and Usher, 1998; Slater 2009) of presence. However, it can be deducted from all the definitions that presence is, at least in part, a psychological factor. In fact, in all the definitions, terms that are usually referred to the individual are used (e.g. "sensation", "illusion", "consciousness"). Being a psychological and individual concept, are the determinants of presence also individual? Or are they triggered by the technology?

2.5.3 Determinants of presence

As for the definition, the determinants of presence are also not commonly agreed by all the authors (Lessiter et al., 2001). As Lessiter and colleagues (2001) explained in their work, there are two main categories of determinants: user characteristics and media characteristics. As the names suggest, the user characteristics are individual attributes influencing presence and media characteristics belong to the technology itself. Moreover, media characteristics are divided into media form and media content, the first one referring to the actual attribute of the system and the second to the content of the VR environment. Figure 2.9 clarifies the Lessiter and colleagues' (2001) model of the determinants of presence.

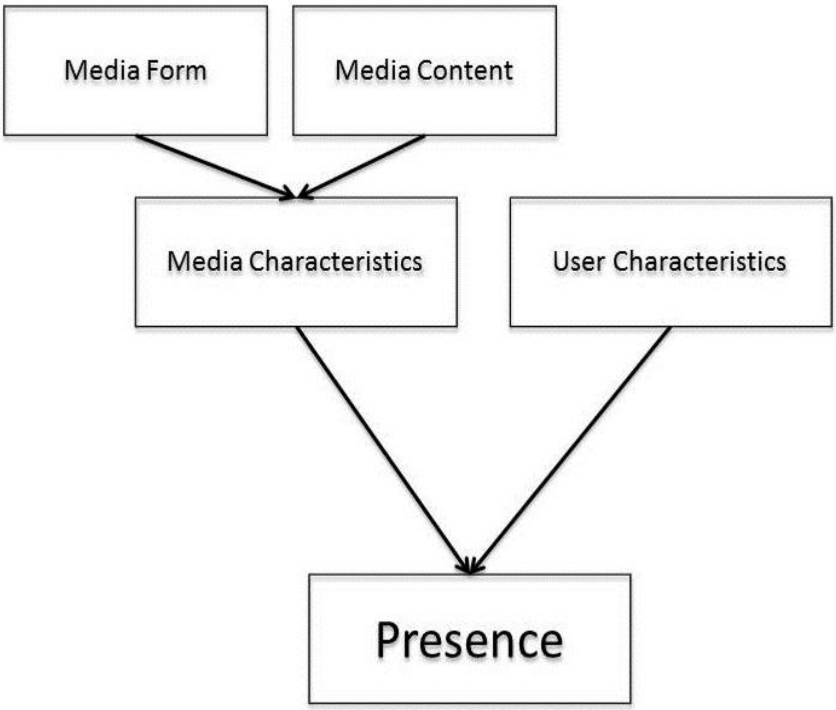

Figure 2.9 Determinants of presence following Lessiter et al. (2001) work.

One of the most commonly mentioned determinants of presence is immersion. However, even though it is commonly associated with presence, there is no agreement among researchers on the nature of immersion. Some authors treat immersion as an individual factor (Witmer and Singer, 1998) and others treat it as a system characteristic (Slater and Wilbur, 1997). Witmer and Singer (1998) define immersion as a "*A psychological state characterized by perceiving oneself to be enveloped by, included in, and interacting with an environment that provides a continuous stream of stimuli and experiences"* (p. 227), while Slater and Wilbur (1997) define it as "*a description of a technology, and describes the extent to which the computer displays are capable of delivering an inclusive, extensive, surrounding and vivid illusion of reality to the senses of a human participant*" (p. 604). However, despite thinking of immersion as an individual attribute, Witmer and Singer (1998) stated that factors which influence immersion are also technological. For example, a system blocking the users' perception of the real environment would enhance immersion compared to a normal display. Slater and Wilbur (1997), on the other hand, argued that a system is considered immersive if it is: inclusive, thus capable of blocking physical reality, extensive, thus able to involve more senses, surrounding, thus permitting a wide field of view and vivid, thus with a good resolution, fidelity and variety of energy simulated. Slater and Wilbur (1997) think of presence as an "increasing function of immersion".

Witmer and Singer (1998) added another factor influencing presence: involvement. As presence and immersion, involvement is also defined as an individual attribute. Precisely, involvement is a psychological state experienced when an individual is able to focus on a particular set of stimuli. Involvement is, together with immersion, a fundamental characteristic of presence. To make an example of the differences between the concepts of immersion and involvement, a HMD displaying a meaningless environment has high immersion but low involvement. On the contrary, a desktop VR displaying a very engaging scenario has low immersion and high involvement. To make a comparison between the research of Witmer and Singer (1998) and Lessiter et al. (2001), immersion is related to the media form, while involvement is more related to the media content.

2.5.4 Importance of presence

As can be deducted from the last sections, presence is one of the most important factors of VR and, yet, one of the most controversial. Indeed, there is no agreement on the terminology, the definition and the factors. However, some attributes of presence are recognised by the majority of the authors in this field:

- It is important. Slater and Wilbur (1997) gave two main reasons why presence should be studied: because it is the distinctive trait of VR compared to other technologies and because the higher the sense of presence, the higher the possibility for the users to behave in the same way in the virtual environment as they do in real life. This could be particularly important in training or job-related applications of VR.
- It is multidimensional. Presence is both a user and technology characteristic (Lessiter et al., 2001).
- It is multifactorial. Being multidimensional, both system and individual characteristics influence presence (Lessiter et al., 2001).

This work does not aim to analyse presence in depth, thus, the studies will not focus to answer the many questions on presence. However, some of the data could improve knowledge of presence and some aspect of it.

2.5.5 Presence and trust

The relationship between presence and trust was mentioned in section 2.2.4. However, most of studies where the relationship between presence and trust was investigated, referred to trust in VEs and trust in virtual actors inside the VEs. For example, some studies investigated the role of social presence in trust in virtual world (Teoh and Cyril, 2008; Shin and Shin, 2011).

Even though these types of trust are different from trust in the actual systems, they can influence the users' perceived trust.

2.5.6 Why Presence?

As mentioned in the introduction of this chapter, the choice of investigating the relationship between presence and trust is relatively new in the literature, therefore, the reasons for considering presence are not related to previous studies but refers to its importance for the success of VR products (Slater and Wilbur, 1997). However, as described in section 2.2.4, the design of a VE can strongly influence the users experience and trust (e.g. the uncanny valley, manipulation of plausibility and the VE coherence). Furthermore, it can be assumed that if the sense of presence enhances the sensation of being in a real environment and make the individuals behave like they would do in the real world (Slater, 2009), it can influence the trust people have in the system.

2.6 Usability

Usability is a well-studied concept in Human Computer Interaction (HCI) and Human Factors and its evaluation is useful to understand the users' needs and whether the technology satisfies those needs (Bevan, 2009).

The choice of usability was made following studies in the literature on the relationship between usability and trust (Roy, Dewitt and Aubert, 2001; Bevan, 2009) and the fact that usability was included as a factor on trust in some previous studies (Lippert and Swiercz, 2005)

2.6.1 Definition

The definition of usability has seen a development through the years. In 1991, Bevan, Kirakowsky and Maissel gave a series of definitions depending on the meaning authors attributed to usability. There are four views: product-oriented, user-oriented, user performance-oriented and contextually-oriented. In the product-oriented definition, the focus is on the ergonomics characteristics of the product. User-oriented refers to user characteristics, such as mental effort. User performance-oriented is focused on the interaction between user and product, with attributes such as ease of use and acceptability. The contextually-oriented definition complements all the previous ones and states that usability depends on the specific contexts, users, tasks and environments in which it is being measured (Bevan, Kirakowsky and Maissel, 1991).

However, few definitions refer to only one of the above orientations, most of them are actually a product of more of them, or focus on a particular aspect. For example, one of the first, the International Organization for Standardization (ISO) definition is: *"set of attributes of software which bear on the effort needed for use and on the individual assessment of such use"* (ISO, 1991 in Bevan, 2009) that is both product and user-oriented. Eason, 1998 (in Bevan, 1991) defined usability as "the degree to which users are able to use the system with the skills, knowledge, stereotypes and experience they can bring to bear" (p. 20) that is ease-of-use oriented. Brooke et al. 1990 define usability as: *"the effectiveness, efficiency and satisfaction with which specified users can achieve specified goals in a particular environment"* that is user and context-oriented. However, one of the most inclusive definitions of usability was given by Bevan and colleagues in 1991, defining usability as *"the ease of use and acceptability of a system or product for a particular class of users carrying out specific tasks in a specific environment; where 'ease of use' affects user performance and satisfaction, and 'acceptability' affects whether or not the product is used"* (p. 652*).* In the ISO/IEC CD 25010.3, usability is described as a characteristic of quality in use, defined as the user perspective of the quality of a product (Bevan, 1999), together with safety and flexibility (Bevan, 2009). Figure 2.10 summarises the various characteristics of quality in use.

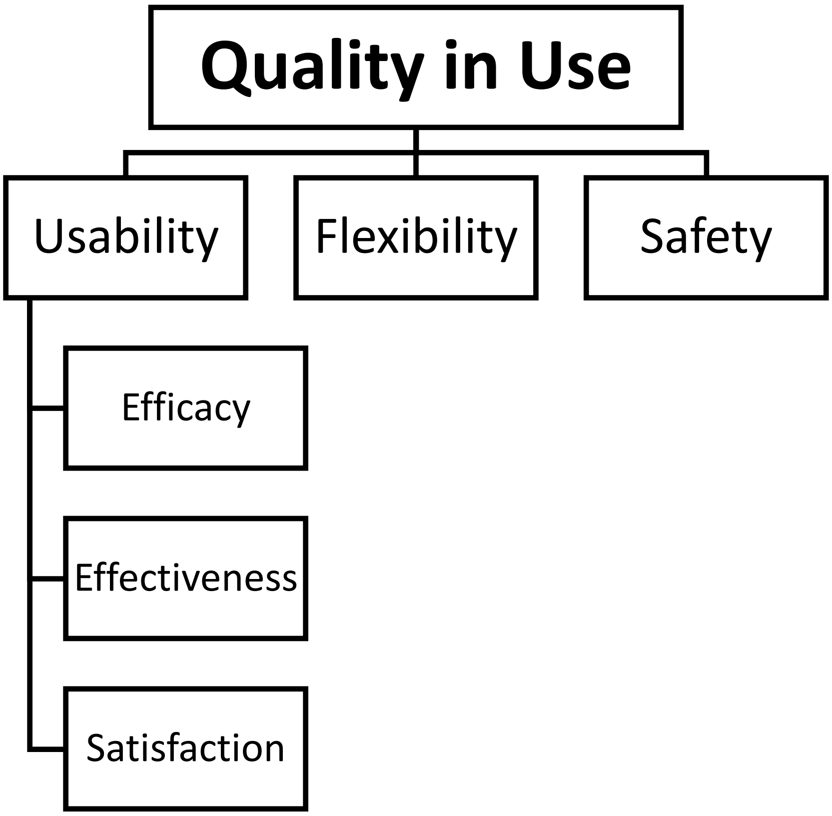

Figure 2.10 Model of quality in use

2.6.2 Dimension of usability

The dimensions of usability are well determined in the Brooke et al. (1990) definition: efficiency, effectiveness and satisfaction. Efficiency refers to the capability of the user to solve a task using the system; effectiveness refers to the effort the users have to invest in performing the task, and satisfaction refers to the perceived comfort in using the system (ISO 9241-11, 1998, in Bevan, 2009). However, the definition of satisfaction was expanded in ISO/IEC CD 25010.3. In fact, as Hassenzahl (2001) pointed out, the former satisfaction definition (and measure) related more to the efficiency and effectiveness of the system. Therefore, the new definition of satisfaction includes, not only the "pragmatic" attribute of the user experience, which is already included in efficiency and effectiveness, but also the hedonic user goals. Thus, Bevan (2009) gave a series of attributes of satisfaction. The pragmatic goals are likability, (the level of satisfaction the user has for the performance of pragmatic goals) and trust (the ability of the system to behave as expected) (ISO/IEC CD 25010.3 in Bevan, 2009). The hedonic goals are stimulation, referring to the increase of knowledge and skills, identification, referring to self-expression, evocation, referring to self-maintenance (Hassenzahl, 2001), pleasure, that is the degree of satisfaction of the user of the hedonic goals and comfort, that is the physical satisfaction (Bevan, 2009).

2.6.3 Determinants of usability.

Bevan (2001) gave two main determinants of usability: ease of use and acceptability. Ease of use determines if a system is actually usable and acceptability determines if the system will actually be used. The ease of use is determined by systems attribute such as interface quality, nature of functionality, system efficiency and reliability. Figure 2.11 depicts the model in Bevan (1991).

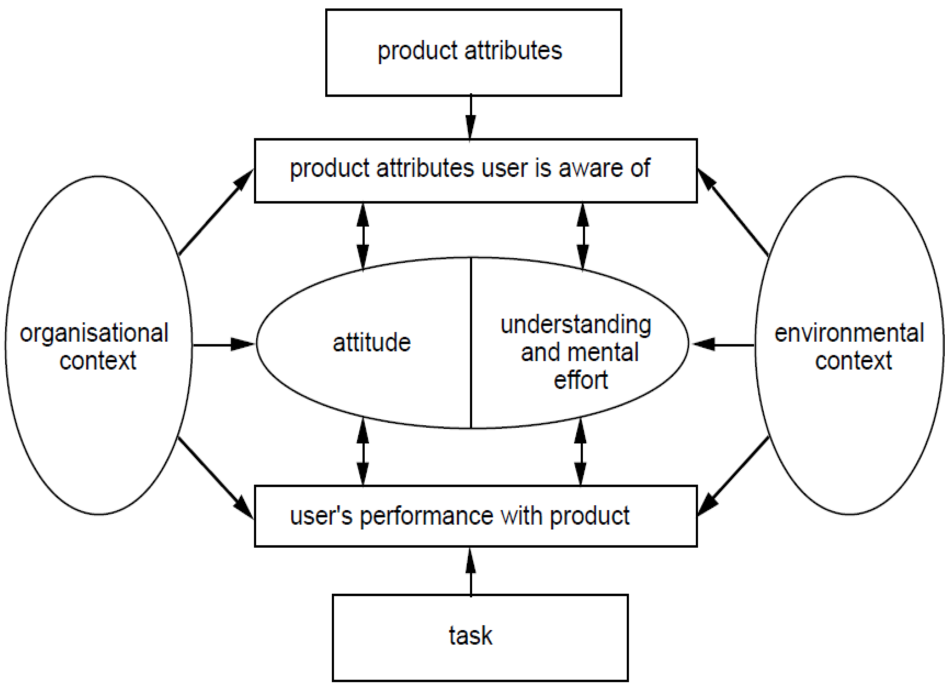

Figure 2.11 Determinants of usability. Source: Bevan, 1991

2.6.4 Application of usability

The applications of usability are spread in all fields of human computer interaction. Among the fields where usability is measured are websites (e.g. Palmer 2002; Brinck and Hoffer 2002) and mobile applications (e.g. Zhang and

Adipat, 2005; Kaikkonen et al., 2005), but usability is investigated in several sectors, including the building industries (e.g. Alexander, 2006), automotive (e.g. Green, 1999), and aviation (e.g. Kaber, Riley and Tan, 2002).

Usability has also been measured in VR systems with different purposes, such as education (e.g. Virvou and Katsionis, 2008), medic rehabilitation (e.g. Cameirão et al., 2010), navigation (e.g. Santos et al., 2009) and training (e.g. Borsci et al., 2016).

2.6.5 Usability and Trust

Roy, Dewitt and Aubert (2001) investigated the relationship between usability and trust in web retailers. The authors found a strong influence of usability of web interface on the perceived trustworthiness of the supplier. However, this study differs from the aim of this thesis for two main reasons: the first is that the authors investigated a different type of trust, that is trust in a supplier, which is more similar to trust in people than to trust in technology. The second reason is that the researchers used a web page, which is very different from a VR system due to the other types of factors that may influence the relationship (such as presence).

2.6.6 Why usability?

However, there are many reasons why, in this thesis, it is theorised that usability may influence trust. First of all, Lippert and Swiercz (2005) included system usability as one of the possible determinants of trust. Secondly, some of the dimension of usability can easily be considered as dimensions of trust. For example, as written in the previous paragraph: *"The ease of use is determined by systems attribute such as interface quality, nature of functionality, system efficiency and reliability"*. It is important to note that functionality and reliability are actually two dimensions of trust in technology (McKnight et al., 2011) as explained in the previous section of this chapter.

Bevan (2009) included trust as one of the possible dimensions of usability, mainly regarding satisfaction. However, this is a different type of trust, strongly related to privacy (mostly data security) and, thus, not applicable to VR systems studied in this project.

This work is, therefore, pioneering in the investigation of the relationship between usability and trust in VR systems. Usability is the last factor theorised to have an influence on trust.

2.7 Chapter Conclusion

Trust is a fundamental factor in the interaction between the users and the technology. However, even if trust has been investigated for some types of systems, such as e-commerce (Ba, Whinston and Zhang, 1999), e-market and online retailers (Gefen, Karahanna and Straub, 2003), there is a lack of literature concerning VR systems. Therefore, a framework has been developed, which aims to investigate the determinants of trust in VR. The framework theorises that there are three main factors influencing trust: technology acceptance, presence and usability.

Technology acceptance is a well-known concept in human computer interaction and, as trust, has been seen related to intention to use a system (Davis, 1985). Even if some studies investigated the relationship between technology acceptance and trust (Hernández-Ortega, 2011; Wu et al., 2011), most of them focused on the influence trust has on technology and not the contrary. Moreover, some of the dimensions of technology acceptance, such as perceived usefulness, are very similar to some dimensions of trust, such as functionality.

The second factor is presence. Presence is an omnipresent factor in the VR field and, even though there is no agreement on some of its characteristics, it has been deeply studied (Witmer and Singer, 1998; Slater and Wilbur, 1997). Unfortunately, there is a lack of research regarding the relationship between presence and trust. Some authors investigated how presence can enhance trust in virtual worlds (Teoh and Cyril, 2008; Shin and Shin, 2011) and how changes in the VE influence users trust behaviour (Pan and Steed, 2017). Furthermore, conceptually, it can be assumed that if the users are able to behave in the virtual environment as they do in the real world, this can enhance the perceived trust in the system to be functional for the task to be performed.

The third factor is usability. Usability is one of the most studied concepts in human computer interaction and it is considered one of the most important influencers of the actual use of a system (Bevan, 2009). However, even if some studies analysed the relationship between usability and trust (Roy, Dewitt and Aubert, 2001), most of them are focused on trust connected to perception of privacy and security, due to the fact that most of the usability studies have web-based technologies as the object of study (e.g. e-market, web retailers). Nonetheless, trust is considered an important part of satisfaction that is one of the dimension of usability and efficiency and effectiveness, which are two technological dimensions of usability, can be seen to be related to functionality and reliability, which are two dimensions of trust.

It is important to note that apart from presence, some dimensions of usability, technology acceptance and trust are very similar. Consequently, it can be assumed that there will be a strong correlation among these three concepts and some indirect relationships can be found among them.

The next chapters describe the experiments conducted to validate the model.

3. Chapter 3 – Research method and pilot study

3.1 Chapter Overview

This chapter first gives an overview of the measures used in the PhD research, then describes the first experiment designed to validate the framework described in chapter 2. The study was conducted at the Jaguar Land Rover CAVE and had three main aims: first to understand if the questionnaires selected after the literature review were suitable to be used with VR systems, second to have the first set of data on the relationship between usability, technology acceptance, presence and trust in VR and, finally, to identify possible methodological problems before progressing with larger studies. The experiment was designed as a between-subjects study and involved 19 JLR staff members. The results of the study demonstrated the reliability of the questionnaire to be used for VR systems and showed that there is a relationship between technology acceptance and usability with trust. No significant relationship was found between presence and trust.

3.2 Measures

During the PhD research, several questionnaires were used to assess the level of each factor studied. As a rule, only previously validated questionnaires were used, in order to be certain that no measurement issues could influence the results. However, most of the questionnaires used had limited previous use in VR. Thus, reliability analyses were included in the pilot study. In addition to questionnaires, physiological measures were used in one of the experiments.

The following paragraphs describe the measures used for each factor.

3.2.1 Trust and Pre-interaction trust

Regarding trust, a questionnaire on trust in technology was used for all the experiments. The questionnaire (see appendix A1.4 for the questionnaire on trust and A1.6 for the questionnaire on pre-interaction trust) was developed by McKnight et al. (2011) and aimed at investigating trust in a specific technology. This questionnaire, however, is not specific for VR systems. Indeed, in the questionnaire that can be found in the appendix of the McKnight et al. (2011) paper, the subject is a software program. Therefore, the name of the program was changed to "VR products" when the subject was general or to the specific VR system (e.g. "The CAVE" or "The system") when the subject was specific.

The questionnaire was divided in two, one part was given to the participants before the actual interaction with the system and the second was given after the interaction. This was decided because of the nature of the factors investigated. The questions investigating propensity to trust and institution-based trust were used as pre-interaction questionnaires, while the questions on trust in a specific technology were given after the interaction. This is because the first set of questions investigate trust in general technology or in VR systems in general and refer to the opinion of the user before the actual use of the specific system. The second set of questions, on the other hand, refer specifically to the system used, therefore the user needed to have an experience of the system before they could answer this.

In the desktop-VR and flight Simulator studies (chapter 4), the questions referring to helpfulness, which was not applicable for the nature of the experiment, were not taken into account.

3.2.2 Technology acceptance

To measure the level of acceptance of the technology, a mix of two validated questionnaires was used. The first questionnaire, developed by Venkatesh and Davis (2000) is composed of 26 questions, analysing all the factors included in the TAM2 described in the previous chapter (intention to use, perceived usefulness, perceived ease of use, subjective norm, voluntariness, image, job relevance, output quality and results demonstrability). Ten questions were then added to this questionnaire, taken from a questionnaire used by Hernández-Ortega (2011) concerning the concepts of performance, perceived compatibility and continuity of intention.

The entire questionnaire was used in the pilot study. However, after the results of this experiment, the questionnaire was modified and reduced to 19 questions. In particular, the questions on subjective norms, voluntariness, job relevance, output quality and results demonstrability were deleted as they were not applicable to the studies. In fact, the participants of the experiments were recruited from students and staff at the university; hence, the questions regarding the work practice were not applicable. Both the questionnaires (the original version and the modified one) can be found in appendix (A1.1.1 for the entire questionnaire and A1.1.2 for the adapted questionnaire).

3.2.3 Usability

To assess the level of usability the System Usability Scale (SUS) was used. The SUS questionnaire was developed by Brooke (1996) as a broad measure that could be used to investigate the level of usability in different context. The questionnaire is widely used (Brooke, 2013) in the HCI field and in industry, especially for its high reliability, its low-cost (the questionnaire was actually made free by the author) and its brevity.

The questionnaire is composed of 10 different questions, 5 positive and 5 negative. In this research, the SUS was used as it is without any modification and can be found in the appendix (A1.2).

3.2.4 Presence

The issue of measuring presence was discussed in the previous chapter. Unfortunately, there is no agreement on a questionnaire that is able to investigate presence and even on the usefulness of questionnaires at all (Slater, 2004). Therefore, measuring presence in this project was a more challenging task than measuring the other two factors.

In the pilot study, the ITC-Sense of presence inventory (Lessiter et al., 2001) was used. The questionnaire is composed of 44 questions divided in two parts. The first part, composed of six questions, refers to the thoughts and feelings of the participants immediately after the interaction, while the second part, composed of 38 questions, refers to the participants' experiences during the interaction. The questionnaire assesses four different factors, believed to be the determinants of presence: sense of physical space, engagement, ecological validity and negative effects. The authors argued that the questionnaire should not be analysed as a whole, to assess the general presence level, but the four factors should be analysed separately (Lessiter et al., 2001). Due to this characteristic and the length of the questionnaire, the decision to use other measures was made after the pilot study. The questionnaire is included in the appendix (A1.3.1)

In order to overcome the issues previously described, another questionnaire was used for the remaining experiments analysing presence. For the virtual boot experiment, described in chapter 5, the Witmer and Singer (1998) Presence Questionnaire (PQ) was used (Appendix 1.3.3). The questionnaire is one of the most known in the field of presence and is composed of 32 questions, analysing four factors: control factors, sensory factors, distraction factors and realism factors. The PQ complete questionnaire was used in the presence experiment, described in chapter 6 while a shorter version composed by 14 questions was used for the boot study (chapter 4) and the final study (chapter 6) (Appendix 1.3.2).

In the presence experiment, since it aimed at investigating only the relationship between presence and trust, additional measures were implemented to provide a more complete picture of the level of presence. Indeed, as was argued in the literature chapter and in the first part of this section, it is still uncertain which measures better assess presence. Therefore, another questionnaire was also used: the Slater, Usoh and Steed (1994) (S.U.S.) presence questionnaire composed by 7 questions (Appendix 1.3.4). Moreover, a physiological measure was added. The physiological measure used was the Electro-Dermal Activity (EDA), believed to be one of the most reliable measures (Wiederhold et al., 2001; Meehan et al., 2002). The instrument used to measure physiological activity was the Empatica® E4 wristband.

3.2.5 Cybersickness

Cybersickness is a possible side effect of using VR products (Cobb et al., 1999). It was important, both for the project and for ethical reasons, to assess the level of cybersickness of the participants during the interaction with VR systems. Therefore, the Simulation Symptoms Questionnaire (SSQ) (Kennedy et al., 1993) was used (Appendix 1.5). The questionnaire is composed of 16 questions on different types of side effect, such as visual (e.g. blurred vision), physical (e.g. Nausea) and motion (e.g. vertigo).

It is important to note that participants were free to interrupt the experiments for any reasons, especially for VR side effects. The participants suffering from cybersickness were attended by the researcher until they were confident the symptoms subsided.

3.3 Data analysis

In the experiments described in the following chapters four statistics were used. In order to perform analyses on these statistics, assumptions have to be respected. This section will give details on the assumptions that were investigated prior to performing the main statistical analyses. In the study chapters, the assumptions will not be mentioned unless one or more of them were violated. In this case, the method to modify the data will be described.
All the statistics were performed using IBM® SPSS 24. The Laerd® Statistics website[2] was used as a reference for the data analysis process.

3.3.1 Regressions

3.3.1.1 Single regressions

For single regressions four main assumptions were investigated. The assumption of linearity between the dependent and independent variables,

[2] https://statistics.laerd.com/premium/index.php

was assessed through a visual inspection of an independent variable/ dependent variable scatter-dot plot. The second assumption is the one of homoscedasticity, which states that the variance of residuals is constant across all the values of the independent variable. This assumption was assessed through a visual inspection of standardized residual values versus standardized predicted values scatter-dot plot. The third assumption was the absence of outliers. The presence of outliers was checked with a casewise diagnostic statistic, which identified all the cases where the standardized residual was greater than +/- 3. In case one or more outliers were present, a comparison between the regression with and without the outlier(s) was made and only if the outlier was uninfluential the case was included in the analysis. On the contrary, the case was eliminated from the regression. The last assumption was the normal distribution of residual. This was checked through visual inspection of an Instagram of standardised residual and a Normal P-P plot.

3.3.1.2 Multiple regressions

For multiple regressions five assumptions were investigated. The assumptions of linearity, homoscedasticity and normality have already been explained in the previous paragraph and were assessed in the same way for multiple regressions. The only difference is that the assumption of linearity was checked between the dependent variable and each of the independent variable and collectively through a scatter-dot plot of studentised residual vs unstandardized predicted values. Another assumption of multiple regression was the absence of multicollinearity. In other words, the independent variables should not be highly correlated. The assumption was assessed with the tolerance value. A tolerance value higher 0.1 was accepted as absence of collinearity. The fifth assumption was the absence of outliers, high leverage points and high influential points. The outliers were assessed using the casewise diagnostic method (described in the last section, section 3.3.1.1). High leverage points were assessed with an inspection of the leverage values. Any leverage value higher than 0.3 required more investigation and a value higher than 0.5 was considered as “dangerous”. Influential points were investigated with an inspection of the Cook’s distance values. Any value higher than 1 was considered highly influential. In case of outliers, high leverage or high influential points, the multiple regression was performed with and without these values and then compared. If the results substantially differed (e.g. different significance) the cases were eliminated.

3.3.2 Differences between groups

Two statistics were used to investigate differences between groups, paired sample t-tests and a three-way repeated measure ANOVA. The two tests have the same two assumptions. The assumptions were the absence of outliers and the normality of the distribution of the difference in the dependent variable(s). The first assumption was checked through a visual inspection of box-plots, while the second was assessed with the Shapiro-Wilk test of normality.

3.4 Pilot Study: Introduction

The study reported in this chapter was designed as a pilot study, to understand on one hand if the theorised model has some confirmation in data and, on the other hand, to understand the best procedure and measures to be used for following studies. One of the potential methodological issues that could have arisen was the measurement. In fact, as stated in the previous paragraphs, the analysis of usability and technology acceptance in VR is limited in prior research; therefore, it is useful to understand if the commonly used measures of these factors can be applied to VR.

The study was approved by the University of Nottingham Faculty of Engineering Ethics Committee.

3.5 Hypothesis

H1: The linear regressions between each factor and trust is significative.

The main aim of the study was to have a first set of data on the relationship between the three factors described in the framework and trust in VR. H1 hypothesized that the relationship exists.

H2: The questionnaires are reliable to be used for VR systems.

As stated in the previous paragraph, apart from the presence questionnaire, the questionnaire of usability, technology acceptance and trust have limited use in VR. Therefore, it was important to understand if these measures are reliable for this type of system.

H3: There is an effect of pre-interaction trust on the final trust.

A secondary aim of this study was to gather data on the effect of users' characteristics on the model theorised. H3 hypothesised that pre-interaction trust has a significative relationship with trust when considered alone as independent variable and when considered in the model with usability, presence and technology acceptance.

3.6 Method

3.6.1 Participants

A total of twenty-one participants were recruited among the staff at JLR. Recruitment was carried out by one of the PhD supervisors (Mr. Brian Waterfield) who had access to the recruitment process used by the firm. All the participants were made aware that participation in the study was voluntary, without any type of repercussion if they refused to take part. In addition, certain characteristics which have been seen to increase the possibility of cybersickness symptoms (e.g. suffer from: migraine, epilepsy or being pregnant) were listed as exclusion criteria. Successively, two participants were excluded from the study because they were under-aged (younger than 18 years old). Therefore, the data presented here refers to 19 participants (Mean age= 30.21, SD=13.67; 13 Males) who completed the study.

3.6.2 Materials

3.6.2.1 VR

The participants interacted with the JLR CAVE. The JLR CAVE projects images in four different walls (left, right, front and ceiling) with eight 4K Sony projectors (SRX-t105) (two per wall). The CAVE is powered by 16 computers (4 per screen) each with dual core CPU (Intel Xeon ES-2690). In order to see a 3D version of the model, the participant wore a pair of tracked glasses. The tracking permitted the model to adjust to the position of the participant's head, ensuring that the model (and occlusion effects) matched the participant's perspective. This was particularly important for realism, because the perspective of the object would feel less artificial, and for cybersickness, since the movement in the virtual environment was the same as the participants' head, avoiding contrast of senses, one of the possible cause of cybersickness (LaViola Jr, 2000). The controller used was a joystick. The joystick was tracked, thus the participants had to move it in order to move the pointer on the screen. An example of the CAVE is showed in Figure 3.1.

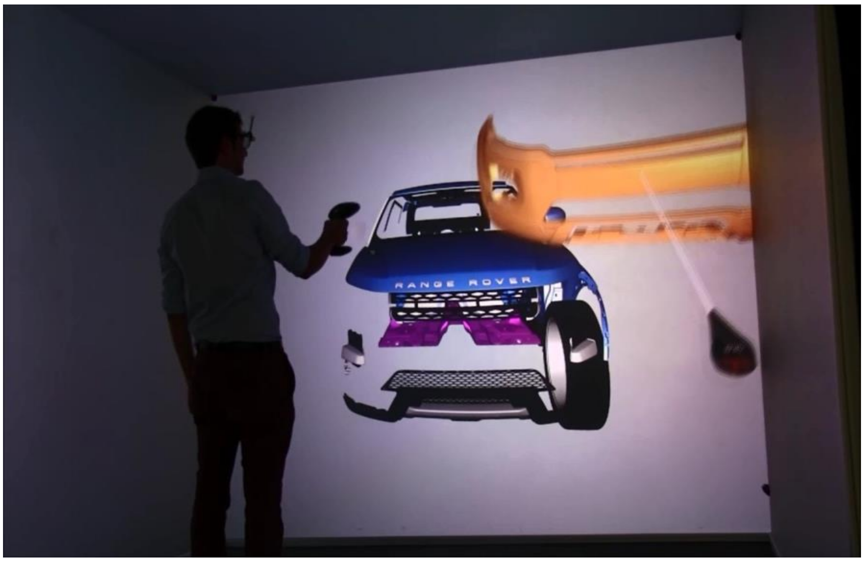

Figure 3.1 Example of a car model displayed in the JLR CAVE

3.6.2.2 Questionnaires

The questionnaires were divided into pre-interaction questionnaires (given before the interaction with the VR system) and post-interaction questionnaires (given after the interaction questionnaire).

Pre-interaction questionnaires:

Demographic Questionnaire (Appendix 1.6):

A demographic questionnaire was built to gather information about the participants.

Trust pre-interaction questionnaire (Appendix A1.6).

The trust pre-interaction questionnaire was developed to assess users' trust of general technology and all VR systems. This trust is developed before interaction with the system.

Post-Interaction questionnaires

ITC-SOPI (Appendix A1.3.1):

The ITC-SOPI has been used to assess the level of presence perceived by the participants.

SUS (Appendix A1.2):

The SUS has been seen as a useful tool to assess people's perceived usability.

Technology Acceptance Questionnaire (Appendix A1.1.1)

The technology acceptance questionnaire has been used in the literature to understand the level of technology acceptance of the users.

Trust in Technology measure (Appendix A1.4)

The questionnaire has been used to assess the level of users' trust in the specific system.

Other questionnaires

SSQ (Appendix A1.5):

The SSQ has been used to monitor the participants' cybersickness symptoms and was given to the participants at the end of each task.

3.6.3 Tasks

The participants had to perform six assembly and disassembly tasks on a car model already loaded into the CAVE.

3.6.3.1 Task 1

The first task consisted in the rotation of the car model at 90 degrees. To perform the task, the participant had to access the main menu, select the sub-menu “navigate”, select “rotate world”, and rotate the joystick at 90 degrees. Figure 3.2 shows the completed task.

Figure 3.2. Representation of the first task: "Rotate the car at 90 degrees"

3.6.3.2 Task 2

The second task consisted of zooming in to the car until the participant was “inside” the model. To perform the task, the participant had to access the main menu, select the sub-menu “navigate”, select “fly” and then move the controller toward the screen. The completed task is shown in Figure 3.3.

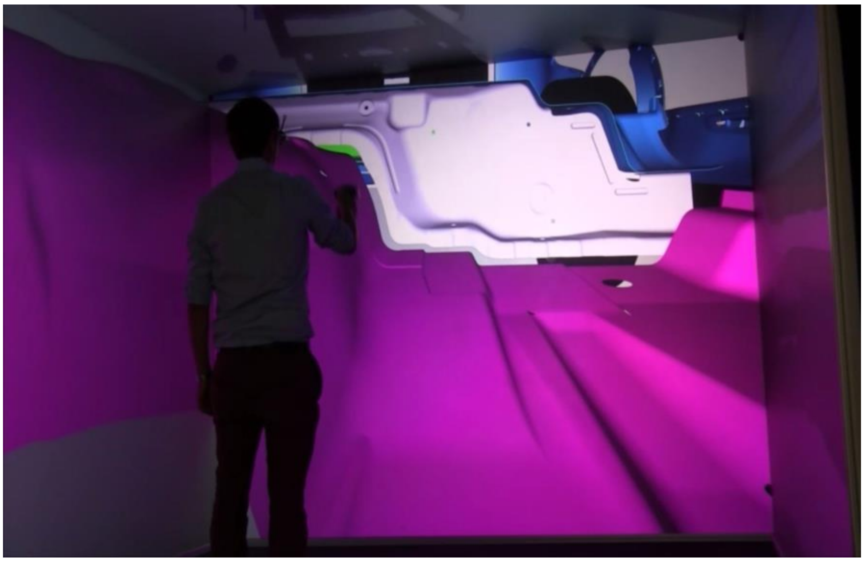

Figure 3.3 Representation of the second task: "Zoom the car using the fly menu"

3.6.3.3 Task 3

The third task consisted of moving the front bumper of the car and then reset the position of the bumper. To perform the task the participants had to access the main menu, select the sub-menu “edit”, select “work”, select the front bumper and move it from its position. To reset the position, they then had to select the bumper, access the main menu and select “reset” (Figure 3.4).

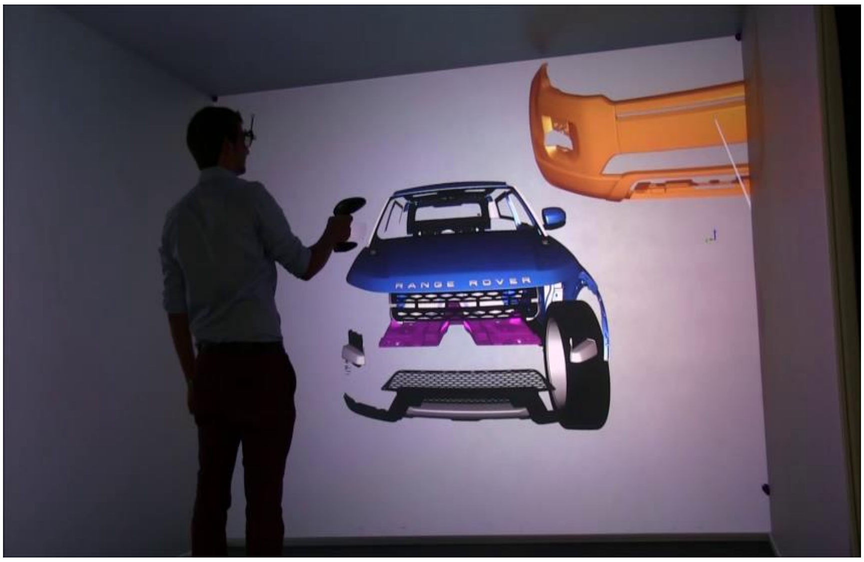

Figure 3.4 Representation of the third task: "Move the front part of the car and reset the position"

3.6.3.4 Task 4

The forth task consisted of measuring the size of the car logo. To perform the task, the participant had to access the main menu, select the sub-menu “eval”, select “measure”, select pick point, and then select the beginning and end of the front logo. Figure 3.5 depicts the performed task.

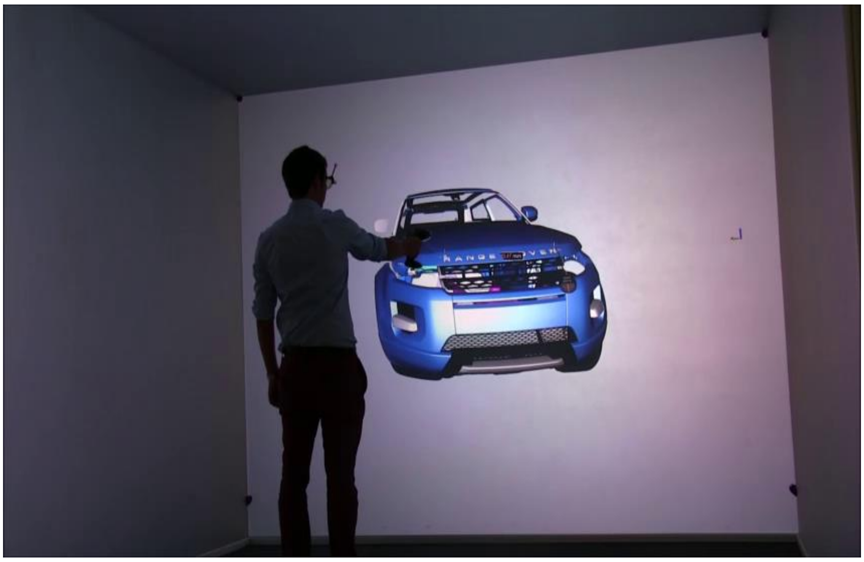

Figure 3.5 Representation of the fourth task: "Measure the car's logo"

3.6.3.5 Task 5

The fifth task consisted of “cutting” the car until both of the front wheels disappeared. To perform the task the participant had to access the main menu, select the sub-menu “eval”, select “cut” and select “cutplane” at this point a square would appear in the environment. Then, the participant had to exit all the menus and access the main menu again, select “edit” select “work” and, selecting the square, move the controller toward the screen (see Figure 3.6).

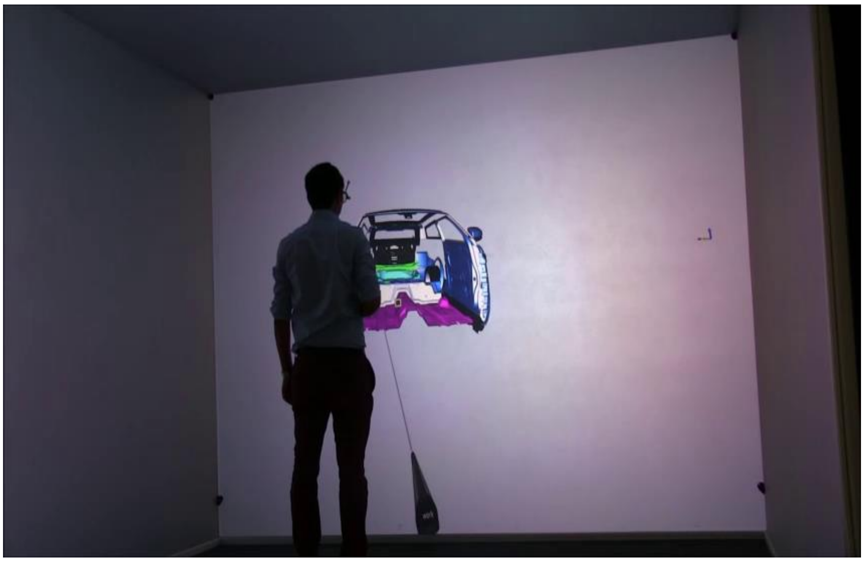

Figure 3.6 Representation of the fifth task: "Cut the car until the front wheels disappear"

3.6.3.6 Task 6

The last task consisted of taking a snapshot. To perform the task the participant had to access the main menu, select the sub menu “doc”, select “snap state” by moving the head to centre the frame and then take the snapshot (see Figure 3.7).

Figure 3.7 Representation of the sixth task: "Take a snapshot of the car logo"

3.6.4 Procedure

The entire procedure lasted approximately 45 minutes. The participants were invited into the room and asked to read the information sheet and complete the consent form. The participants were informed both through the information sheet and by the researcher of the possible side effects of using VR systems. If the participants decided to take part in the study, the pre-interaction questionnaires were given. After they completed the questionnaires, a trial phase started. In the trial phase, the researcher first explained the main features of the CAVE and the controller buttons. Then, the participants watched an explanatory video on a laptop for each task and perform the task straight away inside the CAVE. In the trial phase, the participants could ask questions and help to complete the task to the researcher. After the trial, the participants started the experiment. The participant had to perform the task within 3 minutes in the same order they performed it during the trial. The participant was interrupted after every two tasks to complete the SSQ. The participant had to verbally confirm when and if they thought the task was completed. If the participants did not complete the task in time, the task would be considered failed. In the experimental phase, no help was given to the participants. After the interaction, the participants were invited to complete the post interaction questionnaires. The maximum exposition time to VR was 18 minutes.

3.6.5 Data analysis

In order to understand the nature of the sample, frequencies were performed with the data from the demographic questionnaire and the SSQ.

To investigate the reliability of the questionnaire used, a reliability analysis was performed for all the questionnaires used.

To understand the relationship between the three factors and trust, four regression analysis were performed. Three with each factor as independent variable and trust as dependent variable and a regression analysis with all the factors as independent variables and trust as dependent variable.

Finally, to assess the influence of pre-interaction trust factors on the post-use trust, a regression was performed with pre-interaction trust as independent variable and trust as dependent variable and, in case of a significant result, a regression was performed with technology acceptance, usability, presence and pre-interaction trust as independent variables and trust as independent variable. This last regression aimed at investigating the influence of pre-interaction trust on the model.

3.7 Results

3.7.1 Demographic

Table 3.1 shows the frequencies of the demographic questionnaire data.

Frequencies			
		Number	Percentage
Sex	Male	13	68.4%
	Female	6	31.6%
Propensity to motion sickness	Not at all	10	58.8%
	Slightly	6	35.3%
	Moderately	1	5.9%
	Very much so	0	0%
VR Experience	I have never heard of Virtual Reality	0	0%
	I have heard of it but do not know what it is	0	0%
	I have some idea of what VR is	2	10.5%
	I know what Virtual Reality but have never seen or used it	6	31.6%
	I have seen a Virtual Reality system in use	6	31.6%
	I have used a Virtual Reality system once or twice	4	21.1%

	I have often used Virtual Reality	0	0%
	I use Virtual Reality almost every day	1	5.3%

Table 3.1 Demographic frequencies.

In order to have a visual representation of the four factors measured, four plots were created, one for each measure (see figures Figure 3.8-Figure 3.11).

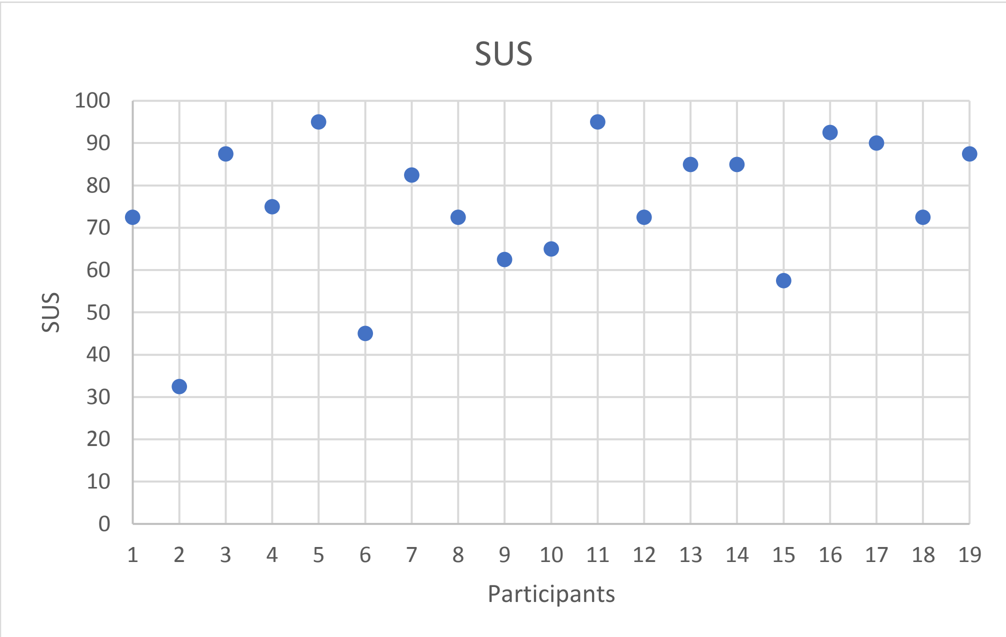

Figure 3.8 Scatter-dot plot of the responses to the SUS questionnaire

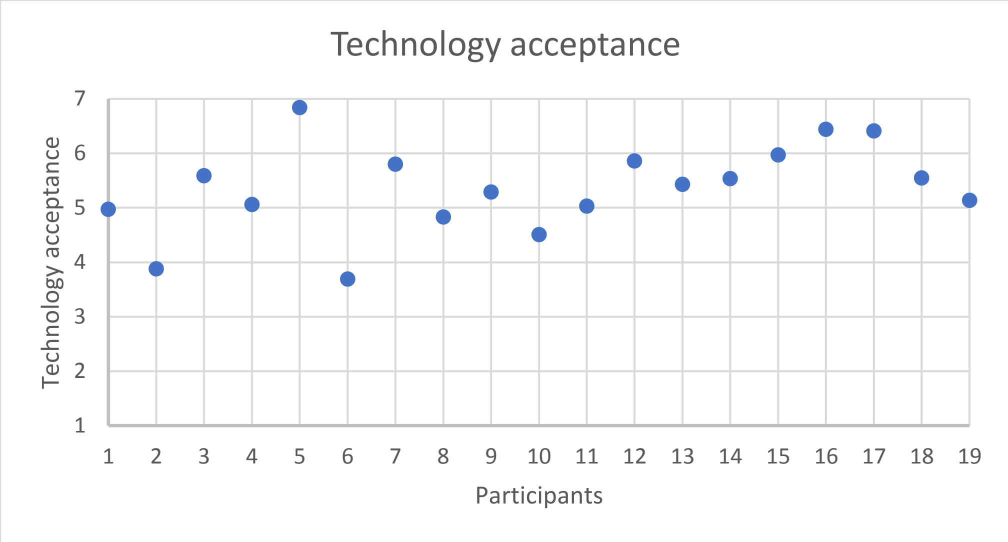

Figure 3.9 Scatter-dot plot of the responses to the technology acceptance questionnaire.

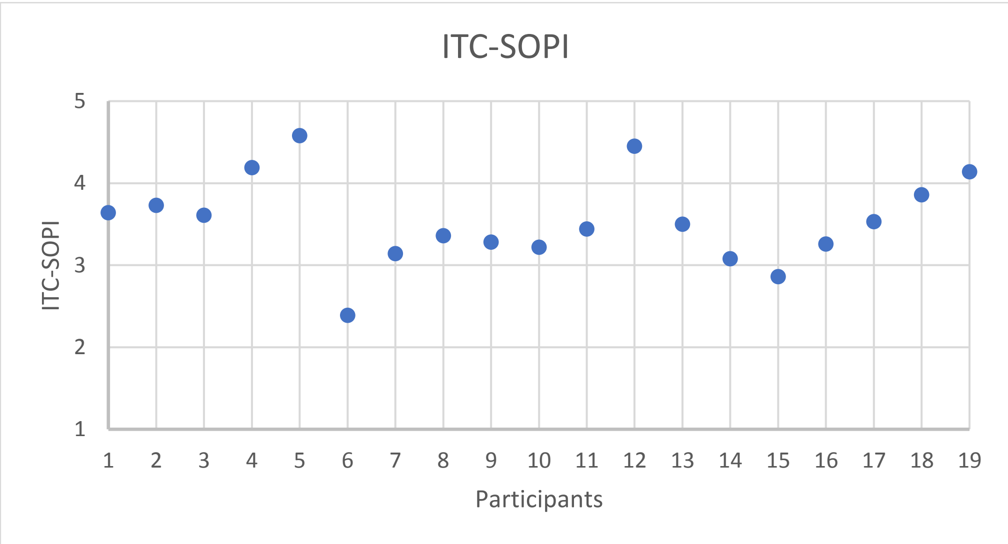

Figure 3.10 Scatter-dot plot of the responses to the ITQ-SOPI questionnaire.

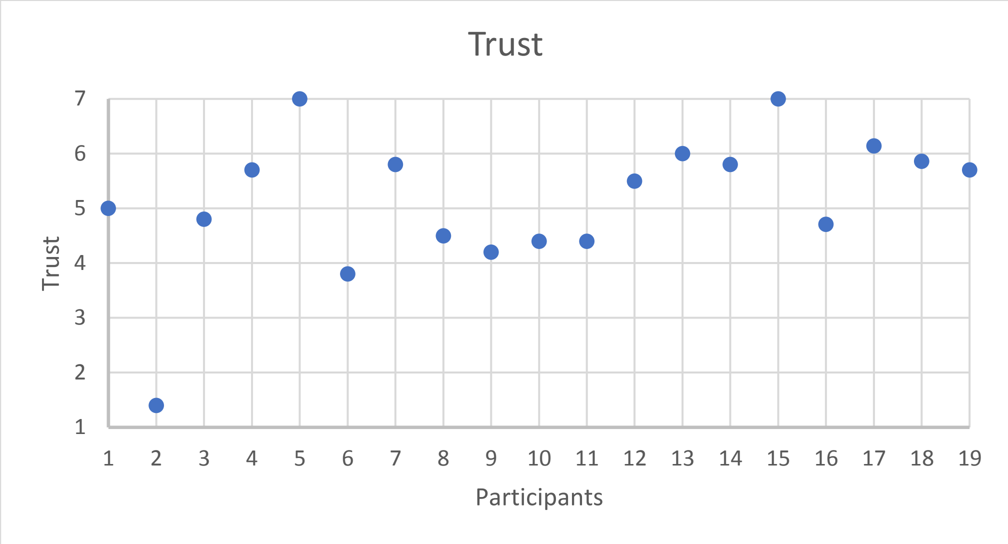

Figure 3.11 Scatter-dot plot of the responses to the trust questionnaire.

Analysing the SUS and trust there is the possibility of an outlier. This possibility will be investigated further in the regression analyses.

Figure 3.12 shows the levels of cybersickness as measured with the SSQ after every two tasks.

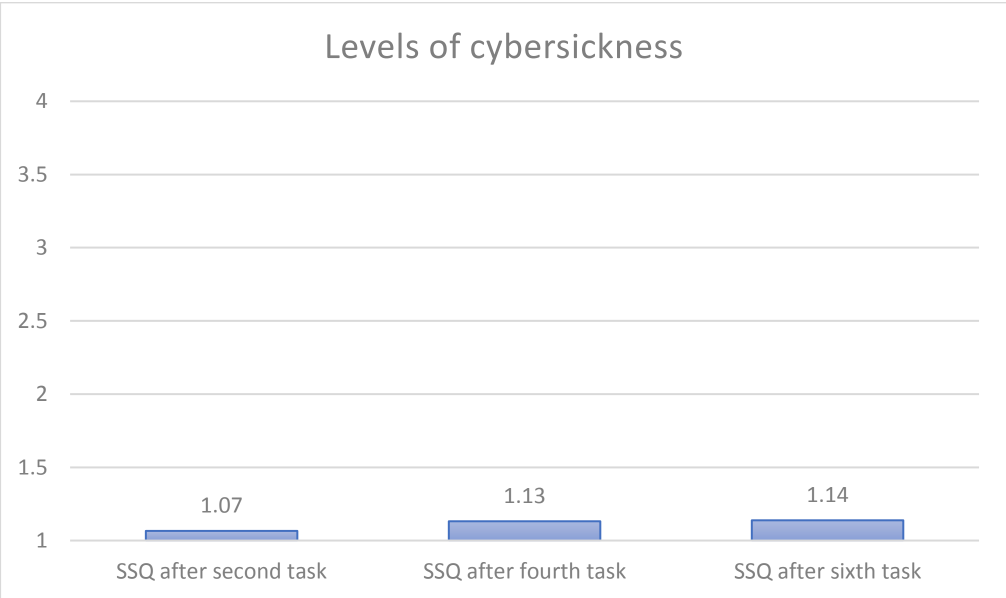

Figure 3.12 Levels of cybersickness as measured with the SSQ (1=none, 2= slightly, 3=Moderate, 4=Severe).

As can be seen from the graph, the cybersickness perceived by the participants is generally low through all the experiment

3.7.2 Reliability Analysis

To investigate questionnaire reliability, the Cronbach reliability analysis was performed for each questionnaire, (Santos, 1999). The internal consistency of all the questionnaire was high, as determined by the Cronbach alphas (SUS=.893, Items: 10; Technology acceptance=.905, items: 36; ITC-SOPI=9.28, items: 44; Trust= .941, items: 10). This means that the questionnaires are reliable with VR systems. These results were expected for the ITC-SOPI, in fact, being a presence and immersion questionnaire, it is designed to be used for VR systems. However, the other three questionnaires have limited use in the VR field.

3.7.3 Regressions

In order to understand the relationship between the three factors and trust, four regressions were performed. In addition, two regressions were performed to investigate the influence of pre-interaction trust on the final trust. Table 3.2 describes the independent and dependent variables of each regression.

Regression	Independent variable	Dependent variable	Aim
Regression 1	Usability	Trust	To investigate the relationship between usability and trust
Regression 2	TAM		To investigate the relationship between TAM and trust
Regression 3	Presence		To investigate the relationship between Presence and trust
Regression 4	Usability, Technology acceptance, Presence		To investigate the relationship between the three factors and trust
Regression 5	Pre-interaction trust		To investigate the relationship between pre-interaction trust and trust

Regression 6	Pre-interaction trust, Usability, technology acceptance, presence		To investigate the influence of pre-interaction trust on the complete model.

Table 3.2 List of regression performed

3.7.3.1 Usability and Trust

The first regression was performed to investigate the relationship between usability and trust. First of all, a scatter-dot plot was created to visually investigate the relationship between the two variables (Figure 3.13).

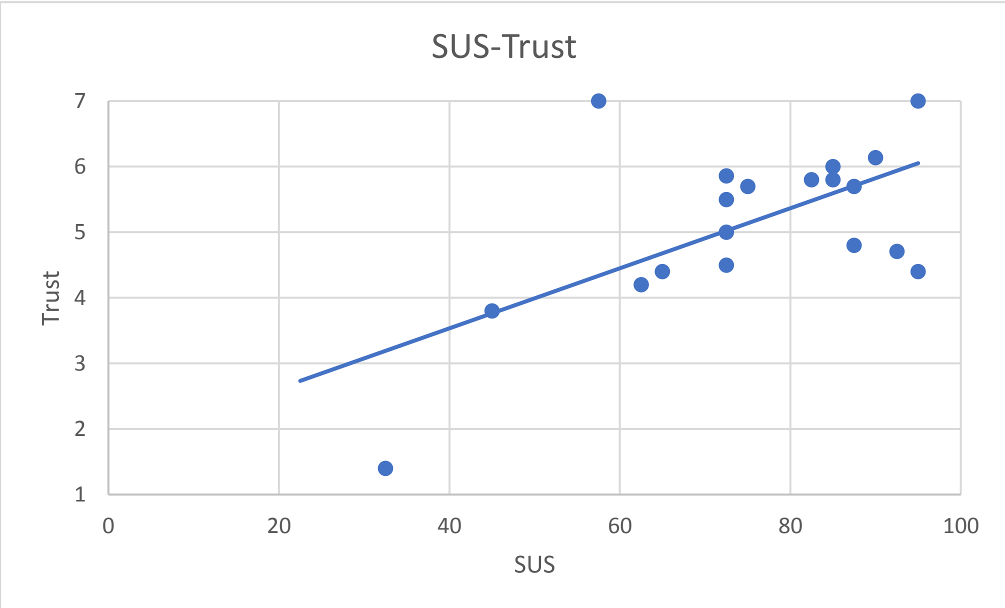

Figure 3.13 Scatter-dot plot of the interaction between SUS and trust.

The regression was significant [F(1,17)= 10.730, p=.004], with usability accounting for 35.6% of trust (Adj. R^2 =.356).

3.7.3.2 Technology acceptance and Trust

The second regression was performed with technology acceptance as independent variable and trust as dependent variable and was used to investigate the possible relationship between these two factors.

A scatter-dot plot was created to investigate the relationship between the two factors (Figure 3.14).

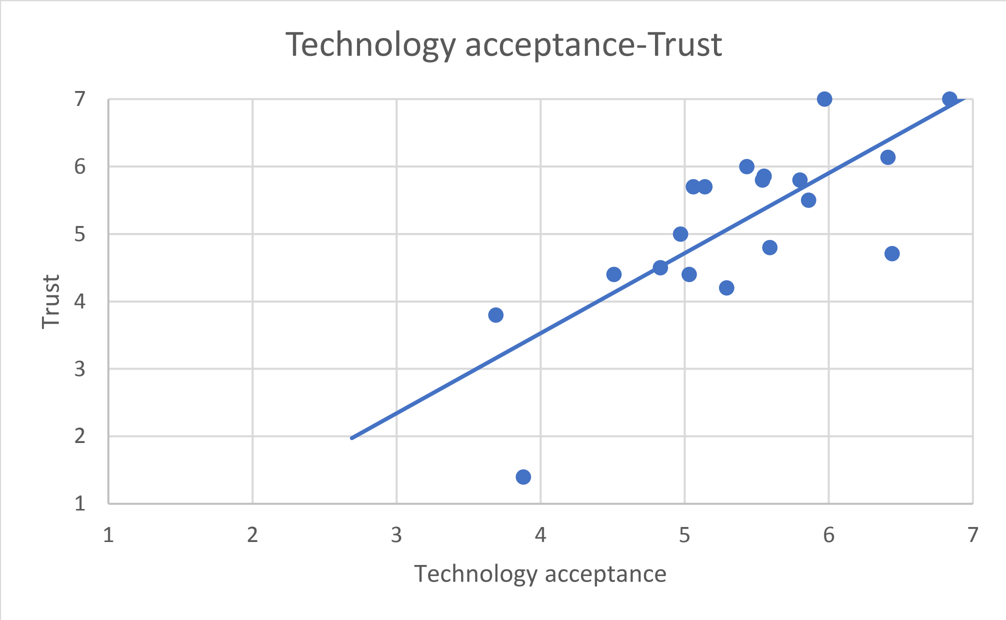

Figure 3.14 Scatter-dot plot of the interaction between technology acceptance and trust.

The regression was significant [F(1,17)= 22.44, p<.001], with technology acceptance accounting for 54.4% of trust (Adj. R^2 =.544).

3.7.3.3 Presence and trust

The third regression was performed to investigate the relationship between presence and trust. Figure 3.15 shows a scatter-dot plot created in order to have a visual representation of the relationship.

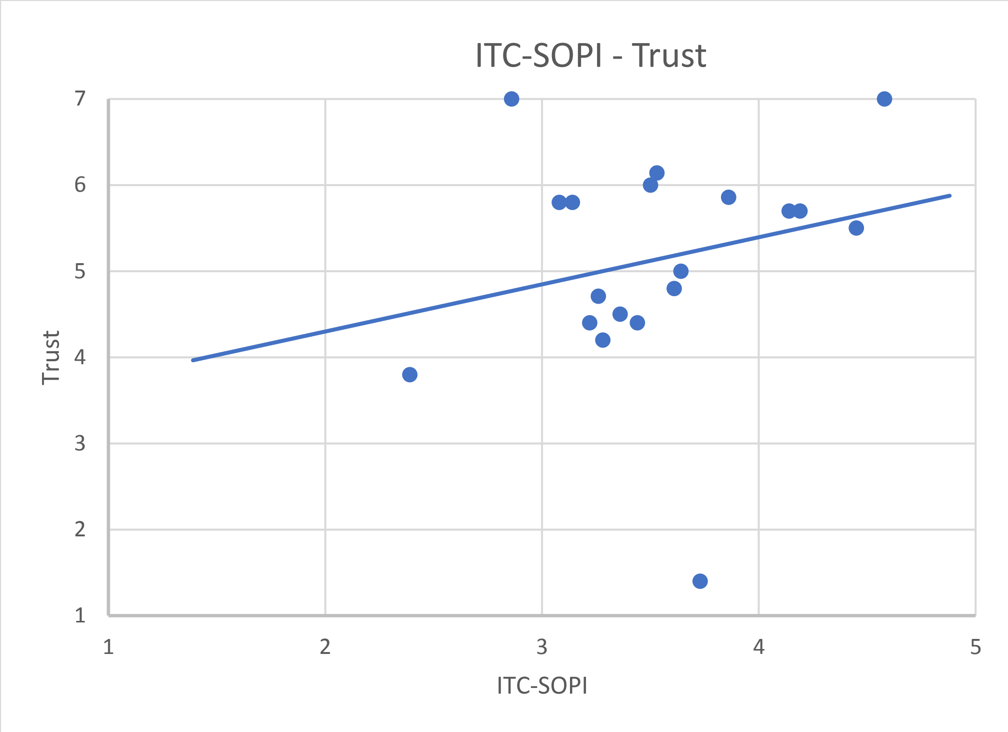

Figure 3.15 Scatter-Dot plot of the relationship between ITC-SOPI and trust.

The regression was not significant [F(1,16)= 3.39, p=.084].

3.7.3.4 Presence factors and trust

The authors of the Presence questionnaire divided the measure in four main factors: Spatial Presence, Engagement, Ecological Validity and Negative effects (Lessiter et al., 2001). Spatial presence refers to the classic presence definition of the "sensation of being there". Engagement refers to the sense of involvement the experience gives. Ecological validity is characterised by the sensation that the environment is as real as possible. Finally, negative effect includes the cybersickness symptoms that can arise during the experience with VR systems. In their paper, Lessiter et al., 2001 state that, even though all the four factors may have an effect on the overall presence, it is not demonstrated how this could happen. The authors suggest analysing them as separated items instead of a unique concept. Thus, four regressions were performed, one for each factor as independent variable and trust as dependent variable.

Three scatter-dot plots were built to visually assess the data distribution. The plots are presented in Figure 3.16 - Figure 3.19).

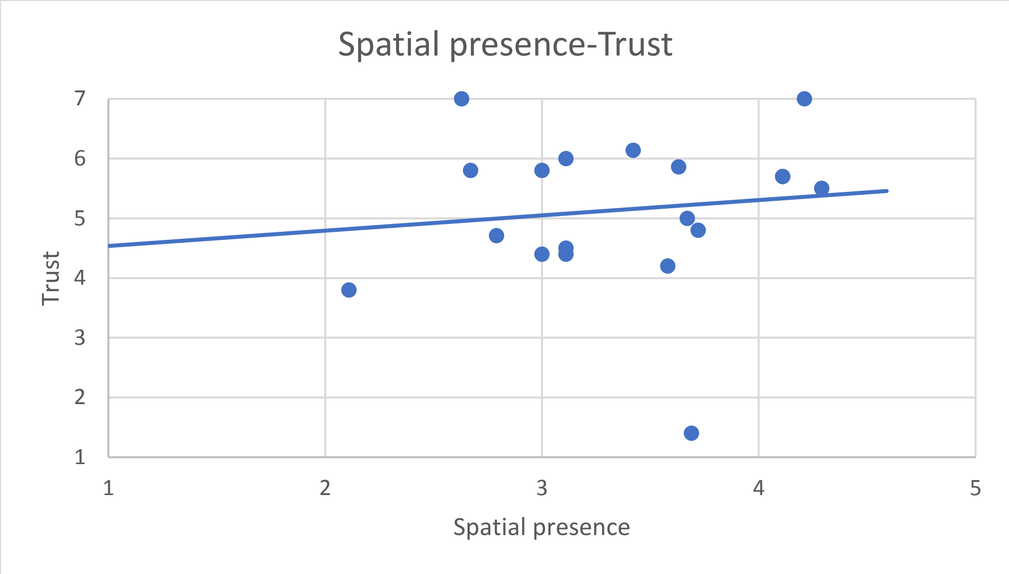

Figure 3.16 Scatter-dot plot of the interaction between spatial presence and trust.

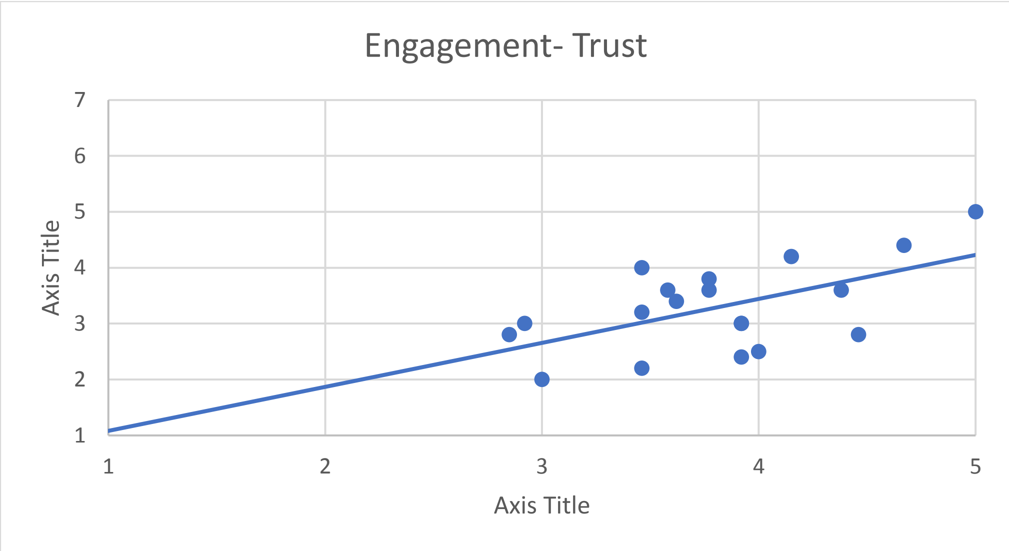

Figure 3.17 Scatter-dot plot of the interaction between engagement and trust.

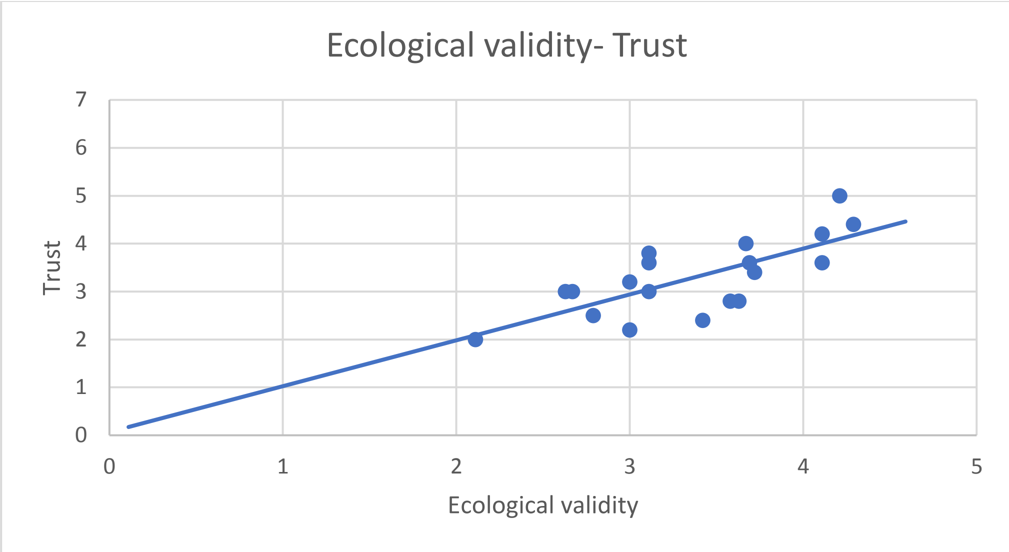

Figure 3.18 Scatter-dot plot of the interaction between ecological validity and trust.

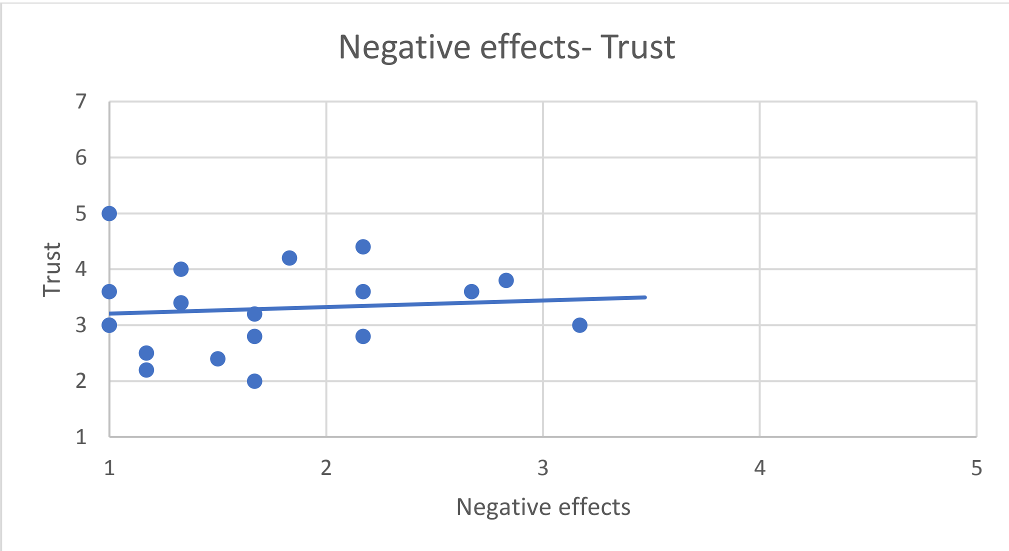

Figure 3.19 Scatter-dot plot of the interaction between negative effects and trust.

Only the regression with Negative effect as independent variable was found to be significant [$F(1,17)=5.842$, $p=.027$] while the others were all non-significant (Spatial Presence: $F(1,17)= .256$, $p=.619$; Engagement: $F(1,17)= 2.685$, $p=.12$; Ecological validity: $F(1,17)= .577$ $p=.458$).

3.7.3.5 Technology acceptance, usability, presence and trust

The fourth regression is the first attempt at the validation of the framework. Even though this was the first experiment, it could be useful to understand if there is the base for confirming the framework as explained in chapter 2. Nonetheless, the possible methodological problems this experiment was trying to highlight could have influenced the results of this regression. Therefore, these results will not be considered as final, and would be explored further in the following experiments. The regression included all the three factors (Usability, Technology acceptance and Presence) as independent variables and Trust as a dependent variable.

Participant 2 was removed from the analysis as the leverage value (.44) and Cook's value (1.68) were high and the leverage and influential points assumptions were not respected.

The regression was significant [F(3,14)=5.467, p=.011] with the model accounting for the 52% of trust (Adj R^2 = .518).

The coefficients of each independent variable are shown in Table 3.3.

Regression SUS, Technology acceptance, ITQ-SOPI - Trust				
	R^2	Adj R^2	Beta	Sig.
SUS	0.599	0.518	0.179	0.458
Technology acceptance			0.655	0.014
ITQ-SOPI			-0.056	0.756

Table 3.3 Coefficients of the regression with usability, technology acceptance and Presence as independent variable and trust as dependent variable.

However, as the table shows, the only variable that significantly added to the model was technology acceptance. This result could be interpreted in various ways depending on the factor. Usability, for instance, had a significant influence on trust when analysed alone, but it lacks significance when included in the last regression. This could be interpreted as an indirect influence of usability on trust, this hypothesis was tested in the next experiments. Presence, on the other hand, was not significant when analysed alone, nor when included with the other factors. This could mean that presence does not have any influence on trust. However, there were some methodological issues (discussed in the following section) which could have influenced the results of this regression. Regarding Technology acceptance, both regressions were significant. This could be the first step for confirming the relationship with trust.

3.7.3.6 Pre-interaction trust and final trust.

The last regressions were aimed at investigating the influence of pre-interaction trust on the final model. A regression was first performed with pre-interaction trust as independent variable and trust as dependent variable.

A scatter-dot plot between pre-interaction trust and trust was created to visually investigate the relationship (Figure 3.20).

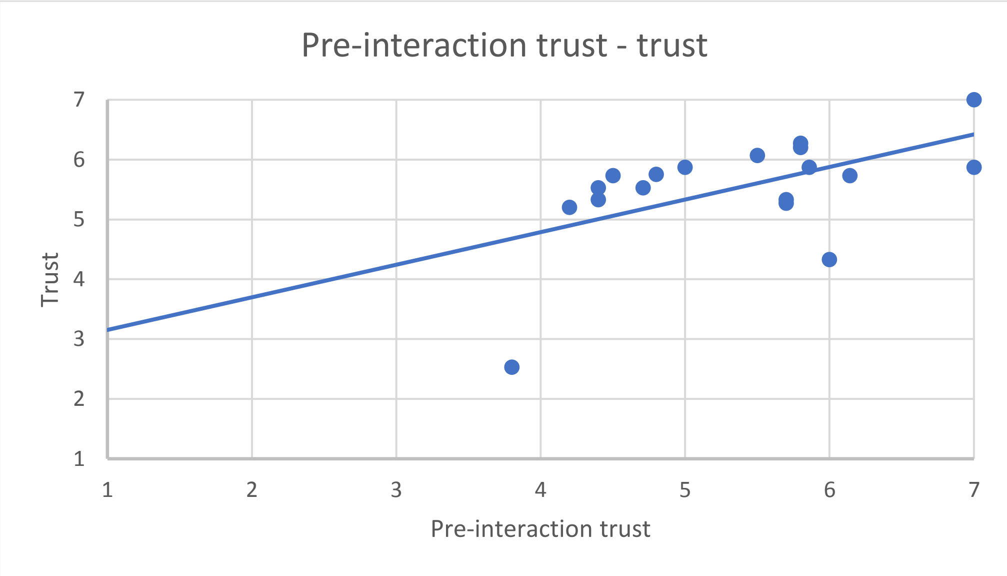

Figure 3.20 Scatter-dot plot of the interaction between pre-interaction trust and trust.

An outlier was found with the casewise diagnostic, and was eliminated from analysis (Participant 2, Predicted value= 5.24, Residual= -3.84).

The regression was significant [F(1,16)=6.655, p=.020) with pre-interaction trust accounting for 25% of trust (AdjR2= .25)

The results show an influence of the pre-interaction trust on the final trust. Although, the low value of the R^2 could mean that the influence is minimal.

3.7.3.7 Model with pre-interaction trust

To better investigate the effect of pre-interaction trust in the model of trust in VR, a regression with all the factors as independent variables and trust as dependent variable was performed.

The regression was significant [F(4,13)= 3.987, p=.025). The coefficients of the regressions are showed in Table 3.4.

Regression SUS, Technology acceptance, Presence, Pre-interaction trust - Trust				
	R^2	Adj R^2	Beta	Sig.
SUS	.551	.413	-.257	.337
Technology acceptance			.647	.036
Presence			.220	.342
Pre-Interaction trust			.180	.470

Table 3.4 Regression with Usability, Technology acceptance, presence and pre-interaction trust as independent variables and trust as dependent variable.

As can be seen, when taken together, pre-interaction trust no longer affects the final trust. As said for usability before, this could be due to an indirect effect of the pre-interaction trust on trust.

3.8 Discussion

As anticipated in the introduction, this study was designed to investigate the reliability of the questionnaires used, to have the first set of data about the factors influencing trust in VR and to investigate any possible methodological and design issues. The results gave an initial idea about the possible relationship between usability, technology acceptance and presence with trust and highlighted some issues in the design and method of the study, especially regarding presence.

H1 hypothesised that the regressions between each factors and trust were significant. The results show that when analysed singularly usability and technology acceptance have an influence on trust. However, while technology acceptance seems to have a strong influence on trust, the same cannot be said about usability. In fact, even though the regression is significant, the effect usability has on trust directly is low. This could be interpreted as a sign of an indirect relationship. This interpretation is confirmed by the last regression, where all the three factors are included together. The results of this regression show that usability does not have a significant influence on trust. Although, this was the first experiment designed and it could be too early to establish the nature of this relationship. The short tasks and the continued interruption of the interaction with the VR system (as stated in the procedure section of this chapter, the participants were interrupted every two tasks to fill the SSQ questionnaire) could have affected the measurement of usability. The third factor studied was presence. Presence was not found to have an influence on trust. In fact, both when taken singularly and when added in the last regression, the results were not significant. These results could mean that presence does not have any type of influence (direct or indirect) on trust in VR. However, there was a methodological problem in the experiment that may have affected these results. As explained in the method section, the participants had a brief interaction with the VR system and were, then, interrupted and asked to complete the SSQ questionnaire. This procedure may have interrupted the flow of the experience. Flow has been described as one of the most important determinants of presence (Lessiter et al., 2001). Another possible cause of the lack of results could have been the type of questionnaire. In fact, as stated in the las section, the ITC-SOPI is composed of four factors, which should not be analysed together but separately. The results of the additional four regressions with each of the four factors of the questionnaire (Spatial presence, Engagement, Ecological validity and Negative effects) were not significant, apart from the negative effects, which seems to have a negative influence on trust. Dividing the questionnaire into four sections and analysing them separately could not be ideal for the purpose of the project since in this work, presence is considered as a unique concept. Indeed, adding more variables to an already complicated framework, could affect the validity of the results. It would be better, for future studies, to use a questionnaire intended to investigate the overall presence.

Even though presence was not found to have an influence on trust, Technology acceptance and usability were. These results give a good starting point for the continuation of the project and partially confirm H1, which stated that there is a relationship between the three factors and trust.

H2 stated that all the questionnaires were reliable. The results of the reliability analysis show that all four questionnaires had a high internal consistency. Even though this result was expected for the presence questionnaire, since presence is a factor mainly studied in the VR field, the other three questionnaires have limited application in VR. The results of the reliability analysis demonstrated that the questionnaires could be used in VR. This is particularly important for the future studies. Therefore, H2 was verified.

The third aim of the study was to analyse the effect of the pre-interaction trust on the final trust. The regression performed showed that pre-interaction trust has a weak effect on trust only when taken singularly as independent variable, while it does not have any effect when considered in the model. These results are surprising, since the users' characteristics do not seem to have a big impact on the final trust compared to the other factors studied. This relationship will be investigated further in the next studies (chapter 5 and 6).

3.9 Chapter Conclusion

To summarise, the results of this study gave important insight on the practice to follow for next studies. First of all, the results of the reliability analysis showed that the questionnaires selected to measure usability, technology acceptance and trust can be used with VR systems.

The results of the regressions show that there are bases for validation of the framework described in chapter 2, even though, it seems, that the relationship is not linear but can involve indirect relationships. Moreover, the influence of pre-interaction trust was not found when included in the model with the other factors. These results could be surprising, since pre-interaction trust was theorised in previous studies to have an effect on post-use trust (McKnight et al., 2011). However, this relationship will be investigated further in the next studies.

Finally, the experiment highlighted some methodological issues: the tasks were probably too short to give exhaustive results of usability and presence and the fact that the participants were constantly interrupted could have disrupted the sense of presence perceived. Besides, the questionnaire used for presence could be replaced with a more comprehensive one, where presence is measured as an only factor instead of four separated ones.

The next studies were designed to overcome the issues encountered in this experiment. However, to better validate the framework, the factors will be first analysed singularly and paired, in order to design experiments that are suited to the characteristics of each factor. Finally, the factors will, again, included together in an experiment, aimed to the final validation of the framework.

4. Chapter 4 – Single and paired factors

4.1 Chapter overview

This chapter will describe three experiments, which were the results of collaborations between the main author of this work and colleagues at the University of Nottingham. Concerning this PhD research, the aims of these studies were to investigate the relationship between usability and trust (Desktop VR study and Flight simulator study) and between technology acceptance and presence with trust (Virtual Boot study). The results confirmed the pilot study hypotheses, with technology acceptance having a strong influence on trust, usability a weaker effect and presence having no significant relationship with trust.

4.2 Introduction

The previous chapter described the first experiment to validate the trust in VR model in chapter two. As stated in the previous section, this chapter describes three collaborations made with colleagues from the Human Factors Research Group (HFRG). Dr. Simone Borsci, Dr. Chrisminder Hare and Dr. Glyn Lawson agreed to include in their studies some of the questionnaires designed to investigate the relationship mentioned above. The studies were relevant to the PhD research as they all used VR systems. The three studies were: the desktop VR study, conducted using a normal desktop, the flight simulator study, conducted using a flight simulator and the boot study, conducted using a CAVE system. The total number of participants was 52 (22 for the Desktop VR, 8 for the flight simulator and 22 for the Boot study). The Desktop VR and Flight simulator studies were focused on the relationship between usability and trust, while the virtual boot study investigated the relationship between presence and technology acceptance with trust. The aim of the collaborative studies was to have more data on the relationship between the factors described in chapter 2.

This chapter will describe in detail the three studies. It is important to note that only the parts relevant to the PhD project will be explained. The main aims that will be highlighted in the hypothesis section refer to this thesis and do not take into consideration the aims presented in the original designs of the three studies. However, the scopes of the studies will be described in the studies introduction, in order to have a more complete understanding of the study design. The chapter will be divided in three parts, each describing a different study.

4.3 Contribution to the studies

As stated in the last section, the three studies had a different purpose to that of this thesis. This paragraph will state the contribution the author of this thesis made to the three experiments.

In study 1 (desktop VR) and study 2 (Flight simulator) the design and conduct of the experiments and the recruitment of participants was left to the main investigators. Nevertheless, all the data analysis, results gathering and results discussion regarding the measures of usability and trust were responsibility of the author of this thesis. Moreover, the design of the experiments was carefully studied to avoid procedural issues, and the main investigators were instructed on when and how give the questionnaire on usability and trust.

In study 3 (Virtual Boot), the role of the PhD student was to design the part related to the study of presence and technology acceptance and to analyse all the data regarding these two factors and trust. Additionally, to contribute to the conduction of the experiment being in charge of it.

All the studies were granted approval from Faculty of Engineering Ethics Committee at the University of Nottingham. Each researcher was in charge of submitting their own ethics application.

4.4 Study 1 (Desktop VR)

The Desktop VR study was part of the Live Augmented Reality Training Environment (LARTE) project (InnovateUK, reference number: 101509). The aim of the study and the project was to evaluate the effectiveness of VR as a learning and training tool. The project was an Innovative UK project in collaboration with Jaguar Land Rover (JLR) and HoloVis. More details about the study can be found in Borsci et al. (2016).

4.4.1 Introduction

The desktop VR study was designed to investigate the effectiveness of VR and computer-based training in assembly and disassembly processes. Usability was already part of the original design, given its importance in the perceived effectiveness of a technology. Moreover, usability was measured with the SUS questionnaire, which is the questionnaire used in this PhD project. After an agreement with the study principal investigator, the decision was made to add the trust questionnaire.

65 adult volunteers participated in the study and were divided into three groups, one using a Video-based training, one using a trial and error-based training and one using a Desktop VR- based training. Only the latest group will be taken into consideration in this thesis. This also means that only part of the method, results and discussion, referring to usability and trust, will be described.

To investigate the relationship between usability and trust, the data from 22 participants interacting with the desktop VR system were analysed.

4.4.2 Hypothesis

As anticipated in the introduction of this chapter, the desktop VR study used, among other questionnaires, the measures of usability and trust. Therefore, the hypothesis concerning this study is:

H1: There is a linear relationship between usability and trust.

4.4.3 Method

4.4.3.1 Participants

There were 22 participants (Mean age= 28.73, SD= 7.30; 14 males) all recruited among students and staff members at the University of Nottingham. Responsibility for the recruitment was given to the lead researcher, but the recruitment criteria were agreed in the design and respected the criteria for the recruitment of participants in VR studies, excluding participants susceptible to motion sickness.

4.4.3.2 Materials

4.4.3.2.1 VR

The VR system used was a normal desktop computer running the LEGO® digital design software, used as an assembly and disassembly tool. The participants had to perform two tasks with the desktop VR and then replicate it with a real LEGO® model. However, only the training with the desktop-VR will be considered here. The model shown in the software was exactly the same as the physical one and was the LEGO® Technic 4X4 Crawler car. The software was run with a desktop computer with Microsoft® Windows 7 Enterprise, processor Intel® core i7, 3.70 GHz, 8GB of RAM and a dedicated graphics and sound system.

Figure 4.1 shows the real and virtual model of the LEGO car.

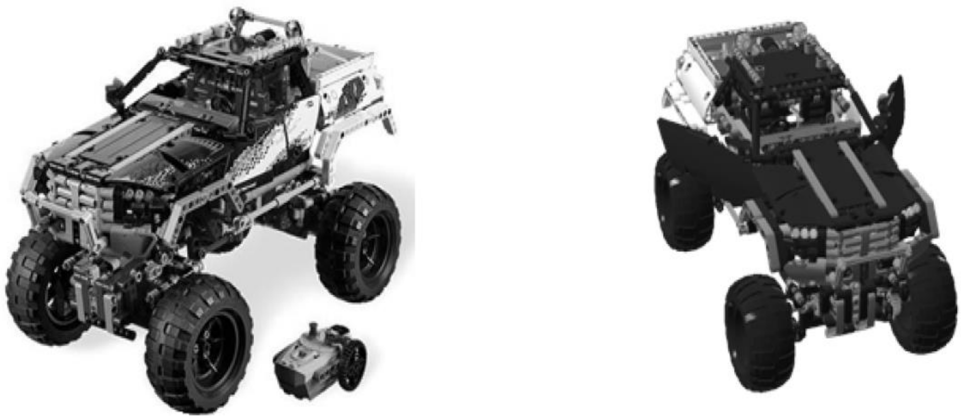

Figure 4.1 Real (left) and virtual (right) model of the car. Image from Borsci et al. (2016)

4.4.3.2.2 Questionnaires

The questionnaires used were:

System Usability Scale (SUS) (Appendix A1.2): to assess the perceived usability of the systems, and

Trust in Technology Measure (Appendix A1.4): to assess the perceived trust in the system.

4.4.3.3 Procedure

The participants were invited into the room and asked to read the information sheet and to sign the consent form. If and when the participants agreed to take part in the study, a five-minute explanation of the material and procedure of the study was given. After that, the participants had a trial of the LEGO digital design software with a simplified car model. They were then invited to perform the two tasks described in the next section with the virtual model.

4.4.3.4 Tasks

4.4.3.4.1 First task

The first task consisted of the replacement of the main engine of the car model. It was composed of 49 total steps, both physical (e.g. remove pieces, open compartments) and manipulative (rotate the model)

4.4.3.4.2 Second task

The second task consisted of the replacement of the left front damper of the car. It was composed of a total of 89 steps.

4.4.3.5 Data analysis

First, the data on the perceived level of usability and trust were analysed. Then, to investigate the relationship between usability and trust, a regression was performed, with usability as independent variable and trust as dependent variable.

4.4.4 Results

To have a complete picture of the data, scatter dot plots have been created for each of the variable (see Figure 4.2 and Figure 4.3).

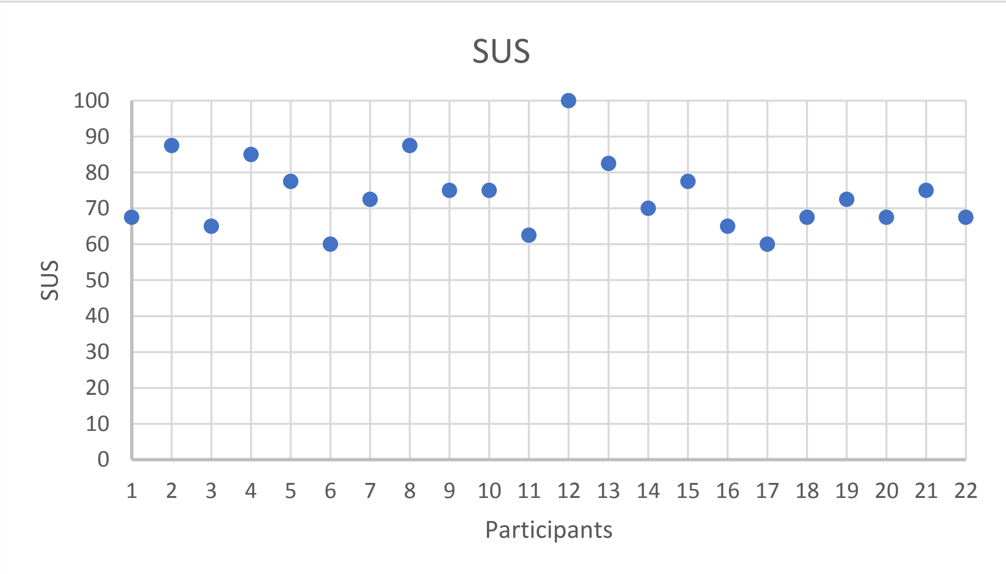

Figure 4.2 Scatter-dot plot of the responses to the SUS questionnaire.

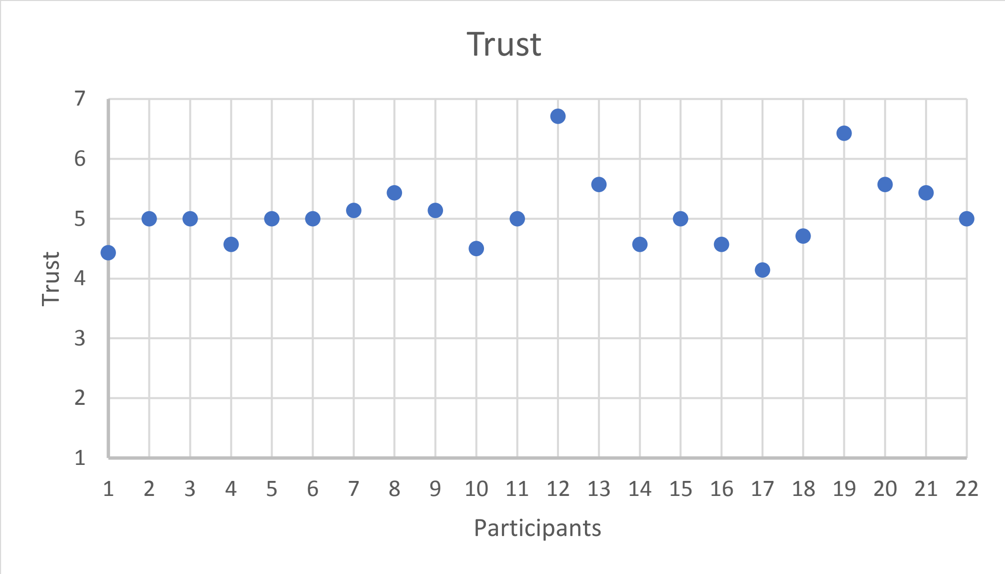

Figure 4.3 Scatter-dot plot of the responses to the trust questionnaire.

4.4.4.1 Regression

A regression was conducted to investigate the relationship between usability and trust. Figure 4.4 shows the distribution of the data.

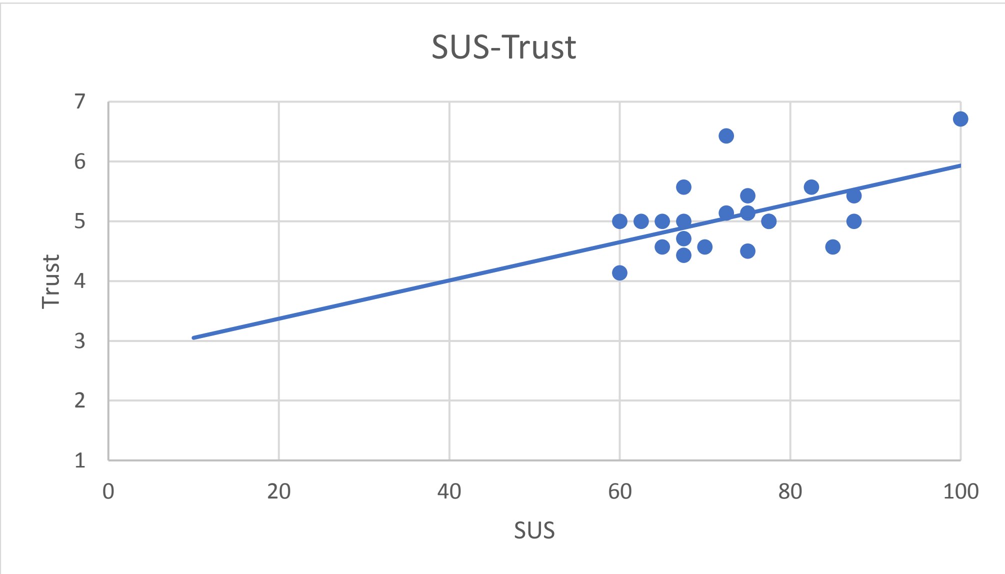

Figure 4.4 Scatter-dot plot of the interaction between SUS and trust.

The regression was significant [$F(1,20)=7.695$, $p=.012$] with usability accounting for 24.2% of trust (Adj $R^2=.242$).

4.4.5 Discussion

The aim of this investigation was to determine the relationship between usability and trust. To do so, a regression was performed with trust as dependent variable and usability (SUS) as independent variable. The result of the regression shows that there is a significant relationship between the two, although the value of Adj R^2 is low (Adj R^2= 0.242), meaning that the influence is minimal. As stated for the first experiment described in chapter 3, a possible interpretation of the weak relationship between usability and trust could be the possibility of an indirect relationship between the two factors. In fact, as can be deducted from the result of the last chapter regression with all the three factors as dependent variables (see section 3.7.3.5) and the result of this regression, usability is not the strongest predictor of trust. However, in both the experiments so far there was a significant relationship between the two factors when analysed alone. Thus, usability should not be discarded as a possible (indirect) influencer of trust.

4.4.6 Conclusion

As stated in the introduction of this chapter, this study was designed to investigate the effectiveness of desktop VR training compared to different training methods. Thanks to the collaboration between the author of this thesis and the main researcher of the study, the questionnaire of usability and trust were added. The main hypothesis explored was that there is a significant relationship between usability and trust. This hypothesis was verified, as the results of the regression show. However, it seems that the relationship between usability and trust could be indirect, given the weak relationship with trust and following from the results of the first study described in the previous chapter. The next collaborative study examined this relationship further.

4.5 Study 2 (Flight simulator)

In the previous chapter and in the first part of this one, it was demonstrated that usability has an influence on trust in a CAVE and in a Desktop VR. However, there are a multitude of VR systems and it could be useful for the purpose of this work to investigate this relationship in various technologies, in order to have a stronger validation of the model described in chapter 2. To do this, the questionnaires on usability and trust were added to a study using a flight simulator. The experiment was aimed at investigating the interaction between pilots and a new cockpit interface.

The study was conducted at Airbus group in Manching, Germany. There were 8 participants (Mean age= 49.375, SD= 7.94; all males), all of whom were professional pilots. The participants had to perform three tasks including an emergency one. The main aim of the study was to investigate the adoption of a new cockpit interface.

The experiment described here is part of a project part funded by the RCUK's Horizon Digital Economy Research Hub grant, EP/G065802/1 and part funded by Airbus Group.

4.5.1 Hypothesis

As anticipated in the introduction section of this chapter and this section, the aim relevant to the PhD research was to investigate the relationship between usability and trust. Given the significant results showed so far, the hypothesis is as follows:

H1: The linear relationship between usability and trust exists also in a flight simulator.

4.5.2 Method

4.5.2.1 Participants

A total of 8 participants were recruited among Airbus group by the main investigator. The participants were all professional pilots.

4.5.2.2 Materials

4.5.2.2.1 VR

The VR system was a part task simulator of a commercial jet aircraft. The simulator had all the functions and interfaces required to complete the tasks given to the participants. The characteristics of the flight simulator are confidential and will not be explained here.

4.5.2.2.2 Questionnaires

The questionnaires used were:

System Usability Scale (SUS) (Appendix A1.2): to assess the perceived usability of the systems.

Trust in Technology Measures (Appendix A1.4): to assess the perceived trust in the system

4.5.2.3 Procedure

The procedure required two experimenters in the assessment. The first experimenter was the lead experimenter, who looked after the participants, explained the tasks and delivered the questionnaires. The second experimenter's role was to handle the simulator, explain the cockpit philosophy to the pilot and act as Air Traffic Control (ACT).

Firstly, the lead experimenter briefed the participants regarding the flight including the route, what they would be required to do i.e. to manually fly the aircraft, the weather, etc. This could be considered similar to what would occur during a briefing session before a flight was to take place. The participants were then introduced to the system and asked to have a trial run using the interfaces. The pilot was given enough time to get familiar with the system. Once the pilots felt comfortable with the system they started the tasks. The order of the tasks was controlled to reduce the learning effect. During the task, the participants needed to maintain aircraft control, attend to the emergency using the relevant checklists and comply with the ATC instructions (delivered by the second experimenter). After completing all three tasks the pilots were asked to complete the SUS and Trust questionnaires.

4.5.2.4 Tasks

The participants were asked to take part in three tasks in the simulator; each task had an emergency activity implemented into the task. The emergencies given to the participant included: engine fire, fuel leak and a combination of the two. Each task started during the cruise phase; consequently, the participants did not have to take-off or land.

4.5.2.5 *Data analysis*

First of all, an average of the levels of usability and trust was analysed. Then, in order to investigate the relationship between usability and trust, a regression was performed, with trust as dependent variable and usability as independent variable.

4.5.3 Results

Scatter-dot plots were created to allow visual inspection of the data (Figure 4.5, Figure 4.6).

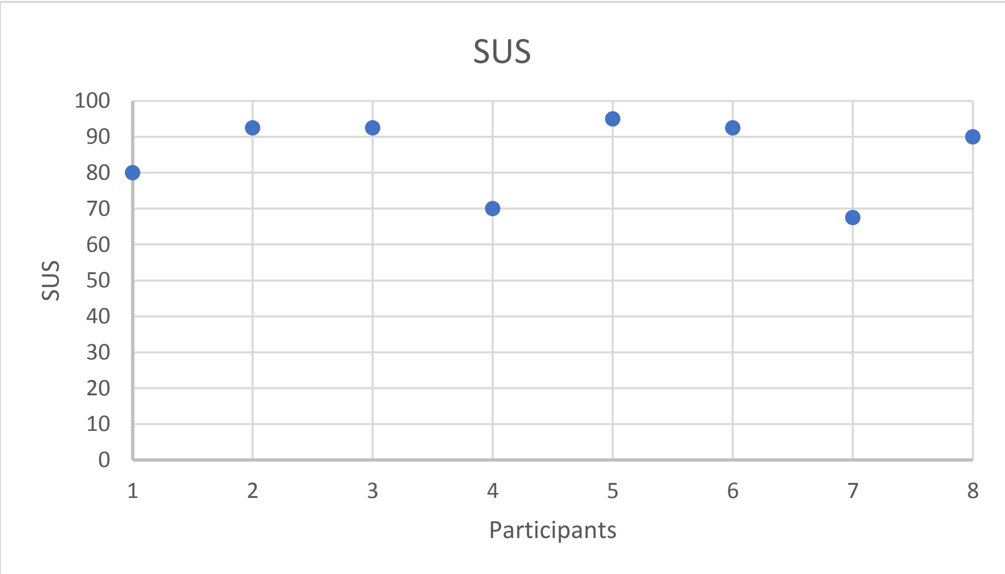

Figure 4.5 Scatter-dot plot of the responses to the SUS questionnaire.

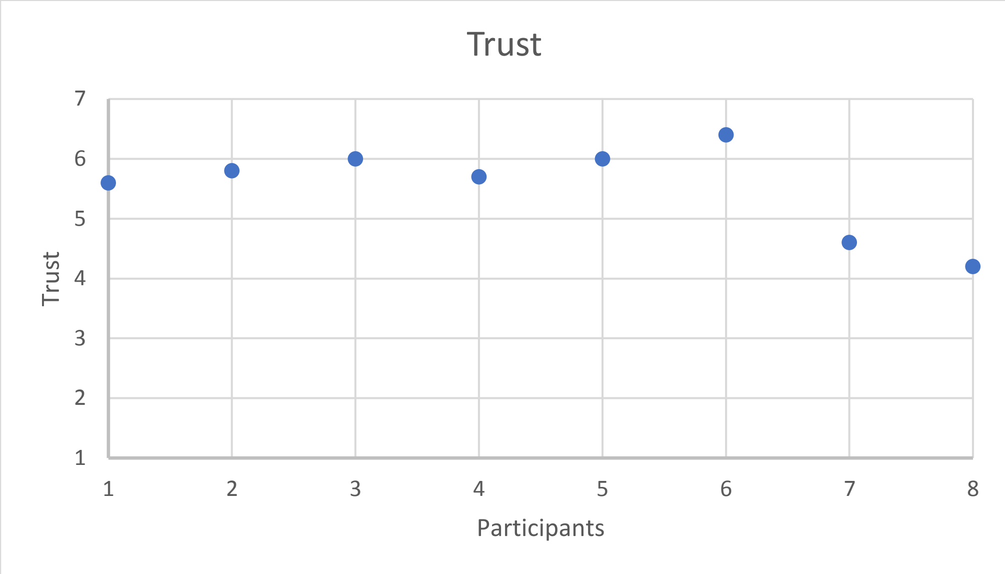

Figure 4.6 Scatter-dot plot of the responses to the trust questionnaire.

4.5.3.1 Regression

A regression was conducted to investigate the impact of usability on trust.

First of all, a scatter-dot plot was created to have a visual inspection of the data (Figure 4.7).

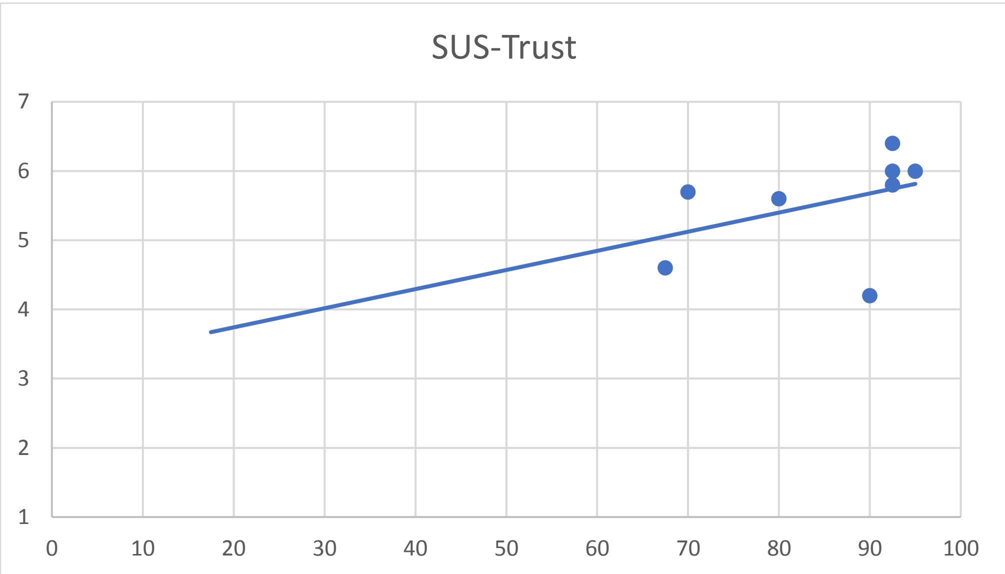

Figure 4.7 Scatter-dot plot of the interaction between SUS and trust.

The regression was not significant [F(1,6)= 2.103, p=.206]

4.5.4 Discussion

The main aim of this study was to investigate the relationship between usability and trust in a flight simulator. To do so, a regression was performed, with usability as independent variable and trust as dependent variable. The results show no significant results. This means that, for this particular system, usability does not influence trust.

The lack of significance in this study could be due to the small sample. Indeed, even though all the participants were professionals, and this was sufficient for the purpose of the main study, the sample size was possibly too small to show the relationship between usability and trust. Unfortunately, there was no possibility to recruit more participants, as pilots have a busy schedule.

Another explanation of the lack of significance could be due to the type of system or type of participants. In fact, it could be that the relationship between usability and trust is not present in flight simulators. This interpretation is not in line with the previous studies conducted for this project, which have found an effect of usability on trust in various VR systems (CAVE, desktop VR). There is no reason to doubt that the relationship exists also in a flight simulator.

The type of participants could also have influenced the results. In fact, it could be possible that the expertise of the sample affected the relationship between usability and trust. Contrary to the interpretation above, this interpretation cannot be compared with previous studies in this thesis, since all the participants in previous experiments were not experts.

However, a more possible interpretation is the small sample used. In fact, it is possible that with more participants, the results could have changed, or, if not, it could have been easier to give an exact interpretation of the lack of results.

Even though the results of the previous study seem to contradict the ones described in this section, there is the possibility already anticipated in the previous section, that usability has an indirect relationship with trust. In fact, it could be possible that the already weak direct relationships found in previous studies, were not detected here due to the small sample.

4.5.5 Conclusion

This study was part of a collaboration between the author of this thesis and Dr. Chrisminder Hare. In this chapter, the method and results concerning the aim of this project were presented. The aim of the study was to have another set of data on the relationship between usability and trust. This was particularly important because this experiment used a different VR system, which could not have been available for the PhD project. However, there was not the possibility to recruit a substantial number of participants and this could have affected the results of the experiments. In fact, no significant relationship was found between usability and trust.

Even though these results do not prove the initial hypothesis and are in contrast with the theorised framework described in chapter 2, it is not enough to reject entirely the possible influence usability has on trust.

4.6 Study 3 (Virtual Boot)

4.6.1 Introduction

The Virtual boot study was the result of a collaboration between the University of Nottingham and JLR and aimed to investigate the difference in width, height, depth and overall capacity perception of a load space between a real car and a virtual model of the same car.

The replacement of physical prototypes with VR systems in the automotive industry is a well-studied process that could be cost and time effective and increase the quality of the final product (Lawson, Salanitri and Waterfield, 2016). The study aimed at investigating the differences and similarities in users' perception between a real car and a virtual model.

The experiment was conducted at the JLR Virtual Innovation Centre with 46 participants (mean age = 36.5; SD = 13.21; 31 male) divided into two groups, one using a real car (Range Rover Evoque) and one using a virtual model of the car. For the purpose of this study, only the data of the second group will be analysed and discussed. For more information about the main study design and results see Lawson et al. (2017).

Concerning this thesis, the main aim of the study was to investigate the relationship between technology acceptance and presence with trust. In order to do so, three questionnaires were added to the design of the experiment, one measuring presence, one measuring technology acceptance and one measuring trust. The questionnaires were given only to the group using the VR system. In this experiment, usability was not measured because the participants did not have to actually interact with the system (see procedure section below).

To analyse the relationship between the three factors, a series of regressions were performed. The results show that there is a strong relationship between technology acceptance and trust, but no significant impact of presence was found.

4.6.2 Hypotheses

As stated in the section above, the main aim was to investigate the relationship between technology acceptance and presence with trust. The main hypotheses of the study were:

H1: there is a linear relationship between technology acceptance and trust

The first hypothesis states that technology acceptance has an influence on perceived trust in the VR system.

H2: there is a linear relationship between Presence and trust

The second hypothesis argues that presence will also have an impact on trust

H3: there is a linear relationship between technology acceptance, presence and trust when analysed together.

The third hypothesis combines the first two and states that if H1 and H2 are verified, the relationship still exists when the two factors (technology acceptance and presence) are analysed together as independent variables. This hypothesis aimed to discard possible indirect relationships between the factors and trust.

4.6.3 Methods

4.6.3.1 Participants

As stated in the introduction of this section, only the group using the VR systems will be considered here. The participants were 22 (Mean age= 36.41, SD= 12.31, 13 Male). The participants were recruited among staff at JLR. People susceptible to motion sickness and suffering from some symptoms enhancing cybersickness (such as migraine, epilepsy and being pregnant) were invited not to participate.

4.6.3.2 Materials.

4.6.3.2.1 VR

The VR system used was the JLR CAVE (for a description of this technology see the 3.5.2.1 section in the previous chapter).

Figure 4.8shows the real car (on the left) and the virtual model (on the right)

Figure 4.8 image of the real car (left) and the virtual model (right) used during the experiment. Image from Lawson et al. (2017).

4.6.3.2.2 Questionnaires

The questionnaire used were divided in pre and post interaction

4.6.3.2.2.1 Pre-interaction questionnaires

Demographic questionnaire with information on the participants age, sex, experience with VR (Appendix 1.7).

4.6.3.2.2.2 Post-interaction questionnaires

SSQ (Appendix 1.5)

The SSQ was used to assess the possible cybersickness symptoms that the participants could experience during the interaction.

Technology Acceptance Questionnaire (Appendix A1.1.2)

The questionnaire has been used in the literature to understand the level of technology acceptance of the users.

PQ (A1.3.2):

The presence questionnaire has been used to assess the level of presence perceived by the participants

Trust in Technology measure (A1.4)

The questionnaire has been used to assess the level of users' trust in the specific system.

4.6.3.3 Procedure

Before starting the interaction with the VR system, participants were asked to read the information sheet and sign the consent form and were reminded of possible side effects of using VR products. After that, participants completed the demographic questionnaire. Participants were then invited to stand in front of the virtual model behind a marker on the floor, positioned one meter from the front screen. The car had the load space open and visible. A virtual suitcase was placed in the load space as reference and the participants were invited to examine the load space. The suitcase was then removed and participants were asked to express their opinion on the overall capacity of the boot. After that, a virtual cube (10cmx10cmx10cm) was placed in the middle of the load space and participants were asked to give an approximation of how many cubes would fit the load space in width (left to right), depth (front to back) and height (top to bottom)

The participants were then asked to complete the post-interaction questionnaires.

4.6.3.4 Data analysis

First of all, the descriptive statistics (frequencies) were performed on the VR experience data taken from the demographic questionnaire, in order to understand the characteristics of the sample. Then the level of presence, technology acceptance and trust were calculated based on the questionnaire response.

To analyse the relationship between presence, technology acceptance and trust three regressions were performed, all had trust as a dependent variable and one with technology acceptance, one with presence and the other with technology acceptance and presence as independent variables. The last regression was performed only if the first two regressions were found significant.

4.6.4 Results

Table 4.1 summarises the participants' information about their previous VR experience.

Frequencies			
		Number	Percentage
VR Experience	I have never heard of Virtual Reality	0	0.0%
	I have heard of it but do not know what it is	1	4.5%
	I have some idea of what VR is	0	0.0%
	I know what Virtual Reality but have never seen or used it	1	4.5%
	I have seen a Virtual Reality system in use	6	27.3%
	I have used a Virtual Reality system once or twice	12	54.5%
	I have often used Virtual Reality	2	9.1%
	I use Virtual Reality almost every day	0	0.0%
	Total	22	99.9% (approximation)

Table 4.1 Frequencies of the demographic data for VR experience.

As can be seen from the table, most of the participants had used VR once or twice. The participants had an average 12.5 years of experience in automotive industry (SD=12.9).

In the graphs below (Figure 4.9, Figure 4.10 and Figure 4.11), the responses to the presence trust and usability questionnaires are depicted.

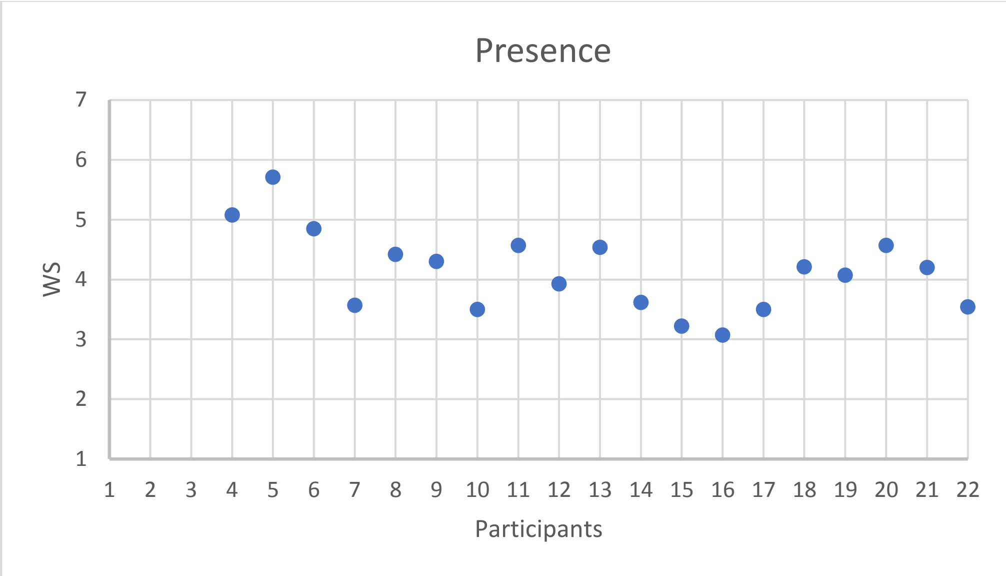

Figure 4.9 Scatter-dot plot of the responses to the WS questionnaire.

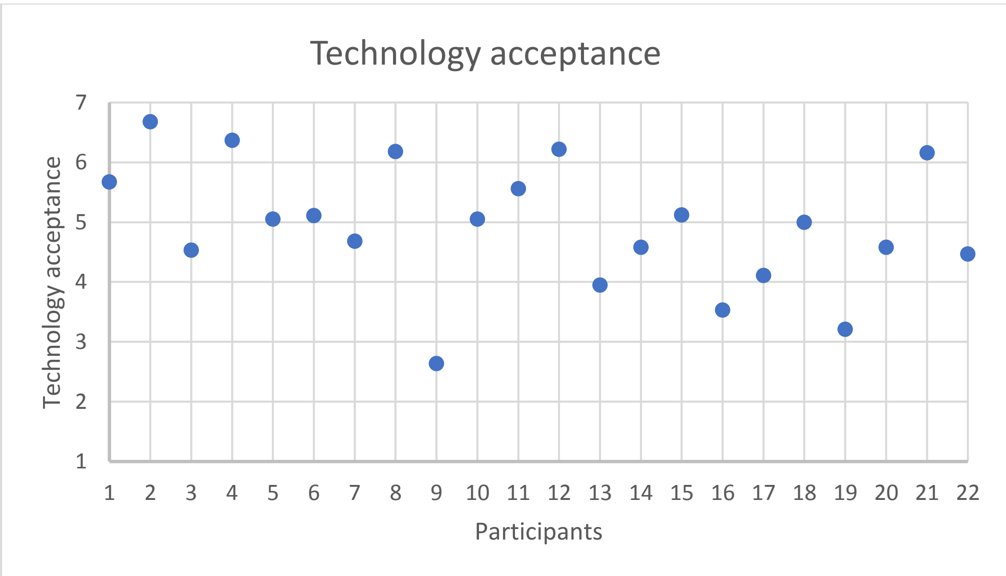

Figure 4.10 Scatter-dot plot of the responses to the technology acceptance questionnaire.

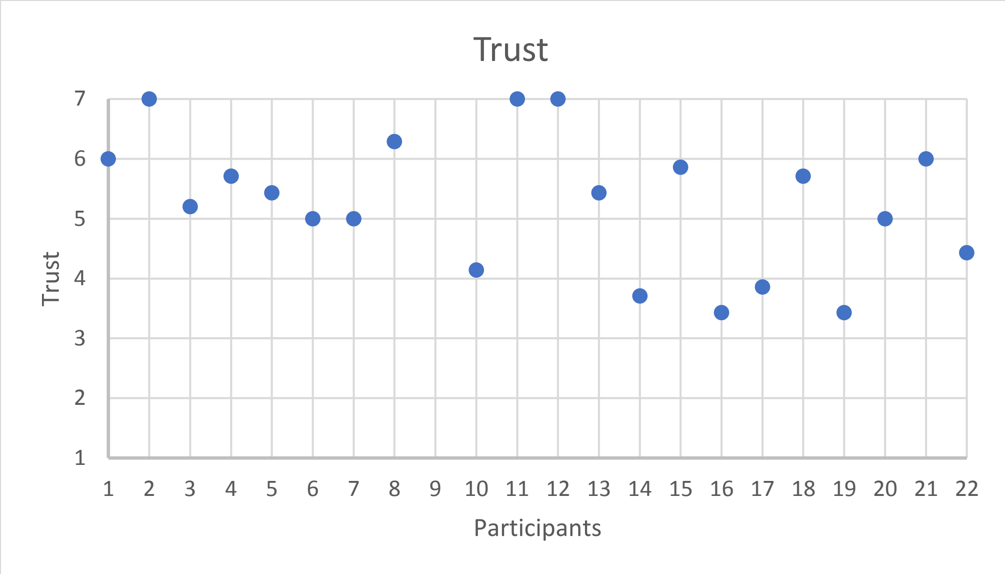

Figure 4.11 Scatter-dot plot of the responses to the trust questionnaire.

4.6.4.1 Regressions

As anticipated in the method section three regressions were performed to investigate the various relationships between the factors.

4.6.4.1.1 Technology acceptance - trust

The first regression was with technology acceptance as independent variable and trust as dependent variable. The results are presented below. Figure 4.12 presents a visual assessment of the relationship.

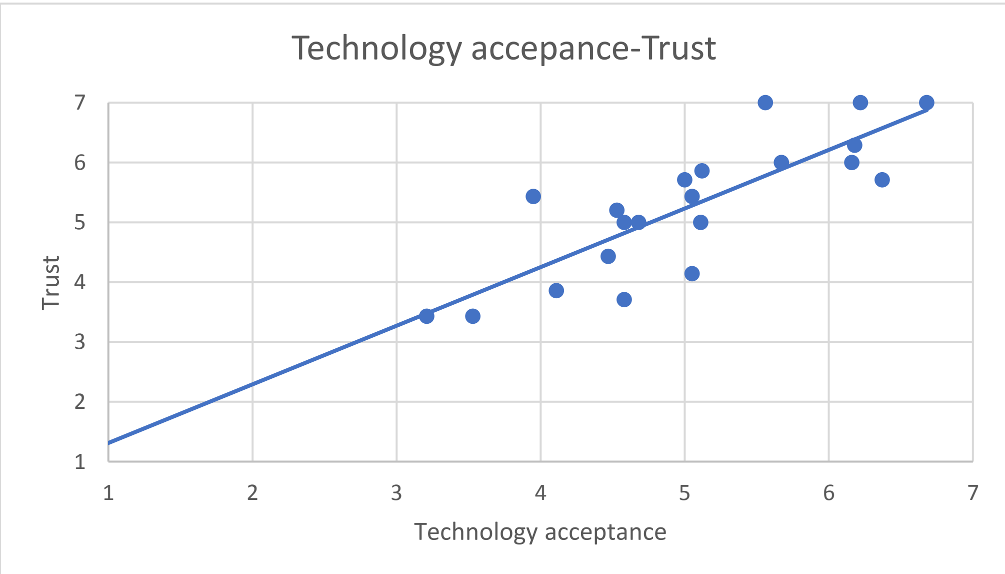

Figure 4.12 Scatter-dot plot of the interaction between technology acceptance and trust.

The regression was significant [$F(1,19)= 40.569$, $p<.001$)] with technology acceptance accounting for 66.4% of trust (Adj R^2=.664).

4.6.4.1.2 Presence - trust

The second regression was conducted to analyse the relationship between presence and trust, thus, presence was the independent variable and trust was the dependent variable.

The scatter-dot plots depicted below (Figure 4.13) was created to visually inspect the relationship between the two factors.

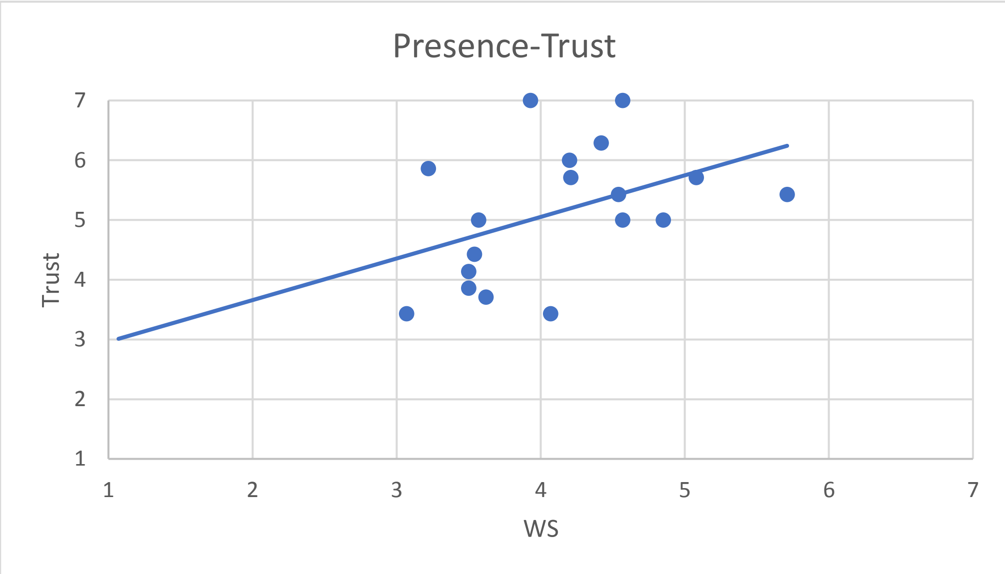

Figure 4.13 Scatter-dot plot of the interaction between technology acceptance and trust.

The regression was not significant [F(1, 16)= 3.701, p=.072]. Therefore, it can be said that there is not an impact of presence on trust in this study.

The lack of results could be due to the study design and the length of the procedure. However, the discussion section will cover more in depth the possible interpretations of these results.

The third regression was designed to analyse the relationship between technology acceptance and presence together with trust. However, given the no significant result of the last regression, this one was not performed.

4.6.5 Discussion

The part of the study concerning this thesis aimed to investigate the relationship between technology acceptance and presence with trust. In order to do so, three regressions were planned and performed, one with technology acceptance, one with presence and one with technology acceptance and presence as independent variables; all three with trust as a dependent variable. As can be seen from the results, the regression between technology acceptance and trust was significant. On the contrary, the regression with presence was not significant. The lack of significance could have two possible interpretations. One concerns the lack of interaction participants had with the system. In fact, as explained in the procedure section (section 4.4.3.3) , there was no interaction with the system at all. This could have influenced the immersion people felt (Lessiter et al., 2001). Another interpretation could be due to the short time people invested in the CAVE. In fact, the procedure required the participants just to express their opinion, therefore the time they spent in the CAVE was very limited. Another possible interpretation could be a combination of both these factors. A study should be designed with the sole purpose of understanding the relationship between presence and trust. Given the lack of significance of the regression between presence and trust, the last regression with technology acceptance and presence together as independent variables was not performed.

4.6.6 Conclusion

As said in the introduction the collaboration in this study was aimed at investigating the relationship between technology acceptance and presence with trust. The hypotheses were that both technology acceptance and presence, when analysed alone and together as independent variables, would influence trust. The results only prove the part referred to technology acceptance which seems to have a strong influence on trust. On the other hand, no results were found on presence. These results are in line with the results of the first study presented in chapter 3, which suggest that technology is the best predictor of trust.

4.7 General Discussion

During the process of designing the experiments to validate the framework explained in chapter 2, three collaborations were made with three researchers at the HFRG at the University of Nottingham. The collaborations added more data on the relationship between usability, technology acceptance, presence with trust. In particular two of the three studies focused on the relationship between usability and trust, while the third focused on the relationship between technology acceptance and presence with trust. The results suggest that usability has an influence on trust, even though it seems to be weaker than expected. Particularly, in the first study a relationship between usability and trust was found, even if with a low Adj R^2 value, while no significant relationship was found in study 2. As stated in section 4.5.4, the sample size could have played a major role in the results. The results of the third study showed that technology acceptance has a strong impact on trust, while presence was not found to be significantly related to trust. As anticipated at the end of the last chapter, the design of the experiments could greatly influence the results about presence, which needs interaction, a sufficient amount of time inside the VR system and the need for the participant to feel inside the environment to be experienced (Lessiter et al., 2001).

These results are in line with the ones described in the previous chapter. The next chapter will focus on the relationship between presence and trust, given the aforementioned uncertainty around the relationship thus far.

5. Chapter 5- Presence Study

5.1 Chapter description

The results of the experiments described in chapter 3 and 4 demonstrated that relationships exist between usability and trust and technology acceptance and trust. However, the same cannot be said regarding presence and trust. In fact, the studies described in previous chapters did not find any relationship between presence and trust. However, as explained in the discussion sections of both the studies (sections 3.8 and 4.6.5), some experimental design issues may have influenced the results. For this reason, a new experiment was designed with the sole purpose of investigating the relationship between presence and trust. In fact, in order to validate the framework described in chapter 2, it is fundamental to understand if and how presence influences trust in VR.

The experiment presented in this chapter was designed as a between-subjects study. Participants were divided into two groups; one using a low immersive VR system and one using a high immersive Head Mounted Display (HMD). Measures of presence (both objective and subjective) and trust were taken. The results of the study show that there is a relationship between presence and trust in VR. However, this relationship depends on the questionnaires used to measure presence.

This chapter describes the reasons for the study, the process of design and the method used. Moreover, it will gather the results and then the discussion and conclusion. This experiment represents an additional step to the final validation of the framework.

5.2 Introduction

The studies described in chapters 3 and 4 were conducted to investigate the relationship between usability and trust and technology acceptance and trust, in order to add information on the validity of the framework described in chapter 2. The next step towards the final validation of the model was to investigate the relationship between presence and trust. In fact, even though presence was included in the pilot study (chapter 3) and in the boot study (chapter 4), the design of the experiments had limitations in the procedure, which could have influenced the relationship (i.e. constant interruption in the pilot study and lack of interaction with the VR system in the boot study).

As stated in the literature review chapter (chapter 2), presence is a complex factor. In fact, even though it has been investigated for decades, there is still debates on its definition and measurement. Even the most commonly used definition, the sensation of being in one place while situated in another (Witmer and Singer, 1998), has been expanded or completely changed by other researchers (Draper, Kaber and Usher, 1998; Slater, 2009). The same can be said about the measurement of presence. There is still debate on whether questionnaires alone can actually measure presence or if other measurements should be added (physiological, behavioural….) (Slater, 2004). This study tried to overcome some aspects of presence such as the questionnaire used and the addition of objective measures. In fact, as will be described in the method section of this chapter, two of the most commonly used questionnaire of presence were used: The PQ (Witmer and Singer, 1998) and the S.U.S. (Slater, Usoh and Steed, 1994). In addition, the recording of the users' EDA was added as objective measure, since previous studies found that it is a reliable measure of presence (Wiederhold et al., 2001; Meehan et al., 2002). These measures were introduced to give a clearer idea on the relationship between presence and trust.

Other than assessing the existence of the relationship between presence and trust, this study also aimed to have a clearer idea on how this relationship works in different VR systems.

Another aim of this study was to understand the influence of users' characteristics in the relationship between presence and trust.

50 participants were recruited and randomly assigned to one of the two groups described before.
The study was approved by the University of Nottingham Faculty of Engineering Ethic Committee.

The next sections will give a more detailed explanation of the study.

5.2.1 Hypotheses

As stated in the introduction, the main aim of the study is to investigate the relationship between presence and trust. Therefore, the first hypothesis is:

H1: A linear relationship exists between presence and trust.

As described before, presence has a subjective and objective nature. The study aimed to investigate the relationship between both the measures with trust. Thus, H1 was divided in two hypotheses:

H1a: There is a linear relationship between the subjective measures of presence and trust

H1b: there is a linear relationship between the objective measures of presence and trust

In the study, the participants were divided into two groups, one using a high-immersive system and another one using a low-immersive system to assess the nature of the relationship in different VR systems. Therefore, the H2 hypothesis is:

H2: the linear relationship between presence and trust exists regardless of the system used.

The literature on trust and presence states that trust is composed by technology characteristics and users' characteristics. One of the aim of this study was to confirm this:

H3: Pre-interaction trust will have an influence on the relationship between presence and trust

The influence of the pre-interaction trust on the model was already investigated in the pilot study (chapter 3) which demonstrated that there is no effect of pre-interaction trust on trust when considered together with usability, technology acceptance and presence. This study will analyse the effect when only presence is considered.

5.3 Method

5.3.1 Participants

50 participants (mean age= 27.38, SD= 6.605; 29 Males) were recruited. The process of recruitment was carried out with posters, through mailing lists for student and staff at the university and through specialised websites and social networks.

All the participants interacted with a VR environment and had to perform three different driving tasks. In order to understand whether the relationship between presence and trust is influenced by the level of presence perceived, the participants were randomly divided into two groups, one using a low immersive system (control group) and one using a high immersive system (VR group). The systems are described in the next section.

5.3.2 Materials

5.3.2.1 VR

As stated in the last paragraph, two different systems were used in the experiment. The Oculus Rift® DK2 was used as a high immersive system and a normal 15" PC desktop was used as a low-immersive system. Both the systems were set to be at the highest resolution available (1280x720 for the oculus and 1600x900 for the desktop).

5.3.2.2 Controllers

The participants of both groups used the Logitech® steering wheel and pedals to interact with the environment. Figure 5.1 depicts the HMD and the controllers.

Figure 5.1 Equipment used in the study.

5.3.2.3 Environment

The environment was the same for both the groups and was the race simulator Live for Speed®. The environment was chosen because of the compatibility with the Oculus rift. Figure 5.2 shows a screenshot of the participants view through the desktop VR and HMD.

Figure 5.2 Screenshot of the environments used: desktop VR on the left and HMD on the right.

5.3.2.4 *Measures*

As stated in the introduction, two measures were used in this experiment, objective measures of presence (EDA) and subjective measures (questionnaires).

5.3.2.4.1 EDA

To measure the EDA, the Empatica® E4 wristband was used. The E4 gathers the skin conductance with a frequency of 4Hz.

5.3.2.4.2 Questionnaires

The questionnaires were divided in pre-interaction questionnaires and post-interaction questionnaires.

5.3.2.4.2.1 Pre-Interaction

Demographic questionnaire (Appendix 1.7): useful to understand and investigate the influence of demographic variables.

Pre-interaction trust questionnaire (Appendix 1.6). Useful to investigate the users' characteristics in the perception of trust in technology.

5.3.2.4.2.2 Post-interaction questionnaires

The PQ (Appendix A1.3.3) and the **S.U.S. (Appendix A1.3.4)** to assess presence.

The Technology Trust Measure (Appendix 1.4) to assess the level of trust in VR.

The SSQ (Appendix 1.5): to assess the possible cybersickness symptoms that the participants could experience during the interaction. The SSQ was given to participants after each interaction

5.3.3 Tasks

The participants of each group had to perform three tasks. The first task was a driving lesson. The participants had to drive in a circle, controlling the acceleration and break. The circles were marked with street cones. The task was completed if the participants managed to complete two circles in twenty seconds without hitting any cones. In the case that the participants did not complete the two circles in time, the game stopped and the attempt was declared failed. In case the participants hit one or more cones during the race they could still finish the race, but the attempt was declared failed. The participants had a total of three attempts to complete the task. In case all the three attempts failed, the experiment progressed to the next task. In case the participants passed the task in the first or second attempt the possibility to use the next attempt(s) to improve their time was given. However, this was not mandatory. The level of the lesson was set as beginner and the car used was the easiest to drive.

The second task was also a driving test. Participants had to reach the end of a small circuit marked by street cones. The circuit was composed of two curves and two straight line. The rules of the task were the same as the first task, but with a shorter time limit (fifteen seconds). Similar to the first task, participants had three attempts to pass the test and the possibility to improve the time was given in the case they passed the task in the first two attempts. The level of the second task was set as beginner, but the car used was more difficult to control in comparison to the first task. The last task consisted of a two-lap race. The participants competed against four other cars controlled by the game. In this task, there was no time limit and no possibility to fail. The car used in this task was the same as the one of the first task.

5.3.4 Procedure

The entire procedure lasted approximately 45 minutes. The participants were invited to read the information sheet and sign the consent form. For participants in the VR group, the possible side effects of using VR products were explained and the participants were made aware that, in case of cybersickness, the experiment would immediately stop. Participants were also reminded that the participation was voluntary and they could withdraw from the study at any point, without the obligation to reveal the reason. Each participant was given a £5 Amazon voucher as compensation to participate, regardless of the completion of the study.

After the participants signed the consent form, the pre-interaction questionnaires were given. Once the participants completed the questionnaires, the wristband was given to the participant. After that, the researcher asked the participants to relax for a period of two minutes, in order to have a baseline measure of the skin conductance.

After the baseline was taken, the participants were invited to sit in front of the VR system and a trial started. The trial consisted of a lap in a circuit. For the trial, a line was painted on the street to give the best trajectory the car should follow. In addition, the line was green when the participants were supposed to accelerate, yellow for decelerate and red for breaking. With this method, the participants could not only get familiar with the controller, but also with the game.

After the trial, the participants started the tasks described in the previous paragraphs. After each task (not each attempt) the SSQ was given. After the third task was completed, the researcher stopped the EDA recording and gave the post-interaction questionnaires.

Figure 5.3 shows the setup of the experiment.

Figure 5.3 Setting of the experiment.

5.3.5 Data Analysis

To investigate the nature of the sample, frequencies were performed on the data taken from the demographic questionnaire.

To investigate the relationship between perceived presence and trust, two regressions were conducted, both with trust as dependent variable and one with the S.U.S and the other with PQ as independent variables.

The data from the EDA were analysed using the software LEDALAB® which is specific for EDA data. In the software, a continuous decomposition analysis was performed and the result was the average phasic activity within the interaction period given in micro siemens (µS) (Benedek and Kaernbach, 2010).

To understand the relationship between the objective measures of presence and trust, another regression was performed with the EDA measures as independent variable and trust as dependent variable.

To assess the influence of pre-interaction trust on the relationship between presence and trust, a forward regression was performed (Brace, Kemp and

Snelgar, 2000), with pre-interaction trust and presence as independent variables and trust as dependent variable.

5.4 Results

5.4.1 Demographic

Table 5.1 shows the frequencies performed to understand the VR experience.

VR Experience	I have never heard of Virtual Reality	2	4%
	I have heard of it but do not know what it is	1	2%
	I have some idea of what VR is	5	10%
	I know what Virtual Reality but have never seen or used it	10	20%
	I have seen a Virtual Reality system in use	6	12%
	I have used a Virtual Reality system once or twice	20	40%
	I have often used Virtual Reality	5	10%
	I use Virtual Reality almost every day	1	2%
	TOTAL	50	100%

Table 5.1 Frequencies of the demographic data for VR experience.

As explained in the introduction, the main aim of the study was to understand the relationship between presence and trust in VR. In this experiment, two types of presence measures were gathered: subjective (questionnaires) and objective (EDA). In order to analyse the relationship between these measures and the measure of trust, three different regressions were performed, two for the subjective measures and one for the objective ones.

However, before analysing the various relationships, it is useful to investigate the level of presence and trust in the two groups. Box plots were created to visually summarise the data (see Figure 5.4 - Figure 5.6).

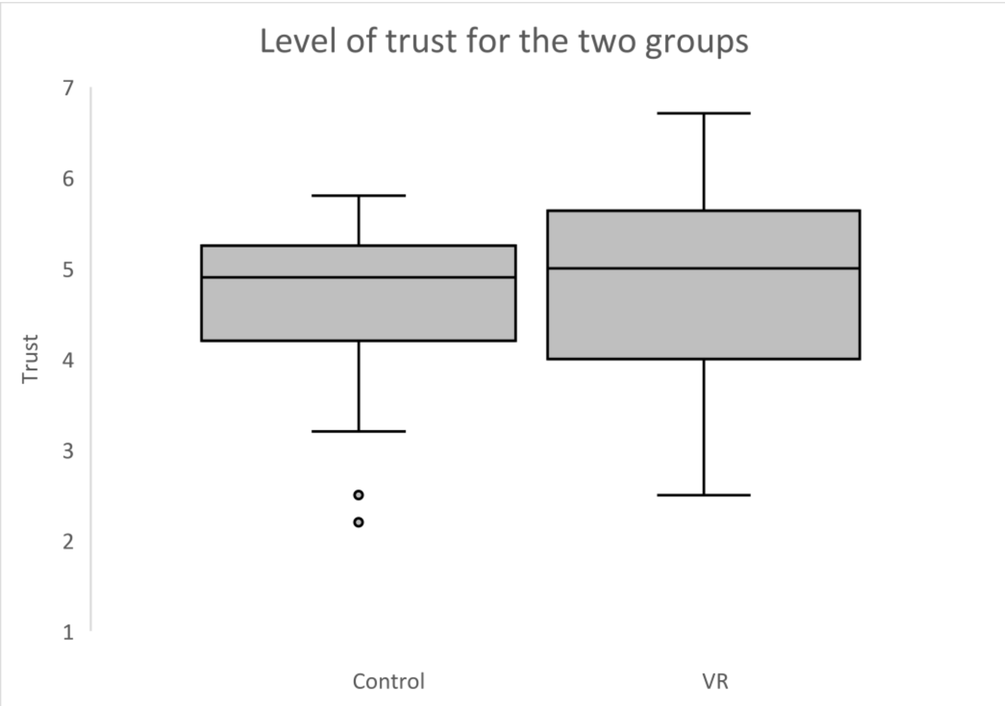

Figure 5.4 Box-plot of the trust questionnaire responses for the control group and the VR group.

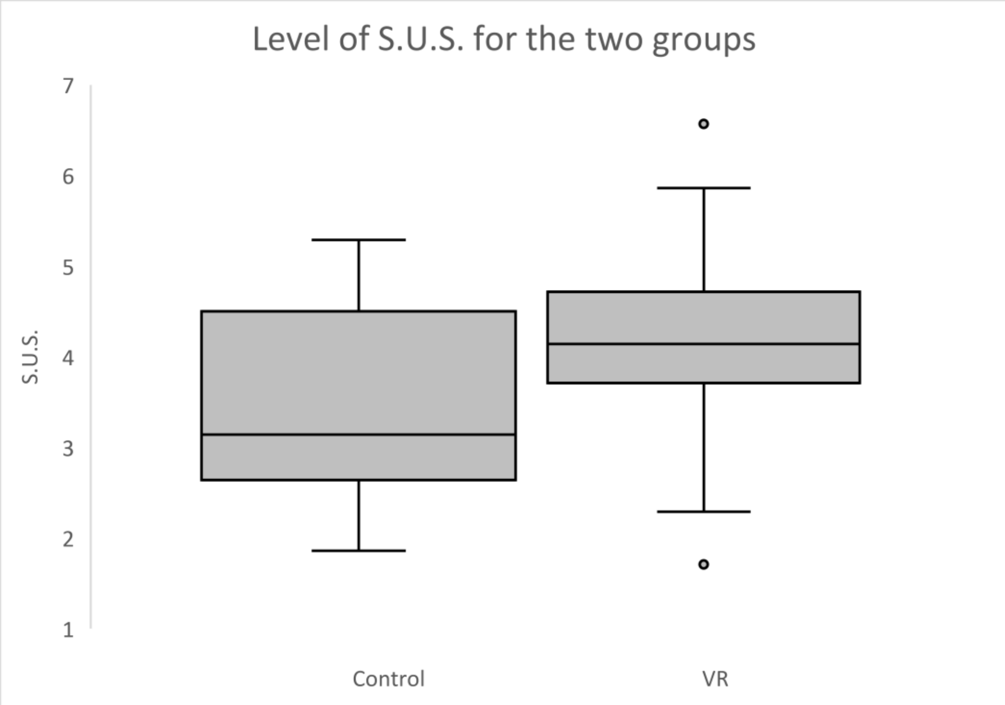

Figure 5.5 Box-plot of S.U.S responses for the control group and the VR group.

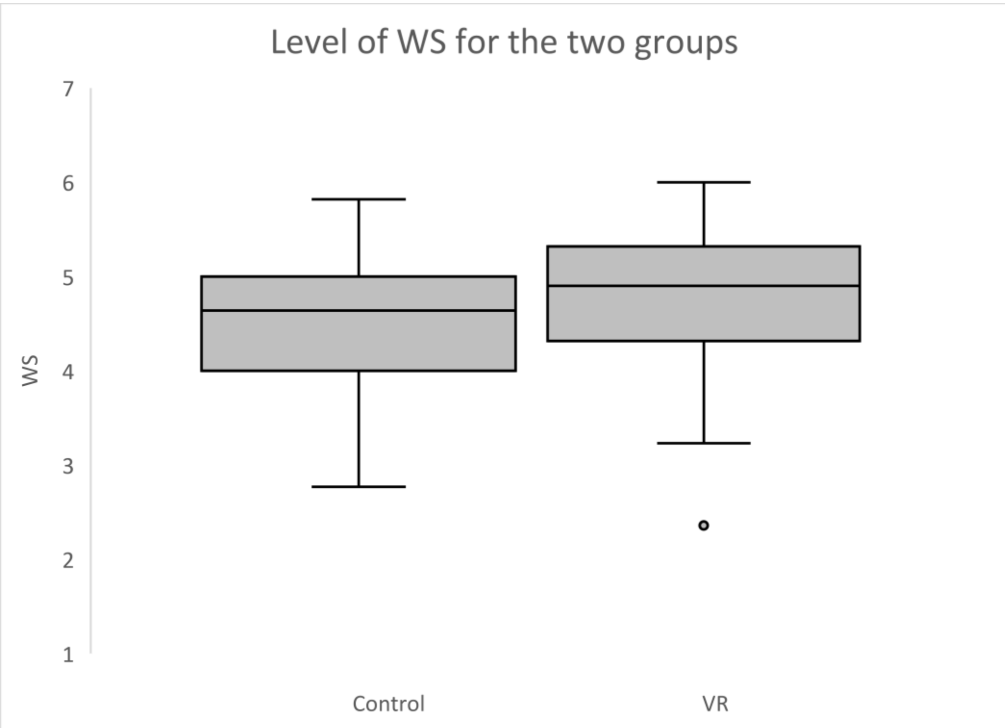

Figure 5.6 Box-plot of the PQ responses for the control group and the VR group.

The graphs show that there may be outliers in the data. In addition, it seems that there is no difference between the two groups in the level of the factors measured. These assumption will be statistically verified in the next sections.

Another graph was built with the results from the SSQ after the first task, the second and the third.

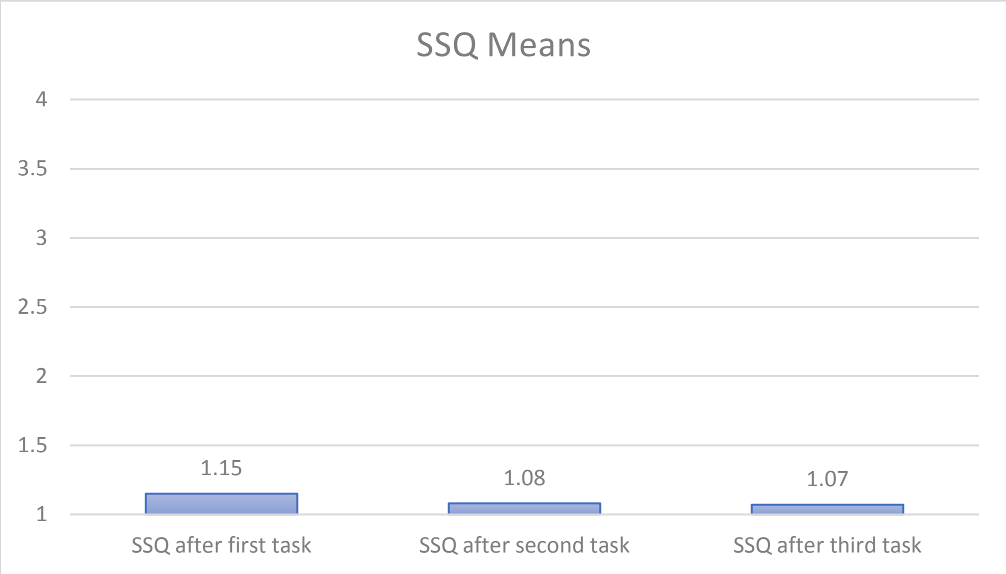

Figure 5.7 Levels of cybersickness as measured with the SSQ (1=none, 2= slightly, 3=Moderate, 4=Severe) for the VR group.

As can be seen from the graph, the level of cybersickness was low after every task.

5.4.2 Relationship between subjective measures of presence and trust.

First, the subjective measures of presence were taken into consideration. To investigate if there was a relationship between the reported presence and trust two regressions were performed: one with the PQ as independent variable and one with the S.U.S. as independent variable. For both the regression the dependent variable was trust. The results of the regressions are presented below.

5.4.2.1 Presence questionnaire - trust

First of all, a scatter-dot graph was created to have a visual representation of the relationship (Figure 5.8).

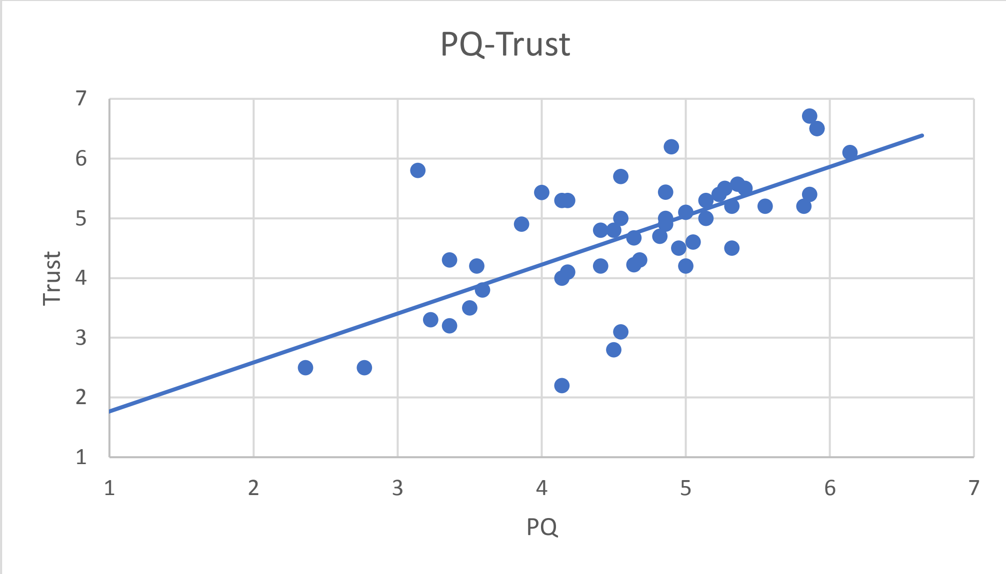

Figure 5.8 Scatter-dot plot of the interaction between PQ and trust.

The regression was significant [F(1,48)= 40.304, p<.001)] with presence (as measured with PQ) accounting for 44.5% of trust (Adj. R^2=.445).

5.4.2.2 S.U.S. questionnaire and trust

Figure 5.9 depicts the relationship between the S.U.S questionnaire and trust.

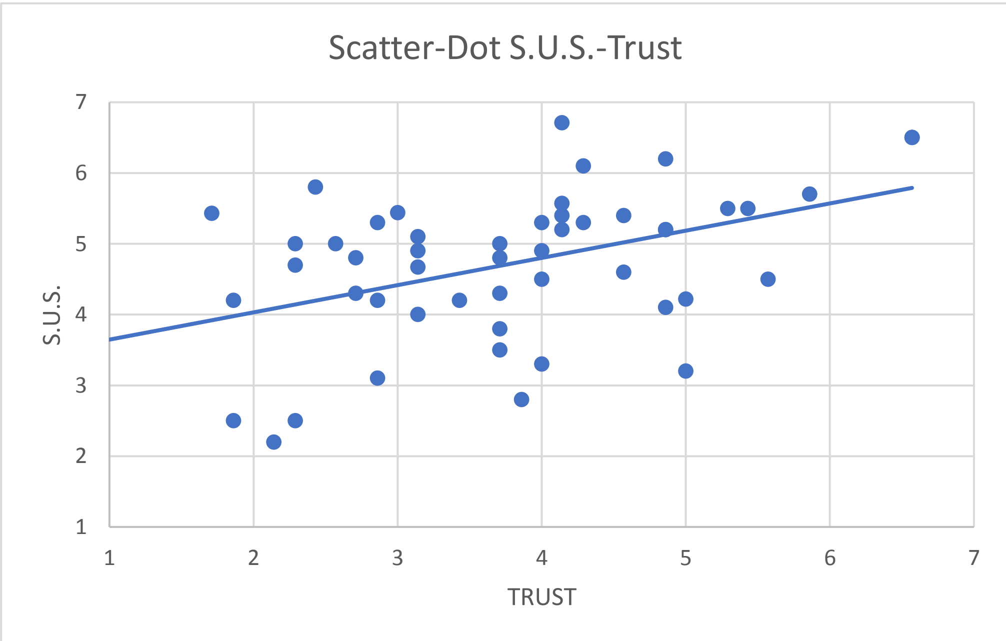

Figure 5.9 Scatter-dot plot of the interaction between S.U.S. and trust.

The regression was significant [F(1,48)= 11.311, p=.002] with presence (as measured with SUS) accounting for 17.4% of trust.

As can be seen from the results, both the regressions are significant. Thus, there is a relationship between presence and trust. However, it seems that presence as measured with the PQ has a bigger impact on trust, compared to presence as measured with S.U.S.

5.4.3 Relationship between objective measures of presence and trust

After stating that there is a relationship between the reported presence and trust, it is useful to understand if the objective measures follow the same tendency. Thus, a regression was performed with the results of the EDA during the interaction period and trust.

For this regression the trust data were transformed with a "reflect and square root" transformation, as the original data were not respecting the assumptions. The new data respected all the assumptions.

The regression was not significant [$F(1, 45)=.915$, $p=.344$)

This result could mean that there was not an influence of the objective measures of presence on trust. These results raise an issue: if the subjective measures of presence have an impact on trust and the objective measures do not, do they measure the same thing? To understand this, a correlation was performed between the subjective measures of presence and the objective ones. The results showed that there was no significant correlation between the variables (EDA-S.U.S.: $r=-.002$, $p=.178$; EDA-PQ: $r=.007$, $p=.962$). These results will be discussed in section 5.5.

5.4.4 Difference between groups

As described in the method paragraph, the participants were divided in two groups. The aim of this design method was to understand if there is a difference in the influence presence has on trust for different VR systems. In order to analyse this hypothesis, first a t-test was performed to see the difference in the level of presence (PQ, S.U.S. and EDA) and trust in the two groups. The results are shown in Table 5.2.

	F	Sig.	t	df	Sig. (2-tailed)
PQ	.576	.452	1.252	48	.217
SUS	.067	.797	2.315	48	.025
TRUST	2.842	.098	.788	48	.435
EDA	.501	.483	.586	45	.561

Table 5.2 T-test for PQ, S.U.S., trust and EDA between the two groups.

The results of the t-test revealed that there was only a statistically significant difference for S.U.S between the two groups.

5.4.4.1 Regression only for the S.U.S. measure

To understand if this difference influenced the relationship between S.U.S. and trust a regression for each group was performed with trust as dependent variable and S.U.S as independent variable.

Two scatter-dot plots were created to have a visual representation of the relationships (Figure 5.10, Figure 5.11)

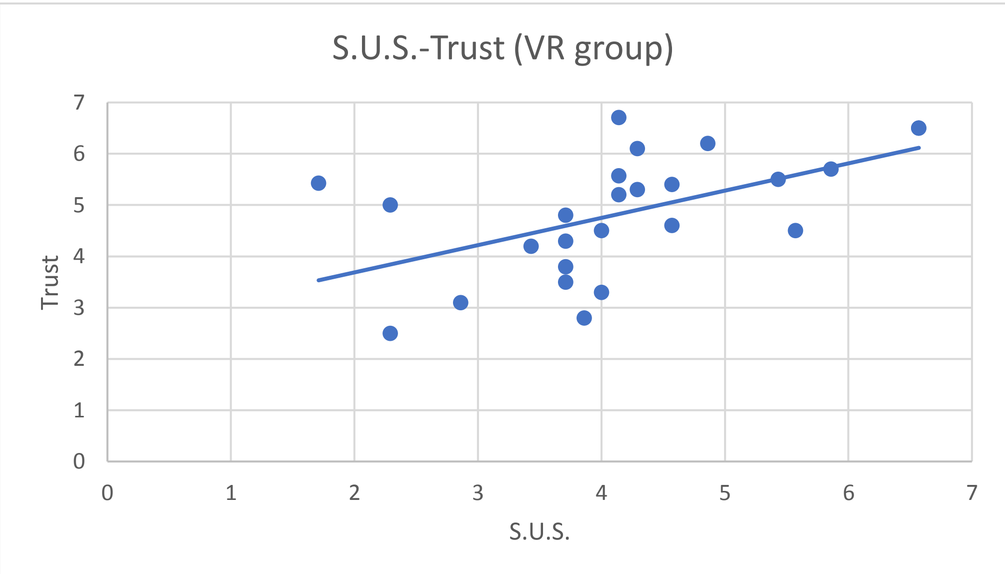

Figure 5.10 Scatter-dot plot of the interaction between S.U.S. and trust for the VR group.

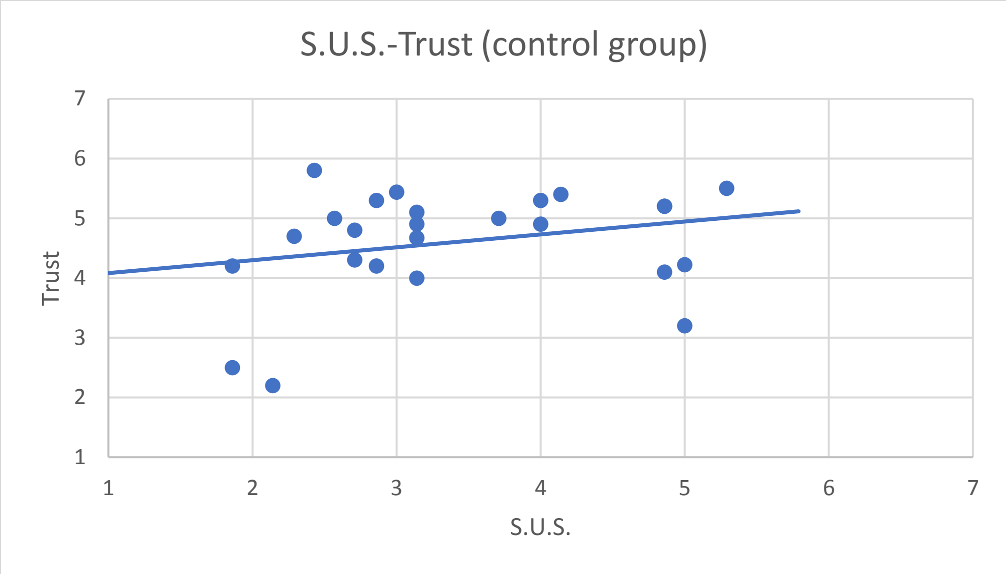

Figure 5.11 Scatter-dot plot of the interaction between S.U.S. and trust for the control group.

The regression between S.U.S. questionnaire and trust was significant in the VR group [F(1,23)=9.457, p=.002] with the S.U.S questionnaire accounting for the 26.1% of trust. For the control group, the regression was not significant [F(1,23)=1.633, p=.214].

5.4.5 Trust as multidimensional concept

To investigate the influence of pre-interaction trust on trust, a regression was performed with pre-interaction trust as independent variable and trust as dependent variable..

First of all, a scatter-dot plot between pre-interaction trust and trust was created (Figure 5.12).

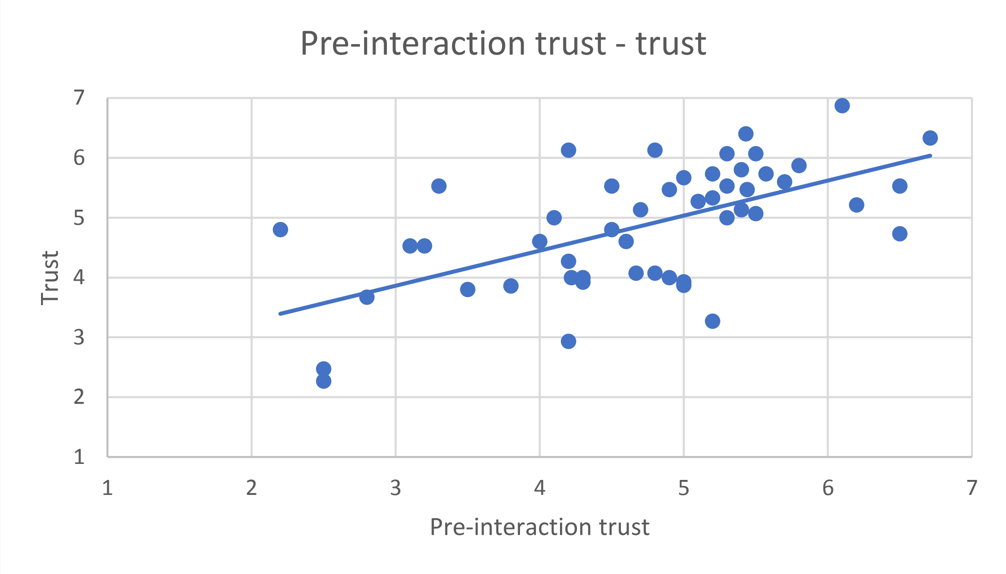

Figure 5.12 Scatter-dot plot of the interaction between pre-interaction trust and trust.

The regression was significant [F(1,48)=26.93, p<.001] with pre-interaction trust accounting for the 34.6% (Adj. R^2= .346) of trust.

The results show that there is an influence of pre-interaction trust on trust. This result was expected and it is in line with the literature (McKnight et al., 2011).

5.4.6 Regressions with “forward” method

To investigate how user characteristics influence the relationship between presence and trust, two regressions were performed with a forward method. The forward regressions will permit to see what factor has a bigger impact on trust between users’ characteristics and presence. The results are presented below.

Participant 46 was removed from the analysis as they were identified as an outlier using the casewise diagnostic method.

For both regressions, the best model was the one including pre-interaction trust in the independent variables. The regression with PQ and pre-interaction trust as independent variables accounted for 61.7% of trust [F(2,46)=39.716, p<.001; Adj R^2= .617] and the regression with S.U.S and pre-interaction trust as independent variables accounted for 47.2% of trust [F(2,46)=22.484, p<.001; Adj R^2=.472].

5.4.7 Measures of presence

In this study, one of the main factors studied was presence. As stated in the introduction, presence is one of the most studied characteristics in VR field. One of the main issues with presence has been the way to measure it. In this experiment, other than subjective and objective measures, two questionnaires were used to assess the level of reported presence. Given the different results of the questionnaires, it was useful to understand if the two measures were, in fact, correlated. This was needed mainly to investigate if the two questionnaires measure the same concept.

In order to verify this issue, a correlation was performed between the two questionnaires. The results show that there is a moderate positive correlation between the two measures ($r=.515$, $p<.001$), which may be too low for two questionnaires measuring the same concept.

5.5 Discussion

As stated in the introduction, the main aim of this study was to understand if presence has an influence on trust in VR. The results of this experiment gave a clearer idea of this relationship. The main statistics used to verify the existence of a relationship between presence and trust were two regressions, one with the PQ questionnaire and one with the S.U.S. questionnaire as an independent variable. Both of the regressions had trust as a dependent variable. The results were in line with the first hypothesis: there is a linear relationship between perceived presence and trust. This is the first experiment in this thesis where the relationship between presence and trust was verified. This result demonstrated that when the design of the experiment is aimed at the measure of presence, the relationship exists..

However, there is a difference between the two questionnaires of presence. Indeed, when presence is measured with the PQ questionnaire, the regression presents higher coefficients. This difference could be due to the issue, anticipated in the introduction chapter, of presence measurement. In order to try to solve this, an objective measure was also taken: EDA. EDA has been seen to be an indicator of presence (Wiederhold et al., 2001; Meehan et al., 2002). This measure could help to identify which questionnaire would be the best for measuring presence. However, the results of this experiment did not give any more information on the validity of the questionnaires. In fact, the EDA data did not correlate with the questionnaires and did not have any type of relationship with trust. This lack of results could be due to problems in the experiment design and in the tools used to measure EDA. In fact, the tasks may not have been suitable for the physiological measure of presence. Specifically, in the literature, when EDA was measured there was an event in the scenario able to trigger a response (Meehan et al., 2002), this was not included in this study. In addition, the constant movement and vibration of the steering wheel could have influenced the data gathering and the results. Another possible explanation of these results could lie with the tool itself. The device used to collect the EDA data was the Empatica® E4 wristband. This device, unfortunately, has a low frequency, recording only four data per second.

Once the relationship between reported presence and trust was demonstrated, one of the objectives of this study was to understand if there are differences in this relationship for different VR systems. In fact, in the experiment, participants were divided in two groups, one using a high-immersive system and one using a low-immersive system. The hypothesis was that, regardless of the system used, the relationship still existed. First of all, however, it was useful to understand if there were any differences between the two groups in the level of presence and trust. To assess this a t-test was performed. The t-test was significant only for S.U.S. This means that there was no difference in the level of trust or presence as measured with PQ between the two groups, but there was a difference in presence measured with S.U.S. Since there is a difference in the S.U.S results, it could be that the relationship between SUS and trust was different in the two groups. Therefore, two regressions were performed between S.U.S (independent) and trust (dependent) the results showed that in the control group there is not a significant relationship between presence and trust when measured with the

S.U.S. questionnaire. The hypothesis that the relationship between presence and trust exists regardless of the environment used is, therefore, partially verified. These results highlight, once more, one of the main issue of presence: its measurement. Questionnaires are useful to understand the perceived presence, but may be not enough to investigate difference in VR systems (Slater, 2004) and this is confirmed in this study by the difference in results for different type of measures. However, one aspect that was the same for both the questionnaires, was the relationship with trust. That is the main aim of the study.

To understand how user characteristics influence the relationship between presence and trust a forward regression was performed for each presence measure, adding also pre-interaction to trust. The results of the regressions show that there is an impact of the pre-interaction trust in the relationship between presence and trust. The impact of pre-interaction trust is, however, different depending on the questionnaires used to investigate presence. These results contrasts with the results of the pilot study. However, as stated in the introduction of this chapter, the pilot study investigated usability and technology acceptance together with presence. A possible interpretation of this difference is that pre-interaction trust has a minor effect on trust when only presence is investigated and when adding usability and technology acceptance, the influence of pre-interaction characteristics is not significant. This could be due to the possible impact that technology acceptance or usability have on trust. This interpretation was investigated further in last study, described in the next chapter.

Through the whole discussion it can be seen that the way presence was measured had an impact on various results. This means that there is a difference on what PQ and SUS measure. To validate this, a correlation analysis was performed and, even though the correlation was significant, the value was too low for two questionnaires measuring the same concept. In this experiment, the two questionnaires were chosen to have two different perspectives when assessing the relationship with trust, so some differences between the two could have been expected. However, the differences were too wide and the objective measures did not help in discerning which one of the two questionnaires should be used for future studies.

To summarise, the results showed an impact of presence on trust, regardless of the questionnaire used. However, a difference between questionnaires exists in the strength of the impact. Given the criticism found in the literature on the use of questionnaires to measure presence (e.g. Slater, 2004), a physiological measure was introduced in this experiment. However, EDA was not found to be related to trust, nor to the presence questionnaire. This could be due to possible design and measurement tools issues. Another dissimilarity between the questionnaire used, could be found in the analysis of the difference between the two groups. While the results of the PQ questionnaire were not different between the two groups, the results of the S.U.S. questionnaire were. The results are in line with some research stating that the comparison between two different VR systems is not possible (Slater, 2004). Finally, the pre-interaction trust effect on post-use trust was investigated, the results show an impact of the pre-interaction trust. This is in line with the literature review (McKnight et al., 2011) but not with the previous studies in this PhD (chapter 3), where pre-interaction trust was not found to have an effect. However, in previous studies, also technology acceptance and usability were considered and this could have affected the results.

5.5.1 Limitations

The main limitation of the study was represented by the objective measures of presence. In fact, the device frequency (number of data per second) and the movement of the steering wheel could have influenced the data recording and the unexpected results are, probably, reflecting this. The lack of significance for the EDA data did not permit to discern which questionnaire of presence was more valid to measure the concept.

5.6 Conclusion

The framework described in chapter 2 of this thesis, theorised that usability, technology acceptance and presence are among the factors influencing trust in VR. The experiment in chapter 3 demonstrated how usability and technology acceptance seem to have an influence on trust. However, no specific experiment was designed to investigate the relationship between presence and trust. This study aimed to assess if presence, like usability and technology acceptance, had an influence on trust. However, given the complexity of presence, more than one measure was used to analyse the relationship. The results of the experiment show that there is a relationship between the reported presence and trust in VR, but this relationship is influenced by the type of questionnaire used. In fact, the results of the PQ seem to be more related to trust than the results of the S.U.S. Moreover, following the results of the PQ, it seems that the relationship exists regardless of the system used, not the same can be said regarding S.U.S.

In addition, the relationship between presence and trust is influenced by pre-interaction trust. The size of the effect pre-interaction trust has, however, is also influenced by the questionnaire used.

After discussing the results of the experiments described in chapter 3, the results of this experiment have validated the model to some extent. However, these experiments evaluated one factor at a time. Until the three factors are included together in a study, the validation cannot be completed. The next step planned in the research was to design an experiment that would take all the factors of the framework (presence, usability and technology acceptance) in consideration. The experiment was conducted and will be described in the next chapter.

6. Chapter 6 – Final Validation

6.1 Chapter Overview

This chapter describes the last experiment conducted for this PhD research. The main aim was to have a final validation of the model described in chapter 2 and to understand how the factors described throughout this thesis (usability, technology acceptance, presence) influence each other and affect trust. The results of the experiment proved that usability, presence and technology acceptance have an influence on trust. However, this influence is not direct for all the factors. In fact, it seems that technology acceptance is the main factor influencing trust in VR and presence has a minor direct impact on trust. Usability has an indirect effect on trust, being the major contributor to technology acceptance.

The first part of the chapter will provide the rationale behind the study and the hypotheses underlying the experiment. Then, the method and data analysis will be described. Successively the chapter will give detailed results. Finally, the results will be discussed and the conclusion will be explained.

6.2 Introduction

The previous studies described in chapters 3, 4 and 5 demonstrated that relationships exists between usability, presence and technology acceptance with trust, for various VR systems. The studies appeared to have validated the framework described in chapter 2. However, apart from the pilot study, the experiments conducted so far have only analysed the three factors singularly or paired. This approach was useful to develop the methodology and to have a first idea of the effect each factor could have on trust, but does not give a complete picture of the real influence the factors have on trust and of the relationships that may exists among the factors. With this information missing it would not have been possible to confirm the framework as the best predictor of trust in VR system.

In order to overcome this methodological limit, a final study was conducted. This was designed to incorporate usability, technology acceptance and presence together. Thus, in addition to confirming the previous study results and having a final validation of the model, it aimed to understand if there is a relationship among the three independent factors and the nature of this relationship. The main concern from the previous studies was that each factor could have an indirect influence on trust. That is, even if there is a significant regression between one factor and trust, this does not necessarily mean that the factor has a direct influence on trust, but that it may have an influence on another characteristic that has an influence on trust. In other words, one of the factors could be a mediating variable. Apart from the pilot study (chapter 3), this possibility was not demonstrated in previous studies, since the factors were not studied together. The pilot study, on the other hand, was mainly designed to identify methodological and design issues, rather than validate the entire framework. The decision to study the factors singularly first was to understand in the early stages of the project if the predicted direction was correct and if each factor had a relation (direct or indirect) with trust. If one of the factors was not found to have any sort of relation with trust, it would have been excluded from the model, and other factors would have been investigated.

In order to investigate these issues a within subjects study was designed. 53 participants took part in the study, but only 40 completed it, predominantly due to dropout rates as a result of simulator sickness. In this experiment, participants had to interact with eight different VEs. Each environment was different from the others in the level of presence, usability and technology acceptance. Pre-interaction questionnaires were given to participants before the first use of the VEs and post-interaction questionnaires were given afterwards. Correlation and regression analyses were performed in order to investigate if there were effects of usability, presence and technology acceptance on trust and the nature of these effect. The results indicated that the best predictor of trust is technology acceptance, with presence having a weaker effect. Usability did not have any direct effect on trust. However, further analyses revealed that usability is the best predictor of technology acceptance. This means that even if in a different order and with different importance, the three factors still influence trust. After the results of this study, the framework described in chapter 2 was changed to better reflect the nature of the relationship among the factors.

Ethical approval was granted to the study by the University of Nottingham Faculty of Engineering Ethic Committee.

6.2.1 Hypotheses

H1: There is a linear relationship between each of the three factors described in the framework (usability, technology acceptance and presence) with trust.

This hypothesis is the confirmation of what has been found in previous studies. In the previous chapters of this PhD research, it has been demonstrated how each factor has an influence on trust. The pilot study (chapter 3) gave the first data on this relationship showing that technology acceptance and usability have an effect on trust. The desktop VR study (chapter 4) confirmed the relationship between usability and trust. The boot study (chapter 4) confirmed the relationship between technology acceptance and trust, but did not find any results for presence. Regarding presence, the pilot study and the boot study had design issues that may have influenced the results (constant interruption, lack of interaction) (Lessiter et al., 2001). In fact, the presence study (chapter 5) found a relationship between presence and trust. This study will consider all the factors together and the hypothesis is that all the three factors will have an influence on trust. The experiment will investigate the nature of the relationship (e.g. direct, indirect) and the relationships among usability, technology acceptance and presence.

H2: There is a significant difference between the environments in the level of presence, usability, technology acceptance and trust.

This hypothesis is: the environments are significantly different from each other. This is because the design of the study aimed to verify the model for various level of the factors.

Corollary. H2b: The model is valid for low and high level of each factor.

Regardless of the type of environment, the model is still valid. This hypothesis is linked with H2. If H2 is not demonstrated, this hypothesis cannot be validated either, since if there is no difference among the environments it cannot be demonstrated that the model is still valid regardless of the type of environment.

H3: There is an influence of pre-interaction trust on the post-use trust.

The influence of pre-interaction trust on the post-use trust was investigated in the pilot study (Chapter 3) and in the presence study (chapter 5). The results were in contrast, since in the pilot study there was no significant influence of the pre-interaction trust on the post-use trust, while there was an effect in the presence study. However, as already explained in section 5.5, the pilot study considered all the factors together, while the presence study considered only presence. This experiment will allow to clarify the relationship, since it consider all the factors as the pilot study, but with a revised method and design.

6.3 Design

6.3.1 Materials

6.3.1.1 VR

For the interaction with the VEs, the Oculus® DK2 Head mounted display was used. The environments were built using Unity personal edition. The PC used was a Lenovo desktop computer with dedicated graphic memory. The controller was a Microsoft ® Xbox ® USB controller.

6.3.1.2 Questionnaires

The questionnaires were divided into pre- and post-interaction questionnaires, the first set given before starting the interaction with the VEs and only in the first session and the second set given after each interaction with each environment both in the first and second sessions.

Pre-interaction questionnaires:

Demographic Questionnaire:

A demographic questionnaire was built to gather information about the participants (see Appendix 1.7).

Trust pre-interaction questionnaire (Appendix A1.6)

The trust pre-interaction questionnaire has been developed to assess the propensity people have to trust a general technology and VR systems.

Post-Interaction questionnaires

PQ (Appendix A1.3.2):

The presence questionnaire has been used to assess the level of presence perceived by the participants.

SUS (Appendix A1.2):

The SUS is one of the most used questionnaire to assess usability preferred to other questionnaires for the ease of use and the short number of questions.

Technology Acceptance Questionnaire (Appendix A1.1.2):

The technology acceptance questionnaire has been used in the literature to understand the level of technology acceptance of the users.

Trust in Technology measure (Appendix A1.4):

The TTM has been used to assess the level of users' trust in the specific system.

Other questionnaires

SSQ (Appendix A1.5):

The SSQ has been used to monitor the participants' cybersickness symptoms.

6.3.2 Environments

A total of eight environments were created for this study. The level of usability, technology acceptance and presence were modified, and combined in order to have a high level of each factor in four environments and a low level in the other four. The environments are shown in Table 6.1:

Environment	Presence	Usability	Technology acceptance
HHH	High	High	High
HHL	High	High	Low
HLH	High	Low	High
HLL	High	Low	Low
LHH	Low	High	High
LHL	Low	High	Low
LLH	Low	Low	High
LLL	Low	Low	Low

Table 6.1. Environments designed for the experiment.

The following paragraph explains in detail what characteristics were changed for each factor.

6.3.2.1 Usability

High: the characteristics for usability were concentrated on the controller and ease of use (Bevan, 2009). In the high usability environments, the way of controlling the avatar was smooth, with a normal speed (modified after the pilot test) and the same speed for each direction. The change of point of view had a normal and constant speed.

Low: the controls were intentionally modified in order to make the movements and interaction with the avatar more difficult. The avatar was moving slower than normal when going sideways and backward, while moving faster than normal when going forward. The change of point of view was altered, being faster than normal and difficult to control.

6.3.2.2 Technology acceptance

High: The two main factors of technology acceptance are perceived ease of use and perceived usefulness (Davis, 1985). Perceived ease was already taken into consideration for usability, so one of the aspects that was added to increase perceived usefulness, was a help function, which may be perceived as a tool to enhance the performance. The help function showed the final stairway and was helpful if the participants did not remember the order of the block or where to start.

Low: the participants had no access to the help function.

6.3.2.3 Presence

High: the environments with high presence were more realistic. The environment was textured and environment details were added (trees, shadows, sun, sky and grass ground). These characteristics aimed at increase immersion (Slater and Wilbur, 1997). Figure 6.1 shows a screenshot of the environment just described.

Figure 6.1. Example of a high presence environment.

Low: In the low presence environment, all the textures were deleted; the environment was just a white floor with a grey sky. No details were added. The image below (Figure 6.2) shows an example of the environment.

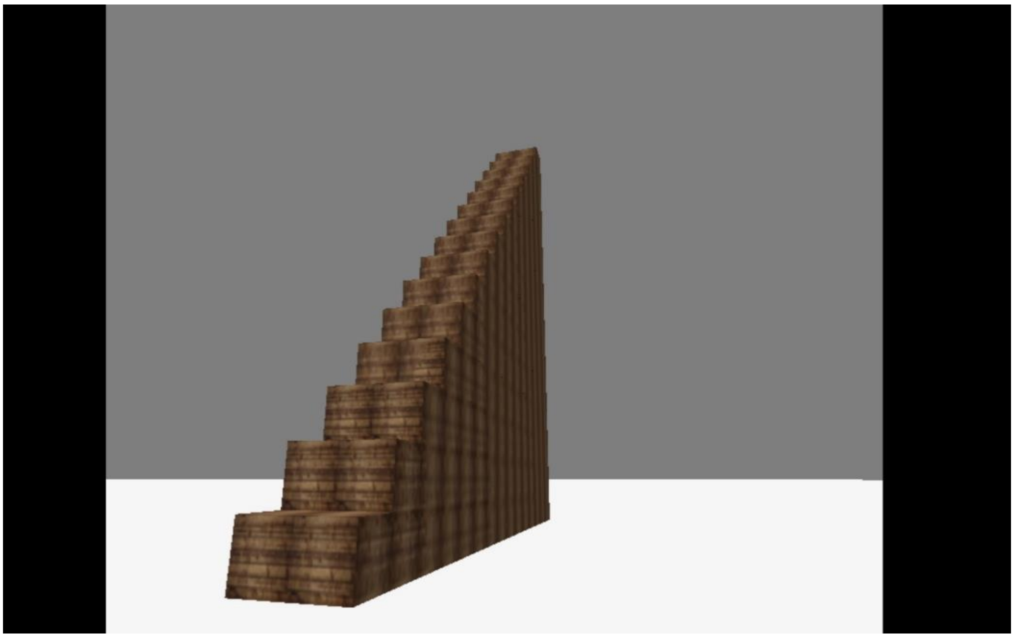

Figure 6.2. Example of a low presence environment.

6.3.3 Task

The participants had to perform a task in the environment. The task consisted of the construction of a stairway to reach an avatar who was floating in the air. To build the stairway, the participant would position blocks one after the other. The blocks had four different materials (wood, stone, brick and concrete). The participants had to build the stairway with an exact order that was wood, stone, brick and concrete. Four rules were given to all participants.

1. The blocks had to be perfectly aligned, thus no space between the blocks and/or overlap were allowed.
2. At least the last five blocks before reaching the avatar had to be the same direction the avatar was facing. Thus, the stairway could not arrive to the avatar from the side, it had to arrive in front of it.
3. The participants could build all the blocks they wanted to help them build the stairway (e.g a block serving as a step in the middle of the structure).

However, before the end of the task they had to delete all the blocks that were not part of the structure.

4. The researcher would lay down the first block, which was the first step of the stairway and could not be deleted. This rule was implemented to be sure that all participants started from the same point.

These rules were made to minimise differences among participants' methods of solving the task. If the participants did not comply with the rules, the task was considered failed. However, if the participants broke one or more rules, the researcher would remind the rule broken during the interaction, thus the participants had time to correct the mistake.

Figure 6.3 shows an example of a completed stairway.

Figure 6.3. Example of a completed task.

The participants had ten minutes to build the stairway. At the end of the ten minutes, the participant was interrupted.

To avoid familiarity with the task, a total of four different task types was developed; each task had a different avatar position (two in front of the participant, one left and one right, and two behind the participant, one left one right). As with the environment, the task was randomly assigned.

6.3.4 Procedure

Given the length of the experiment, the procedure was divided in two different sessions, one week apart.

6.3.4.1 First Session

In the first session, the participants were invited to read the information sheet and complete the consent form. In addition to the written material on the information sheet, the possible risks of using VR products, in particular sickness symptoms, were explained by the researcher. The participants had the opportunity to ask questions and were reminded that they could interrupt the experiment whenever they felt necessary without any obligation to reveal the reason. As stated in the recruitment advertisement and in the information sheet (appendix A.2.2 and appendix A.3.3) each participant received a compensation of £20 in Amazon vouchers for taking part in the study. The compensation was given at the end of the first session, in order to avoid luring the participants to come back for the second session against their wishes (e.g. if suffering from sickness). When the participant confirmed they understood the information, the pre-interaction questionnaires were given.

After the pre-interaction questionnaires, the researcher explained the tasks and the controller. The participants were then invited to have a trial period of about 5 min or until they felt confident enough to start. The trial was performed without the VR headset with a normal 2D desktop screen, in order to facilitate the explanation by the researcher. The order of the environments the participant would interact with was randomly chosen. During the first session, the participant would interact with a total of four environments. After each interaction, the researcher asked the participants to complete the post interaction questionnaires. The total duration of the first session was approximately one hour fifteen minutes, with a maximum of 40 minutes of VR exposure.

6.3.4.2 Second session

In the second session, the participants would only interact with the environments and complete the questionnaires. Therefore, no explanations or trial was given to the participants. As in the first session, the participant would interact with four environments (different from those in the first session) in a random order.

The duration of the second session was approximately forty-five minutes with a maximum VR exposure time of 40 minutes.

Figure 6.4 depicts the setting of the experiment.

Figure 6.4 Setting of the experiment.

6.4 Method

A total of 53 participants was recruited for the study. 13 participants did not complete the study due to cybersickness and, thus, only 40 participants (27 males) were taken into consideration in the data analysis. The participants had an average age of 28.88 (SD=8.46). They were recruited mainly among students and staff at the University of Nottingham, through mailing lists and posters (appendix A.2.2). Other participants were recruited through advertisements in specialised websites and social networks.

6.4.1 Data analysis

First of all, the demographic information was gathered to understand the characteristics of the population studied. To assess the correlation among the factors, a correlation matrix was made.

To investigate the relationship between the three factors and trust, a series of regressions was performed. The first set of regressions aimed to investigate the relationship between each single factor and trust, thus, each factor was considered as an independent variable and trust was considered as the dependent variable. Then, a series of double regressions were performed to investigate the relationship between the factors taken as a pair (independent variables) and trust (dependent variable). Then, a regression was performed with all the three factors as independent variables and trust as dependent variable. In case this last regression was not significant, a regression would have been performed with a "Forward" method, in order to detect which factors had a direct influence on trust (Brace, Kemp and Snelgar, 2000). Finally, a regression was performed with the addition of pre-interaction trust, in order to investigate its influence on the post-use trust.

In order to investigate the difference among the various environments, three t-tests were performed.

6.5 Results

6.5.1 Demographic

The demographic statistics are useful to understand the sample characteristics, such as age, sex and VR experience. Unless otherwise stated, these characteristics had no effect on the relationship among the factors. The data from the demographic questionnaire is gathered in Table 6.2.

Demographic			
		Number	**Percentage**
Sex	Male	27	67.5%
	Female	13	32.5%
Normal state of Health?	yes	40	100.0%
	no	0	0.0%
Handiness	Left	6	15.0%
	Right	34	85.0%
Wear Glasses	Yes	13	32.5%
	No	27	67.5%
Motion Sickness	Not at all	25	62.5%
	Slightly	14	35.0%
	Moderately	1	2.5%
	Very much so	0	0.0%
VR Experience	I have never heard of Virtual Reality	1	2.5%
	I have heard of it but do not know what it is	2	5%
	I have some idea of what VR is	4	10%
	I know what Virtual Reality but have never seen or used it	7	17.5%
	I have seen a Virtual Reality system in use	5	12.5%

	I have used a Virtual Reality system once or twice	17	42.5%
	I have often used Virtual Reality	3	7.5%
	I use Virtual Reality almost every day	1	2.5%

Table 6.2. Frequencies of the participants demographic information.

Before analysing the relationship between the factors, it is useful to investigate the levels of usability, presence and technology acceptance perceived by the users. The general means of each factors are shown in Table 6.3.

Measure	Median	Mean	SD
PQ	4.08	4.17	.85
Technology acceptance	3.38	3.57	1.23
SUS	43.75	44.87	14.03
Trust	4.26	4.13	1.1

Table 6.3 Descriptive of PQ, technology acceptance questionnaire, SUS and trust questionnaire for all the conditions.

In addition, four box plots were created to have a visual assessment of the data (Figure 6.5 - Figure 6.8)

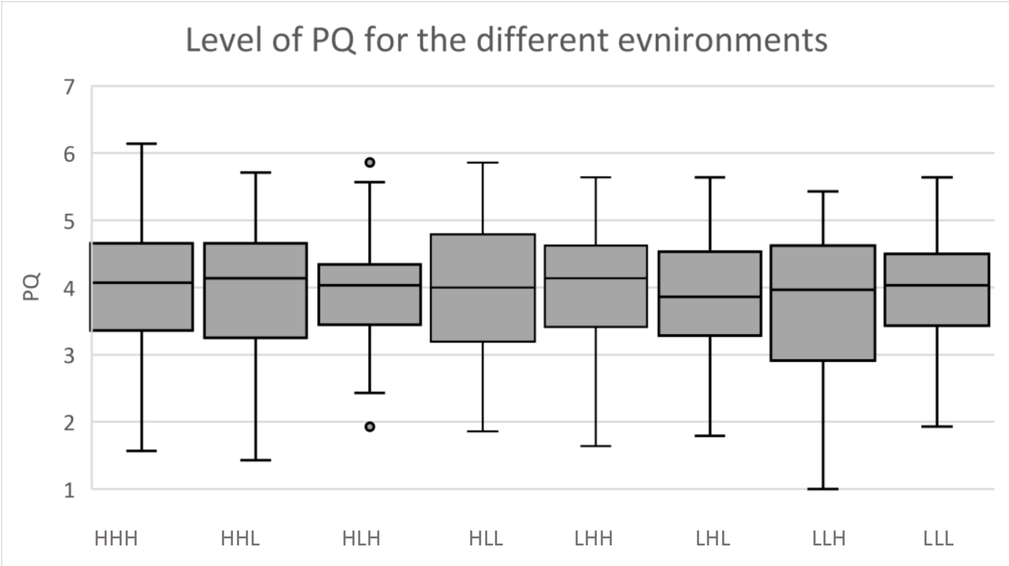

Figure 6.5 Box-plot of the PQ responses for each condition.

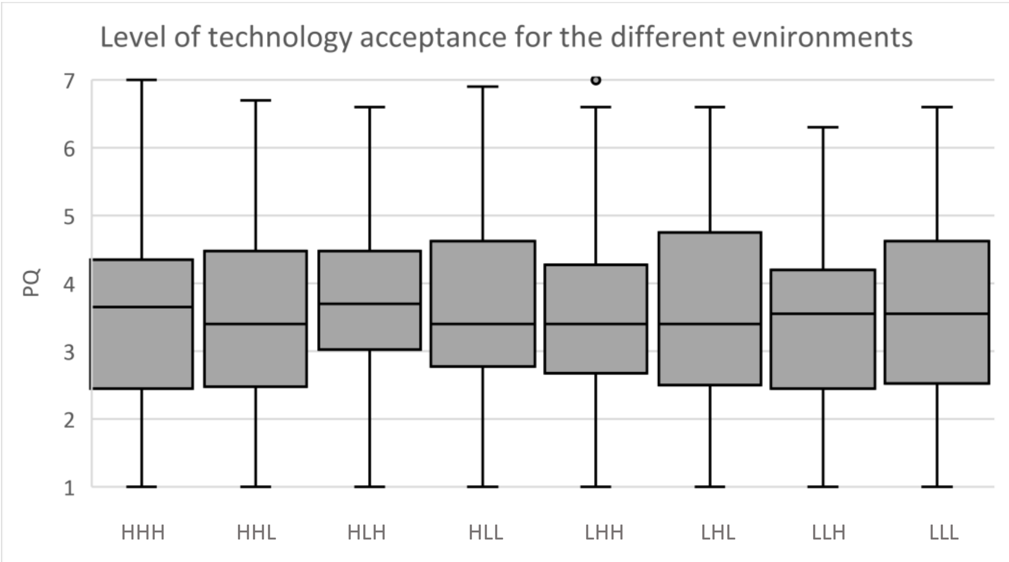

Figure 6.6 Box-plot of the technology acceptance questionnaire responses for each condition.

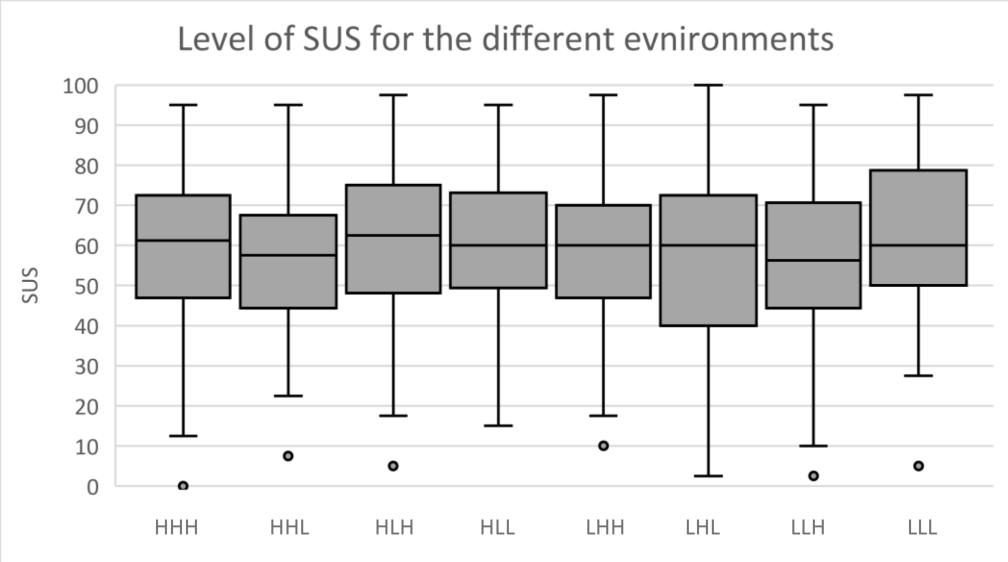

Figure 6.7 Box-plot of the SUS responses for each condition.

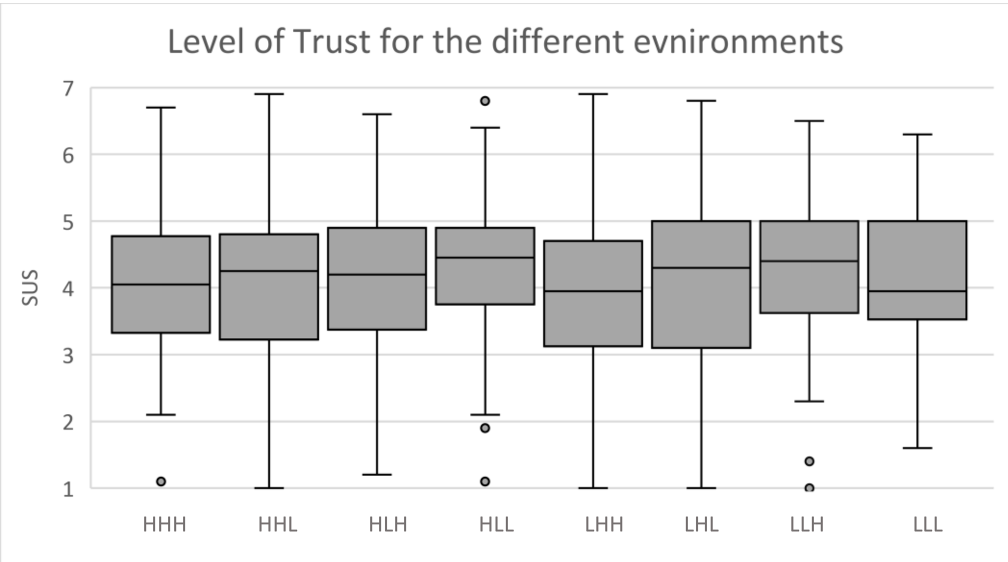

Figure 6.8 Box-plot of the PQ responses for each condition.

As can be seen from the box plots, there may be some outliers. The presence of outliers will be assessed with a casewise diagnostic with the regressions.

The graph below shows the mean of the level of cybersickness for each environment.

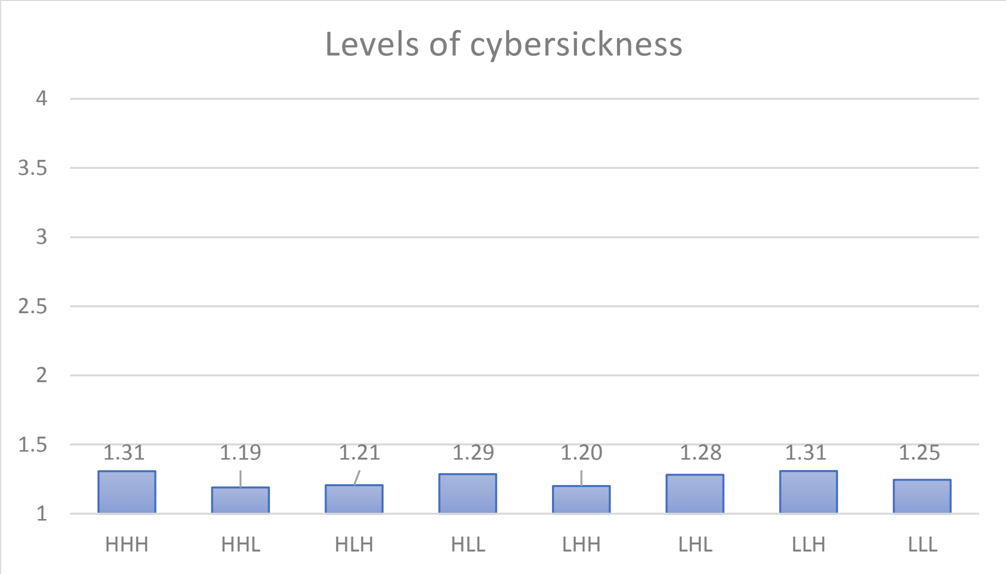

Figure 6.9 Levels of cybersickness as measured with the SSQ (1=none, 2= slightly, 3=Moderate, 4=Severe).

The level of cybersickness was generally low, ranging from 1.19 to 1.31, but, as anticipated in the method section of this chapter, the data from the participants dropping out due to cybersickness are not taken into consideration, therefore, these data refers only to the people finishing the study. It can be deducted from the graph that there is no difference for cybersickness among the environments.

6.5.2 Correlations

In order to understand the relationship among the factors a correlation matrix was used. Table 6.4 shows the results of all the correlations analysed.

Correlations						
		SSQ	Presence	Technology acceptance	Usability	Trust
SSQ	Pearson Correlation					
	Sig. (2-tailed)					
	N					
Presence	Pearson Correlation	-0.125				

	Sig. (2-tailed)	0.442				
	N	40				
Technology acceptance	Pearson Correlation	-0.033	**0.801**			
	Sig. (2-tailed)	0.838	**<0.001**			
	N	40	**40**			
Usability	Pearson Correlation	-0.86	**0.781**	**0.841**		
	Sig. (2-tailed)	0.598	**<0.001**	**<.001**		
	N	40	**40**	**40**		
Trust	Pearson Correlation	0.095	**0.758**	**0.777**	**0.753**	
	Sig. (2-tailed)	0.561	**<0.001**	**<0.001**	**<0.001**	
	N	40	**40**	**40**	**40**	

Table 6.4. Correlations among usability, technology acceptance, presence, trust and cybersickness. The significant correlation have been highlighted in bold.

As can be seen in the table, all the factors correlate among each other. In particular it can be seen that trust correlates with all the three factors, the highest correlation is with technology acceptance (r=0.777) and the lowest is with Usability (r=0.753). It is important to note the highest correlation is between SUS and technology acceptance (r=0.841). Another important result is the lack of relation between cybersickness and any of the factors.

6.5.3 Regressions

In order to investigate the influence the factors have on trust, three single regressions, three double regressions and one triple regression were performed. The single regressions were performed with trust as dependent variable and each factor as independent variable. The single regressions were conducted to confirm the results found in previous studies.

6.5.3.1 *Single regressions*

Figure 6.10, Figure 6.11 and Figure 6.12 give a visual representation of the relationship between each factor and trust.

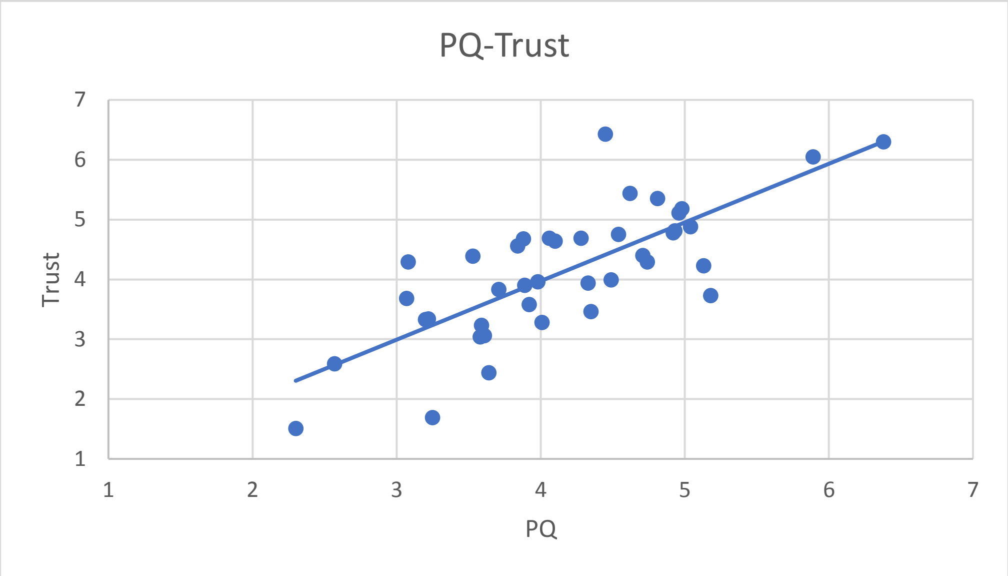

Figure 6.10 Scatter-dot plot of the interaction between PQ and trust.

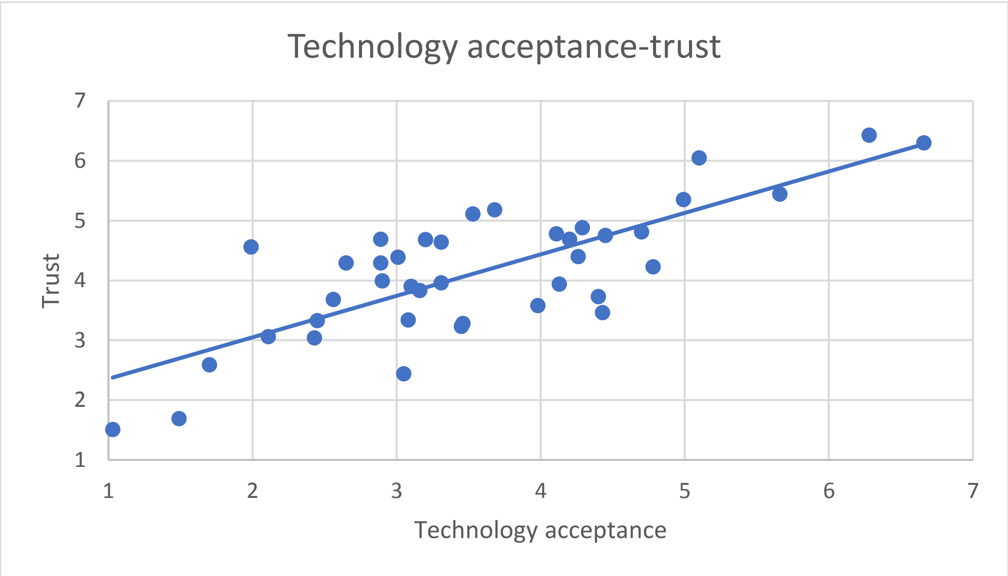

Figure 6.11 Scatter-dot plot of the interaction between technology acceptance and trust.

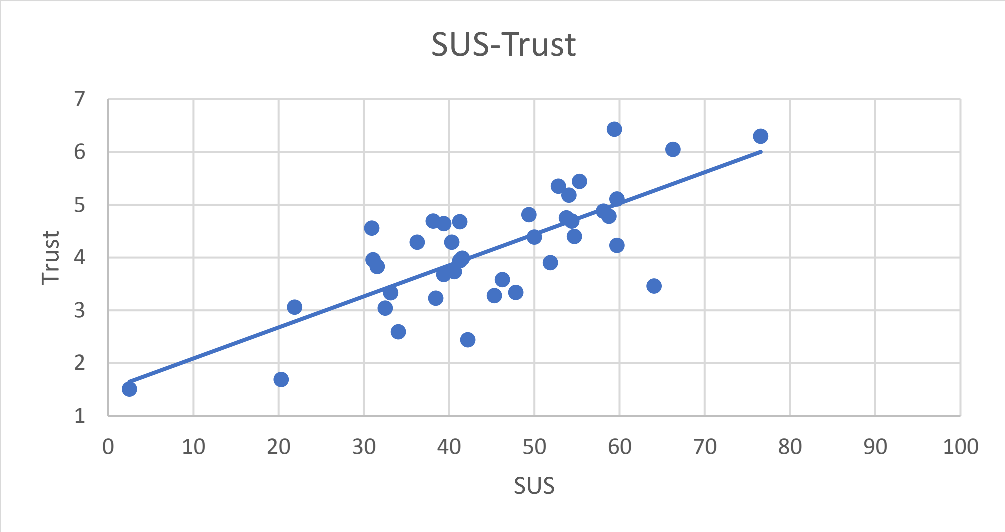

Figure 6.12 Scatter-dot plot of the interaction between SUS and trust.

All the regressions were significant (PQ - trust [$F(1,38)=51.443$, $p<.001$; Adj R^2= .564). Technology acceptance – trust [$F(1,38)=57.935$, $p<.001$, Adj R^2= .593). SUS-trust: [$F(1,38)=49.616$, $p<.001$; Adj R2= .555).

6.5.3.2 Double regressions

To better understand how trust is influenced by the factors when taken together, a series of double regressions was performed.

The regressions were significant. The results are shown in Table 6.5 while the coefficients and standard errors can be found in Table 6.6 - Table 6.8.

Independent variable	Dependent variable	F	Sig.	Adj R^2
PQ/technology acceptance	Trust	F(2,37)=35.191	<.001	.637
SUS/technology acceptance		F(2,37)=32.496	<.001	.618
PQ/SUS		F(2,37)=33.027	<.001	.622

Table 6.5 Results of the double regressions.

PQ/technology acceptance -Trust				
Variable	B	SE	β	Sig.
PQ	.490	.561	.379	.024
Technology acceptance	.422	.144	.473	.006

Table 6.6 Coefficients of the regressions with PQ and technology acceptance as independent variables and trust as dependent variable.

SUS/technology acceptance -Trust				
Variable	B	SE	β	Sig.
SUS	.026	.014	.338	.073
Technology acceptance	.439	.163	.493	.011

Table 6.7 Coefficients of the regressions with SUS and technology acceptance as independent variables and trust as dependent variable.

SUS/PQ -Trust				
Variable	B	SE	β	Sig.
SUS	.032	.012	.411	.013
PQ	.565	.204	.438	.009

Table 6.8 Coefficients of the regressions with PQ and SUS as independent variables and trust as dependent variable.

As depicted in the tables above, all the double regressions are significant. However, the coefficient of the regression with SUS/Technology acceptance as independent variables is not significant for SUS. This could be due to an indirect relationship between one of the factors and trust.

6.5.3.3 Technology acceptance, usability, presence and trust

In order to investigate this further a regression was performed with all the three factors as independent variables. The regression was significant [F(3,36)=24.188, p<.001) with the model accounting for the 64% of the variance of trust. Table 6.9 shows the coefficients

SUS/PQ -Trust				
Variable	B	SE	β	Sig.
SUS	.017	.015	.223	.243
PQ	.404	.220	.313	.074
Technology acceptance	.302	.175	.339	.093

Table 6.9 Coefficients of the regression with SUS, PQ and technology acceptance as independent variables and trust as dependent variable.

Even though the regression is significant, an analysis of the coefficients shows that none of them are significant.

6.5.3.4 Technology acceptance, usability, presence and trust – forward regression

In order to analyse in a better way which factor may cause the coefficients to be non- significant, another regression was performed, again with all three factors, but using a forward method instead of an enter one. This because with the forward method, the factor that does not add any influence on trust will be excluded (Brace, Kemp and Snelgar, 2000).

The output of the forward regressions were two models. One with only technology acceptance as independent variable and one with technology acceptance and PQ as independent variables. Both the models were significant [Model 1: F(1, 38)=28.309, p<.001; Model 2: F(2, 37)=35.191, p<.001]. Table 6.10 gathers the coefficients values for the two models.

Regression SUS, Technology acceptance, PQ – Trust. Method: Forward				
Model	**B**	**SE**	**β**	**Sig.**
Technology acceptance	.693	.091	0.777	<.001
Technology acceptance	.422	.144	.473	.006
PQ	.490	.208	.379	.024

Table 6.10. Coefficients of the regression (method: forward) with SUS, PQ and technology acceptance as independent variables and trust as dependent variable .

The results of the forward regression show that the model best predicting trust was the second, which accounted for 63.7% of trust. SUS was here excluded from the model, meaning that usability did not significantly add to the success of the model (Brace, Kemp and Snelgar, 2000)

6.5.3.5 Factors of technology acceptance

To investigate in further detail whether usability has an indirect effect on trust and if presence is in any way related to technology acceptance, a forward regression was performed, with SUS and PQ as independent variables and technology acceptance as dependent variable.

The output of the regression were two statistically significant models. One with only SUS as independent variable [$F(1,38)=92.130$, $p<.001$; Adj $R^2= .7$] and one with SUS and PQ as independent variables [$F(2,37)=58.926$, $p<.001$; Adj $R^2=.761$]. The coefficients for the two models are presented Table 6.11

Regression SUS, PQ – technology acceptance. Method: Forward				
Model	**B**	**SE**	**β**	**Sig.**
SUS	.074	.008	0.841	<.001
SUS	.048	.011	.553	<.001
PQ	.536	.186	.369	.007

Table 6.11. Coefficients of the regression (method: forward) with SUS, PQ and technology acceptance as independent variables and trust as dependent variable.

As it can be seen from the table, the best model to predict technology acceptance is a combination of usability and Presence, with presence adding a 5% influence on the model (R^2 change=.053).

6.5.3.6 Pre-interaction trust in the model

To investigate the influence of pre-interaction trust on the model, a forward regression was performed, with technology acceptance, usability, presence and pre-interaction trust as independent variables and trust as dependent variable. The results of the regression are exactly the same as the forward regression with usability, technology acceptance and presence as independent variables and trust as dependent. In fact, the pre-interaction trust was excluded from the model together with usability (as expected from the results of the previous regressions). This means that there is no direct influence of the pre-interaction trust on post-use trust.

6.5.4 Differences between groups

6.5.4.1 Difference in trust for different groups

In order to understand if there are differences in the level of trust for the different levels of each factor, a three-way repeated measure ANOVA was conducted with trust as dependent variable and the level of presence, usability and technology acceptance as factors.

There were three outliers in the data. To investigate their influence, the ANOVA was performed with and without the outliers. The significance was not affected; therefore, the outliers were included in the data.

The three-way ANOVA was not significant [F(1,37)= .148, p=.559]. In addition, none of the two-way ANOVAs were significant. This result indicates that there is not difference in the level of trust among the various level of each factor (usability, presence and technology acceptance).

6.5.4.2 Difference in factors manipulation

In order to assess if the manipulation of each factor was successful, three paired sample t-tests were run, one for each factor.

There were three outliers in the data. To investigate their influence, the t-tests were performed with and without the outliers. The significance was not affected, therefore, the outliers were included in the data.

None of the t-tests were significant as can be seen from the results gathered in Table 6.12

		Descriptive			Differences				
Variable	Levels	Mean	SD	N	Mean	SD	df	t	Sig.
Presence	High	3.94	.86	40	.027	.46	39	.379	.706
	Low	3.91	.79	40					
Usability	High	57.89	17.45	40	-1.85	8.78	39	-1.3	.189
	Low	59.74	17.56	40					
Technology acceptance	High	3.58	1.28	40	.01	.49	39	.156	.877
	Low	3.57	1.23	40					

Table 6.12 T-Tests results for each factor (presence, usability and technology acceptance).

These results indicate that the manipulation was not successful and there is not a significant difference between the two conditions for each factor.

6.5.5 Direction of the relationship

Throughout this thesis, the hypotheses always aimed at assessing the influence usability, presence and technology acceptance have on trust. This, however, does not exclude that the relationship could be mutual, and trust could influence one or more of the factors. Particularly, previous literature found that trust could be a factor influencing technology acceptance. Since this study included all factors together, an additional regression was performed to investigate if the relationship between trust and technology acceptance is unidirectional (i.e. technology acceptance influences trust) or bi-directional (i.e. trust also influence technology acceptance). Therefore, a regression with a forward method was performed, including presence, usability and trust as independent variables and technology acceptance as independent variable.

The results of this regression were the same as the regression presented in section 6.5.3.4. Therefore, trust was eliminated from the model as independent variable. This result indicates that, for this study, the relationship is unidirectional. Indeed, technology acceptance influences trust, but trust does not influence technology acceptance.

6.5.6 Other statistics

In this paragraph, some results from the investigation not concerning the relationship between trust and the other factors will be described. Only significant results will be reported.

6.5.7 SSQ

As seen in the introduction, cybersickness is one of the major problems in the interaction with VR products. In this study, 13 participants interrupted the experiment on the way, because they experienced simulator sickness symptoms and felt they could not continue the interaction. The SSQ was given to the participants throughout the entire study. In the data analysis, correlations were performed to see if the results of the SSQ questionnaire would be related to some of the other factors and demographic characteristics, measured in the study. The only significant correlation was found between SSQ and VR experience. Indeed, the correlation is significant and negative (r= -.402, p=.01).

6.6 Discussion

As stated in the literature review chapter (chapter 2) trust is a fundamental factor for the correct adoption and use of a technology (McKnight et al., 2011; Grabner-Krauter and Kaluscha, 2003). This final experiment was conducted to investigate more deeply the relationship between the three factors and trust, that was found in the previous studies (Chapters 3, 4 and 5). The results of this experiment gave a clearer picture on how this relationship takes place, which factors influence trust the most and which factors have an indirect influence on trust. The discussion will be divided by the hypotheses.

H1: There is a relationship between each of the three factors described in the framework (usability, technology acceptance and presence) with trust.

First, the correlation analysis showed that all the four factors are correlated with each other. The high correlation between technology acceptance and SUS is in line with the literature, indeed, as shown in the literature review chapter, technology acceptance is composed of two factors, perceived ease of use and perceived usefulness (Davis, 1985), which, to an extent, are also included in usability (Bevan, 2009). The most surprising result is with presence. In fact, few studies have investigated the relationship between presence and usability or technology acceptance and this research could be one of the first step to demonstrate that presence, other than being a fundamental factor in the interaction with VR system, influences other characteristics of VR, such as trust and technology acceptance.

In order to verify what was already found in the previous chapters (chapter 3, 4 and 5) single regressions were performed, in order to confirm if each factor has a relationship with trust. The results confirm the outcomes of previous studies in this thesis, demonstrating that each factor, when taken singularly, has an influence on trust. However, the singular relationships, as stated in the discussion of chapter 5, do not give information on the behaviour of the factors when included together in the model. In fact, as seen in the pilot study, the influence the factors have on trust could be indirect. This hypothesis is reinforced by the high correlations among the factors.

To more deeply analyse the relationships among the factors and their influence on trust, three further regressions were performed. In this case, the regression had the factors paired as independent variables and trust as dependent variable. These regressions aimed at investigating the possibility of indirect relationships. Dividing the factors in pairs gives the possibility to better spot which of the factors has an indirect influence on trust. When paired together, one factor loses significance, it could have an indirect relationship with trust. The results confirm the presence of an indirect relationship. In fact, while the regression with technology acceptance and presence and the relationship between usability and presence are significant, meaning that they both influence trust and they do not have a strong influence between each other, the regression with technology acceptance and usability is significant only for technology acceptance. The fact that usability is only significant when considered without technology acceptance could be due to an indirect effect of usability on trust, to be more precise, usability may influence technology acceptance which influences trust.

To confirm the suspicion that usability may have an indirect relationship with trust and to have a better understanding of the best predictors of trust, a forward type regression was performed. A forward regression inserts the variables in a precise order and analyses the influence each has with trust, it excludes the variables not fitting the model. The hypothesis was that usability would have been excluded from the model, as it had not a direct influence on trust. The results of the forward regression confirmed the hypothesis. In fact, usability was excluded from the final model. However, it is important to note that the model including technology acceptance and presence together is only slightly better in predicting trust than the one with only technology acceptance as a predictor. This means that even if both technology acceptance and presence have an effect on trust, the effect of technology acceptance is much more important that the one of presence. As expected in the hypothesis, usability was excluded from the model.

From the results of the correlations and regression, it can be assumed that the best predictor of trust in VR is technology acceptance, with presence having a minor effect and usability having an indirect effect. This means that the framework described in chapter 2 has to be changed to something that reflects better the results of this study. Figure 6.13 depicts the framework after the changes.

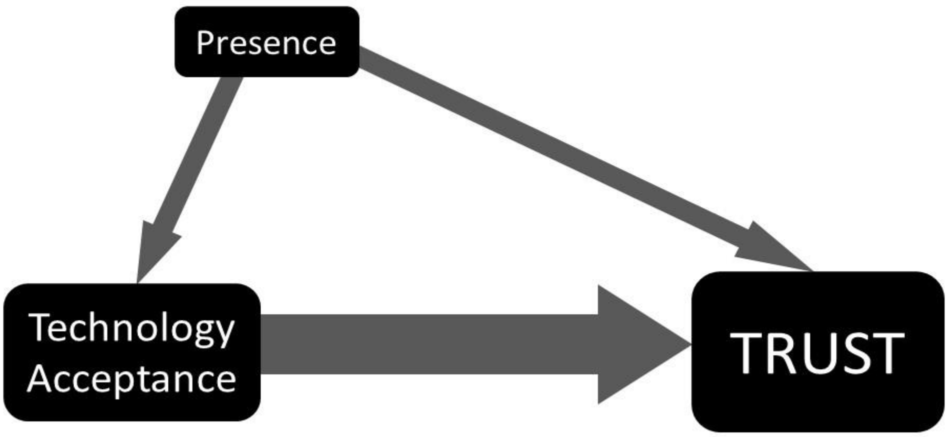

Figure 6.13. New model without the direct influence of Usability.

However, it is not correct to completely exclude usability. In fact, as it was seen in previous studies and from the results of the regressions in this experiment, usability still has an effect on trust, even if the effect is indirect. In fact, when analysing which factors would influence trust's best predictor, the best model is a combination of usability and presence, with usability being the best predictor and presence adding a minor influence. This result is in line with previous studies on the acceptance of VR systems. In fact, as anticipated in the literature review (chapter 2), Bertrand and Bouchard (2008), when applying the TAM to VR systems, found that perceived usefulness directly influences the intention to use, while perceived ease of use has an indirect effect, being a predictor of perceived usefulness, but not having a direct relationship with intention to use. As anticipated in chapter 2, ease of use is a determinant of usability (Bevan, 2001), therefore, it is in line with the literature that usability is a predictor of perceived usefulness (thus, technology acceptance). However, Bertrand and Bouchard (2008) did not consider trust as the target variable. It could be assumed that technology acceptance has the same relationship with trust and with intention to use, or that trust is in the middle between technology acceptance and intention to use. Future studies should investigate these relationships to have a better understanding of how technology acceptance, usability and trust (and their dimensions) are related.

After these results, the model requires some changes, to better depict the relations among the factors. Figure 6.14 is the final version of the model.

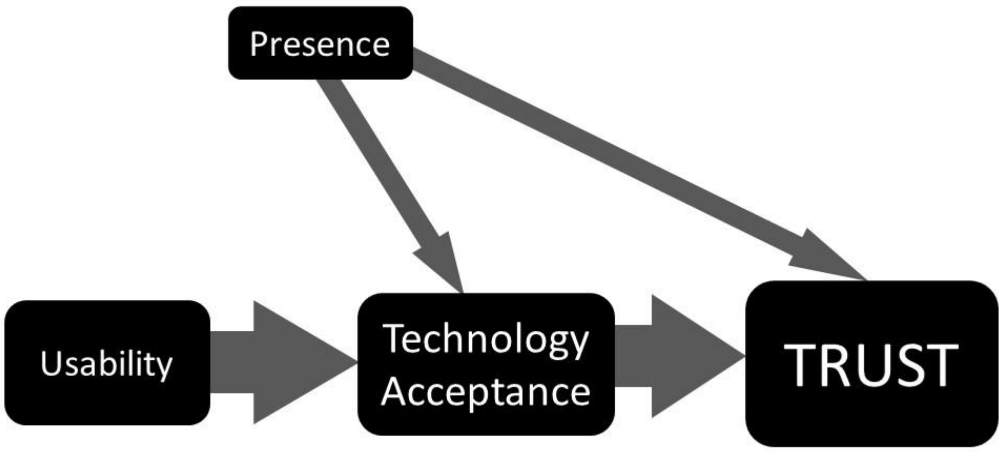

Figure 6.14. Definitive model with Technology acceptance as trust main predictor, presence as minor influencer and Usability as main predictor of Technology acceptance and presence as minor influencer.

As can be seen in the figure above, the model is more complicated than the one depicted in the literature review chapter. Thanks to the results of this study, it has been possible to find that the three factors do not have the same effect on trust. However, even if, for example, usability does not have a direct effect on trust and presence has a weaker effect, this does not mean that they are less important in the construction of trust. In fact, if a system is not perceived as usable, it may result in a low technology acceptance and, consequentially, in low trust.

H1 has been confirmed and demonstrated. Each factor has an influence on trust as the results from the regressions show and as stated in previous studies. However, the influence is not equal among factors. Technology acceptance is the best predictor of trust, usability does not have a direct effect on trust, but it is the best predictor of technology acceptance. Presence has a minor influence on trust and technology acceptance.

H2: there is a significant difference between the environments in the level of presence, usability, technology acceptance and Trust.

H2b: the model is valid for low and high level of each factor.

One of the hypothesis described in the paragraphs above, was that the model is still valid regardless of the level of the four factors. That is even with low usability, presence, technology acceptance or trust, the relationship among the factors still stand. However, this hypothesis could not be verified, since there were no significant differences between the environments. These results could be surprising, since the study was designed to highlight the differences. However, in all the studies conducted, the subjective level of each factor has been measured. This means that the focus was not on the objective level of the factors, but on the perception the participants had of usability, technology acceptance and presence. As seen in the literature the perceptions of users, not always corresponds to the objective level (Slater, 2004).

H2 has not been verified. The t-tests performed to analyse if a difference among the environments existed was not significant.

H2b could not have been verified. Since there is no difference among the environments, it is not possible to investigate if the model is still valid for different levels of the factors.

H3: There is an influence of pre-interaction trust on the post-use trust.

As stated in the introduction of this chapter, one of the hypotheses was that pre-interaction trust would affect post-use trust, as demonstrated in the literature (McKnight et al., 2011). However, when included in the model, the results show no influence. These results are surprising, since they go against the previous literature. The interpretation of this result could be the type of participants, who were not end users or expert of VR, or the fact that the influence of technology acceptance, presence and, indirectly, usability is stronger than the pre-interaction factors. Another interpretation could be the indirect influence of pre-interaction trust on post-use trust. These interpretations should be investigated further in future studies.

Other results

Other than statistics aimed to validate the model and demonstrate the hypotheses, other analysis were performed to understand better the relationship between some other factors. One of the main factor that influence the interaction with VR systems is cybersickness. As stated in the literature review, cybersickness is one of the main problems arising when implementing VR (Cobb et al., 2006). In this study, cybersickness was measured through the entire experiment, before and after each interaction through the SSQ questionnaire. To understand if SSQ has a relationship with the other variables measured in the study, a series of correlations was performed. The only significant result was between SSQ and VR experience. The correlation was negative, meaning that the more experience the participants had with VR, the less cybersickness symptoms were experienced. This result is in line with the literature (Hill and Howarth, 2000)

One explanation for the lack of effect of cybersickness with the rest of variables could be due to the elimination of the data from the participants interrupting the study. This means that the participants completing the study had none to mild symptoms, permitting them to continue and complete the experiment. Whereas, the participants experience severe cybersickness symptoms were not included in the analysis. It would have been interesting to analyse the data from these participants too, but, due to ethics regulations, data of participants not completing the study cannot be included in the analysis.

6.7 Conclusion

After the results of the previous studies, which demonstrated that usability, technology acceptance and presence influence trust in VR when studied singularly, there was the need to investigate this relationship more in details to uncover indirect influence and assess the relationship of the three factors among them. The study was designed to have all the three factors together as independent variables and trust as dependent variable. The results indicated that the model depicted in chapter 2 was too simple to describe the influence the factors have in the perception of trust by the users. In fact, it has been found that technology acceptance is the best predictor of trust in technology, explaining most of its variance. Presence has a minor direct influence on trust and a minor direct influence on technology acceptance, thus it has both a direct and indirect effect on perceived trust. Usability does not have any direct influence on trust, as the results stated, but it is still an important factor in the model, since it has a strong direct effect on technology acceptance, that is the main predictor of trust. This means that, even if the model is not the one hypothesised in the introduction of this thesis, all the three factors still hold an important role in the development of trust and have to be take into account when designing and implementing VR systems. However, the order of importance these factors have changed and designers should favourite a higher perceived technology acceptance rather than a higher presence.

This study has a fundamental importance in the PhD research, since it both confirms and disproves some of the results found in previous studies and contributes to a final, more complete and more accurate draft of the framework.

7. Chapter 7 – Discussion and conclusion

7.1 Chapter overview

This chapter presents discussion of the main results of literature review and experiments conducted during the PhD research, and describes how these results helped at achieving the aims described in the introduction. At the end of the chapter, recommendations are made for: the industrial partner, future work, addressing the limitations of the work.

The main points of this chapter are:

- This research is the first step in the creation of a model to study trust in VR.
- Three factors have been found to influence trust in VR: Technology acceptance, usability and presence.
- The results of the research could have important impact in the academic and industrial sector, such as the improvement of the interaction between the user and the technology.

7.2 Summary of results

7.2.1 Literature review

The results of the literature review highlighted that trust is a fundamental concept in human-computer interaction and greatly affects the adoption and use of a technology (Muir and Moray, 1996; Ba, Whinston and Zhang, 1999; Gefen, Karahanna and Straub, 2003, McKnight et al., 2011). The first phase of the literature review was focused on the concept of trust in technology, the study of its determinants and dimensions. This showed that trust is a multidimensional concept and is influenced by user- and technology-characteristics (McKnight et al., 2011). It is unclear, however, which of the technological characteristics could enhance the trustworthiness of a VR system. Therefore, the second phase of the literature review focused on the studies on trust in technology and the research on VR, which were combined to create a framework of trust in VR. The framework theorised that three main factors would influence trust in VR: technology acceptance, usability and presence.

After the creation of the framework, a series of experiments were designed to validate it.

7.2.2 Studies

To validate the framework, data from six experiments were gathered and analysed. Table 7.1 summarises the factors investigated for each experiment, the method used and results obtained.

Study	Factor(s)	Aim	Method	VR system	Results
Study 1- Pilot Study	Usability/ Technology acceptance/ Presence	To investigate the reliability of the questionnaires chosen, to spot methodological and deign issues and to have a first set of data on the relationship between usability and TAM with trust	19 participants performing six assembly and disassembly tasks	CAVE. Movements controlled with a tracked joystick	Technology acceptance has a strong relationship with trust, usability has a weaker effect, and no relationship was found for presence.
Study 2- Desktop VR	Usability	Investigate the relationship between usability and trust in a desktop VR	22 participants performing one task	Desktop-VR movements controlled with mouse and keyboards	There is a relationship between usability and trust.
Study 3- Flight Simulator	Usability	Investigate the relationship between usability and trust in a flight simulator	8 participants performing three tasks	Flight simulator	No significant relationship was found between usability and trust.
Study 4- Virtual Boot	Technology Acceptance/ Presence	Investigate the relationship between presence and technology acceptance with trust	22 participants looking at a virtual car model.	CAVE Movement controlled with a joystick	There is a relationship between technology acceptance and trust. No results were found

					for presence.
Study 5-Presence	Presence	Investigate the relationship between presence and trust	50 participants divided in two groups, half with immersive VR and half with non-immersive VR	HDMI Movement controlled with a steering wheel and pedals	There is a relationship between presence and trust.
Study 6-Final	Usability/ Technology acceptance/ Presence	Investigate the relationship between the three factors and trust and how the factors interact with each other.	40 participants interacting with eight different VE and performing a task	HDMI Movement controlled with a XBOX controller	Technology acceptance is the best predictor of trust, presence has a limited influence, usability has no direct relationship with trust, but it is the best predictor of technology acceptance.

Table 7.1 Summary of results from each study.

The first study (chapter 3) served as a pilot study to spot methodological and experimental design problems, to investigate the reliability of the questionnaires and to have the first set of data on the framework. The results of the study highlighted how the questionnaires are suitable to be used in VR field and that there is a strong relationship between technology acceptance and trust, a weaker relationship between usability and trust and no relationship with presence. Moreover, the pilot provided the data to support modification of the questionnaires and methodology to match the nature of the next experiments.

Studies 2,3,4 (chapter 4) and 5 (chapter 5) investigated the relationship between each factor taken singularly (studies 2,3 and 5) or paired (study 4), in order to assess if each factor had a relationship with trust and to have more data for recommendations to the industrial partner (aim 3). The results of the experiment were in line with the results of the pilot study regarding technology acceptance and usability. In fact, it was demonstrated that technology acceptance has a strong relationship with trust and usability has a weaker relationship, which may be influenced by the expertise of the participant (study 3). Regarding presence, study 5 demonstrated that presence has a relationship with trust.

The last study, described in chapter 6, aimed at the validation of the model. The results of the experiment permitted the modification of the initial framework to a final trust in VR model. In more detail, technology acceptance is the main predictor of trust, presence has a weaker relationship with trust and usability does not have any direct relationship with trust, but it is the main predictor of technology acceptance. Therefore, the model depicted in chapter 2, was modified in chapter 7.

In addition to investigating the relationship between the factors and trust, during the PhD a secondary hypothesis was investigated. That is the influence of users' characteristics of trust in the model. In the pilot study (chapter 3), presence study (chapter 5) and in the final validation study (chapter 6) a measure of pre-interaction trust was taken and then the relationship with trust was investigated, both alone and included with the factor studied in each experiment. The results showed that pre-interaction trust has an effect on post-interaction trust, however, when included with the factors studied, the significance of the influence disappears.

The next sections will discuss the results of the experiments, the novelty of the research conducted during the PhD project, the impact of the findings and the connection of the results with the justifications and aims described in the introduction chapter (chapter 1).

7.3 Discussion

As stated in the introduction, the adoption of VR is growing in many fields, such as industry (Lawson, Salanitri and Waterfield, 2016), healthcare (Hoffman et al., 2000; Rothbaum et al., 2001) and training (Borsci et al., 2016) and trust could be a fundamental factor for the correct adoption of this technology.

Through the user studies described in this thesis, this work validated a model to investigate trust in VR which is based on previous models of trust for other technologies but differs from them, as it takes into consideration the difference of VR in respect to other systems. The model gave three main results:

Technology acceptance is the most important factor of trust. In all the studies conducted, technology acceptance always had a significative linear relationship with trust, both when taken alone and together with other factors. Therefore, it was been demonstrated that, regardless of the system used, the type of environment or the medium of control, technology acceptance influences trust in VR systems. Referring to the literature on technology acceptance (Davis, 1980; Venkatesh and Davis, 2000; Venkatesh and Bala, 2008), it can be said that the perceived ease of use and the perceived usefulness of a system are important in order to increase the sense of trust people have in a VR system.

Presence has an effect on trust and technology acceptance, but it is dependent on the system and the type of interaction. Unlike technology acceptance, the relationship between presence and trust exists but not in all the VR system studied in this research and for all the type of interactions. The relationship between presence and trust was only found significant using HMD (chapter 5 and 6) and was not significant in CAVEs (chapter 3 and 4). The reasons for this could rely on the level of immersion experienced by the participants, the type of interaction in the VEs (active versus passive), the type of navigation (no navigation versus driving versus walking) and the flow of interaction (interrupted versus uninterrupted) (Slater and Wilbur, 1997; Lessiter et al., 2001). These factors could all influence the sense of presence, as explained in the literature review chapter (chapter 2). However, the fact that presence was found significantly related to trust in the last two studies, can be a strong enough reason to add it to the final model. Moreover, in the last experiment it was also demonstrated that presence has also an effect in the development of technology acceptance. The fact that presence influences important aspects of a technology (acceptance and trust) confirms the importance this factor has in the VR field (Witmer and Singer, 1997), but the fact that the relationship is not constant confirms that this VR characteristic is strongly dependent of the type and content of the system (Usoh et al., 2000).

Usability does not have a direct influence on trust. In most of the studies conducted, usability had an effect on trust when considered alone as independent variable. However, when included in the model the effect of usability was not significant. This result was interpreted in the thesis as a possible indirect relationship. In the last experiment, it was demonstrated how usability has no direct effect on trust, but it has a strong influence on technology acceptance. Therefore, it can be said that even usability is not a factor of trust, it is still important in the model, as it has a strong effect on the main predictor of trust.

Other than increasing the knowledge about trust, this research confirmed some of the theories already presented in the literature. For example, the confirmation that usability is one of the strongest predictor of technology acceptance, already theorised in the first TAM, where ease of use was included as a factor (Davis, 1985). The connection between usability and technology acceptance was also theorised in the TAM3 model, where usability was added as a factor of ease of use (Venkatesh and Bala, 2008). Bertrand and Bouchard (2008) demonstrated how ease of use does not have a direct influence on intention to use, while perceived usefulness does. Perceived ease of use, on the other hand, was a predictor of perceived usefulness. This PhD research supports the possibility that perceived ease of use (which is a determinant of usability) is not a part of technology acceptance, but it is its predictor.

Another theory demonstrated was the doubtful usefulness of presence measures for VR comparison. In fact, as Usoh et al. (2000) demonstrated, presence questionnaires are useful when measuring the level of presence of a system, but fail to detect differences between two different systems, especially in between studies. Interestingly, the authors use the same questionnaires used in study 5 of this thesis (chapter 5) and found that there was a slight difference for the S.U.S. questionnaire but not for the PQ questionnaire, which are the same results found in this research.

In the pilot study (chapter 3) the presence study (chapter 5) and the final validation study (chapter 6), the influence of users' characteristics on trust was also investigated as a secondary aim. The results were surprising, since an effect of the pre-interaction trust was found when taken singularly, but no effect was found when included in the model. The interpretations of this result could be many: one could be the indirect influence of the pre-interaction trust, which may influence some factors affecting trust in VR. Another explanation could be the importance of the factors affecting trust, with usability, technology acceptance and presence being stronger than the pre-interaction trust. These results could be a turning point in the study of trust, because they could switch the attention from users to technology characteristics. It would be interesting to investigate this notion further in future research.

One of the most important findings of this PhD research is that the relationships between the factors and trust were investigated for different VR technologies, making it possible to generalise the model to a great variety of systems, such as desktop VR, CAVEs and HMD.

7.3.1 Novelty

The importance of the results of the experiments could be a starting point for a new line of research focusing on trust, in order to increase the capability of VR systems to satisfy users' needs and increase the quality of the interaction, and the product.

One of the most important novelties of the research was the study of the relationship between presence and trust. In fact, technology acceptance and trust and usability and trust have already been seen to be related (Hernández-Ortega, 2011; Roy, Dewitt and Aubert, 2001), even though the focus was on other technologies. However, little research focused on the relationship between presence and trust in VR. The results of this research could further increase the importance of presence in the VR field, since it has been demonstrated that it is one of the factors influencing trust in VR.

Another novelty in this research is the application of the TAM to VR. As said in the introduction, the model, although vastly used in various field (King and He, 2006), has limited application in VR fields. With only few studies analysing the influence of technology acceptance in VR. However, the results of this PhD research are in line with the studies conducted on this matter (Bertrand and Bouchard, 2008). Moreover, the results of the last experiment also showed that presence is a predictor of technology acceptance. This result, combined with the one regarding usability and technology acceptance, could demonstrate how, regarding VR, the acceptance of a system is determined by the perceived usability and the perceived presence.

Finally, in the last experiment the direction of the relationship between technology acceptance and trust was investigated. In the literature, trust was mostly considered as a factor of technology acceptance, in this work the focus was on the opposite direction. The last experiment showed that while there is an effect of technology acceptance on the development of trust, there is not a direct linear relationship between trust and technology acceptance when the latest is considered as the dependent variable. This finding adds a new possibility in the theory of technology acceptance and trust. However, further investigations are necessary to demonstrate this relationship in other VR systems and technologies.

To summarise the novelty of the research, the results open up a new field of research, focused on trust in VR to enhance the probability of an appropriate and right VR interaction. Moreover, the importance of well-known factors such as presence and usability in VR was supported.

7.3.2 Impact

This model gives three important opportunities in the VR field:

1. The solution of issues derived from the lack of trust the users have in a system.
2. The possibility to focus on certain characteristics of a VR system in the process of design and development of a VR system.
3. The possibility to further investigate the model of trust in VR to add, modify or add specificity to the factors enhancing trust in VR.

Regarding the first opportunity, the model could help improve the quality of interaction for existing users of VR systems. Indeed, the model could help develop a set of recommendations on what to prioritise if a trust issues is found between the users and the technology (i.e. technology acceptance to prioritise on presence). The recommendations will be listed in the next sections.

The second opportunity refers to the influence this model could have in the design of new systems in the future. That is, if, in the design process, more importance is given to the aspect increasing the acceptance, usability and presence of a system, it could be assumed that the system will be perceived as trustworthy.

7.3.3 Aims

In the first chapter of this research the aims of the project were listed. This section summarises the results found for each of the research aims as described in chapter 1.

Aim 1: to identify the possible factors influencing trust in VR

Aim 2: to develop and validate a model to assess trust in VR

Aim 3: to develop a list of recommendation for industries on how to increase the trustworthiness of VR systems.

Aim 1 was fulfilled with the literature review. In fact, the results, discussed in the first section of this chapter, showed that technology acceptance, usability and presence could have been three factors influencing trust in VR. The factors were decided by combining the literature on trust in technology with the literature on VR.

Aim 2 was achieved both with the literature review and the six experiments described in the previous chapters. The model was first theorised to be a linear model, with the three factors having an equal and direct influence on trust. However, after the results of the studies, the framework was changed, because of the different importance of each factor and the nature of relationships.

Aim 3 was achieved through the literature review and confirmed through the user studies. The model resulting from the experiments elicits the main factors that have to be taken into account in VR systems design, and extensive pre-existing research on technology acceptance, presence and usability allows to set guidelines to inform VR developers on which factors to take into account in order to increase the trustworthiness of the system. As stated in the introduction (see section 1.3) the guidelines are generic and are based on previous research on the factors.

7.3.4 Recommendations

To better understand how the model can inform the evaluation of VR systems, especially concerning trust, a graph was created (Figure 7.1). The graph depicts a possible evaluation of a trust issue detected in a VR system.

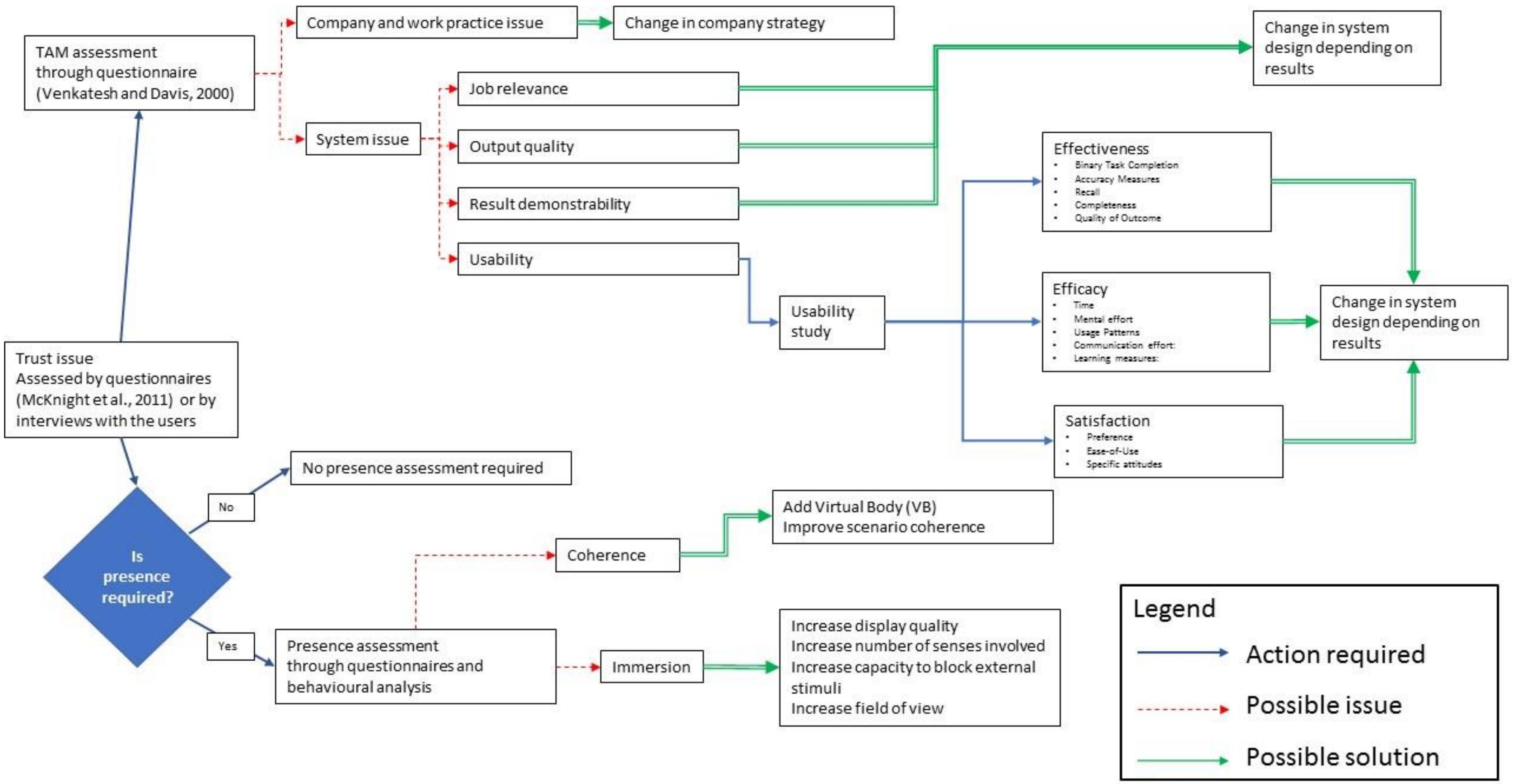

Figure 7.1 Evaluation timeline of a trust issue referring to the trust model.

The first two assessments should be technology acceptance and presence, which directly influences trust, followed by usability.

7.3.4.1 Presence

However, as stated in section 2.4.4, presence is not always required (i.e. reproduction fidelity continuum). Therefore, a presence assessment is not always necessary. When it is, the assessment should be performed using both questionnaires and objective measures (e.g. behaviour analysis, physiological measures). In fact, as was demonstrated in the presence experiment (chapter 5) and in the literature (Usoh et al., 2000) presence questionnaires are not always reliable and strongly depend on the user perception. When a presence issue is detected, the designer could take action depending on the system characteristics (i.e. presence/absence of a VB, high/low immersive system) and the type of issue encountered (i.e. immersion, coherence). Generally, one way to increase the sense of presence (in particular the PI (Slater, 2009)), is to increase the sense of immersion. This could be achieved through the involvement of more senses in the interaction, the improvement of the quality of display, improvement of the capability to block external stimuli and the enhancement of the field of view (Slater and Wilbur, 1997). Another important consideration to improve the sense of presence is the focus on coherence, which has been seen to enhance PSI (Skarbez et al., 2017). This could be achieved with the introduction of a VB in the VE, the improvement of the coherence between the VE and the scenario (e.g. if the system simulates a factory, the virtual environment should match a real factory environment) and the enhancement of the interaction with virtual object that the users have to use extensively, such as virtual tools (Skarbez et al., 2017). When taking presence into account, the focus on the quality of interaction and realism should depend on the application field. In fact, as stated in section 2.2.4, it is not clear that a better-quality display will give a higher level of immersion. Moreover, the design of the VE should also take into account the phenomenon of the uncanny valley, especially if there are avatars included in the scenario. Therefore, the level of realism of the displayed objects should be carefully assessed, as this could influence the users' familiarity and believability in the VE and, therefore, the sense of presence.

7.3.4.2 Technology acceptance

Together with presence, technology acceptance should be the first factor to be assessed in case of a trust issue. In addition, technology acceptance was the factor with the most important impact therefore its assessment should have an increased attention. The assessment of technology acceptance could be conducted through questionnaires (e.g. Venkatesh and Davis, 2000; Hernandez-Ortega, 2011). Referring to the theories on technology acceptance (TAM, section 2.4) the most important factor to enhance acceptance is perceived usefulness. Some of the factors increasing the perceived usefulness of a technology are related to the company strategy, these are "social influence processes" (Davis, 1985) and include factors such as voluntariness, image, job relevance and subjective norms (Venkatesh and Davis, 2000). For example, subjective norm is the users' perception that someone important to them thinks that they should or should not perform an action (Venkatesh and Davis, 2000). Image is another company factor which could influence the acceptance of a technology. Image is defined as the perception that using a specific system will enhance the social status of the users (Moore and Benbasat, 1991). Therefore, if the technology acceptance assessment reveals low scores in the social influence processes, the company should change its strategy about the system. This may include the way that the system is presented to the users, highlighting the importance of the system in the company culture and improving the support of managers and colleagues.

Another contribution of technology acceptance is defined as "cognitive instrumental processes" and can be influenced by the system characteristics. As described in section 2.4 there are four cognitive processes: job relevance, output quality, result demonstrability and perceived ease of use. In order to increase the level of these four factors, the system should provide: 1) a direct demonstration of what the system is capable of (job relevance) which may be achieved through a tutorial of the potentiality of the technology, 2) a clear demonstration on how well the system performs the job (output quality) this could include understandable and measurable outcomes 3) obvious advantage on the task the users have to perform (result demonstrability), which may be achieved through a comparison between the performance with and without the system and 4) an effortless experience (perceived ease of use), for example without cumbersome and uncomfortable navigation controls.

To summarise, in order for a system to be accepted and, therefore, trusted there should be common effort by the designer and companies. Designer should make the system easy to use and capable to demonstrate its advantage in terms of job performance and output. The company should provide clear advantages in the usage of the system, both for the single user and the entire company.

7.3.4.3 Usability

Even though usability was not found to have a direct influence on trust, when a trust issue arises, usability could be one of the possible cause, since it is the best predictor of technology acceptance. The assessment of usability can be done through questionnaires (e.g. SUS) and through usability studies. In a review, Hornbæk (2006) described a series of measures used to evaluate usability, specifically, the author divided the measures for the assessment of the usability dimensions (efficacy, effectiveness and satisfaction).

In general, in order to perceive a system as usable, the users have to perceive it as efficient, comfortable, effortless and satisfactory. Therefore, the focus should be on an effortless interaction, concentrating on the interface quality, the system efficiency and reliability (Bevan, 2009). Research on mobile phone usability, found that simplicity and interactivity are two determinants of the satisfaction in the use of mobile phones (Lee et al., 2015) and could be applied to VR interaction as well. Virvou and Katsionis (2008) found that the familiarity of user interfaces, the navigation effort and the environmental distractions were possible issues in the usability of VR games. Interestingly, Sun et al. (2015) found that promotion focus is positively related to efficacy, effectiveness, user satisfaction and overall usability perception and that involvement correlated with effectiveness. Other studies focused on the types of interaction and their link to usability (e.g. Kaur, Maiden and Sutcliffe, 1999) or the use of gestures (e.g. Cabral, Morimoto and Zuffo, 2005). However, in this work a general suggestion to modify the system characteristics is given. This is due to the strong link of usability to context. As stated in section 2.6, usability of a precise system should be evaluated for precise users, in a precise context and this thesis concerns trust in general VR systems. Nevertheless, as Hornbæk (2006) stated: "*even discussing and analysing usability measures at a general level can identify problems and research challenges concerning how to measure usability in particular contexts of use*" (p. 98).

To summarize, VR designers should focus on the interaction with VR, making it as effortless and efficient as possible. However, usability is dependent on the type of task, type of system and the context (Brooke, 2001). Therefore, it is fundamental for the designers and the companies to perform usability tests tailored to their field, technology and target users, in order to understand the usability issue in that particular context.

Figure 7.1 provides guidance to assess trust issue in existing VR systems: the system implementation should follow the steps in the diagram from left to right. However, in the process of designing a new system, the VE developers should follow the diagram from right to left. In order to design a trustworthy system, it should be perceived as usable, this will increase the acceptance of the system and therefore its trustworthiness. Moreover, if presence is required and does not pose an obstacle in the use of the technology, the system should also give a high level of presence.

7.4 Limitations

The first limitation of this research regards the context of experiments. In fact, most of the studies designed were situated at the University of Nottingham laboratory in a controlled environment and with participants recruited from the university students and staff population. It would have been interesting to have more experiments conducted in industrial settings, with real end-users, to analyse the difference in the perception of trust and in the influence the factors have on trust. However, the industrial environment is not always suitable for a research, due to their tight schedule and the difficulties of accessing systems when sensitive material is displayed. Moreover, some experiments conducted at the university required different settings to investigate the differences among different types of environments or systems (e.g. chapter 5 and chapter 6), which would have been difficult to implement in an industrial environment, since changes in the systems could cause delays in the normal work routine. This issue also influenced the types of participants available for recruitment. In most of the studies, the participants were not experts of VR systems and did not use VR systems in their daily job. It would have been interesting to understand how the expertise of the users could influence the framework.

Another limitation concerned the measurement of presence. As said in the literature review chapter, for some researchers, the use of questionnaires is considered to be insufficient (Slater, 2004) and other measurements should be used in association with subjective responses. This aspect was taken into consideration in study 5 (chapter 5), where EDA was also measured. However, the instruments used and some aspects of the design of the experiments, like the inclusion of vibration as a feedback, could have strongly influenced the results. Moreover, the ideal hardware to measure physiological responses was over the budget limit of the project.

The third limitation concerns a long-standing problem of using VR systems, that is cybersickness (Cobb et al., 2006). In fact, especially in the final validation study, more than ten participants had to interrupt the study because of adverse symptoms. This issue delayed the time required for the experiment and avoided the possibility to conduct follow up studies to add specificity to the model. Moreover, due to the possibility of cybersickness symptoms, a requirement imposed by the Ethics Committee was that participants' interaction with the system should be interrupted to ask them to complete the cybersickness questionnaire (After every two tasks in the pilot study, after each task in the presence study and final validation study. An interruption every 3-5 minutes of interaction). As discussed in chapter 3, this could have affected the flow of the interaction and decrease the sense of presence experienced by the participants (Lessiter et al., 2001).

The fourth limitation of the research is the lack of investigation for each dimension of the factors studied. For example, it would be interesting to understand which dimension of trust (functionality, reliability, helpfulness) is more influenced by usability, technology acceptance and presence. Moreover, it would be interesting to understand if there is a specific dimension of the factors influencing trust in VR. For example, if, regarding technology acceptance, perceived usefulness is more important than perceived ease of use in the influence they have on trust. In this research priority was given to the factor as a whole, since the model is new in the literature landscape.

A general limitation of the researchy is the lack of consideration for the aspects of the technology which could influence each factor studied (usability, presence and technology acceptance). The study of technology attributes could have led to a more specific set of guidelines for the industrial partner. For example, if was found that a specific technology attribute, such as a help function, would increase the technology acceptance of a VR system, a specific recommendation could have been given to the industrial partner. However, this investigation would have required an enormous amount of time since there is not enough literature on factors such as usability and technology acceptance for VR systems and these factors are strongly dependent on the context of use and the users. However, this PhD research could be the starting point for a new line of research investigating the aspects influencing the validated model of trust. In fact, new research could be done on each of the factors taken alone, investigating its attributes and technological determinants.

Another limitation of this PhD research is the failure to manipulate different levels of the variables, despite their manipulation. This limitation concerns study 5 and study 6 where presence (study 5 and 6), technology acceptance (study 6) and usability (study 6) were manipulated. However, as discussed in the chapters concerning the studies, no significant difference was found. It could be that the characteristics manipulated were not the right one or were not enough to differentiate the level of the factors. However, a possible interpretation could be the difficulty in spotting differences when subjective measures are used. As demonstrated for presence, questionnaires often fail to show the difference between different systems (even between a VR system and reality) (Usoh et al., 2000). This could be applied to usability and technology acceptance. Future studies should focus on a better manipulation of the systems to investigate the effectiveness of the model for different environments.

7.5 Future steps

Starting from the framework validated in this thesis, it could be possible to expand the model, adding other attributes and, maybe, changing the importance of each factor. Other characteristics of the system or the users could influence trust in VR, it will be useful to continue to identify new factors and add them to the model validated in this research, to investigate how the new factors interact with trust and with usability, presence and technology acceptance.

Another way to expand the model is to add each dimension of usability, presence and technology acceptance and investigate their connection with the dimensions of trust (functionality, reliability and helpfulness). It could be found that there is one specific dimension of usability, presence and technology acceptance that influence trust, or that the model influence one specific dimension of trust. For example, from the fact that usability does not have a direct relationship with trust, but that it is the best predictor of technology acceptance, it can be deducted that perceived ease of use and perceived usefulness (dimensions of technology acceptance) have a different impact on trust, with perceived usefulness being more important. Furthermore, it could be useful to investigate the secondary aim of this research, that is to understand the users' characteristics and their influence in the model. In this research, pre-interaction trust was not found to have an influence on final trust when included in the model. This result is new in the literature and should be investigated further.

To increase the impact of the framework for industrial or real-life application, future studies could investigate technological attributes improving technology acceptance, usability and presence and give specific recommendations to VR designer in order to make the systems more trustworthy. As stated in the previous section, the recommendations developed in this research are not specific. This is because there is still uncertainty on which characteristics of the technology enhance usability, technology acceptance and trust. For instance, it could be assumed that a seamless interaction with the system could enhance usability, and therefore, trust. However, due to time and resources constrain, the specific characteristics were not taken into consideration in this work.

Other than expanding the model, this work could be a starting point to build a questionnaire on trust in VR. In fact, combining the factors influencing trust and the dimension of trust, it could be possible to build a unique validated measure of trust in VR, which could help future studies.

Referring to the limitations described in the previous section, future works should investigate the model in an industrial setting, possibly with end-users, in order to analyse the influence of expertise in the development of trust and investigate how the model change in a real setting. These studies could also improve the validity of the model and improve the recommendations for design of future systems.

Moreover, especially regarding presence, it would be useful to have more measures other than questionnaires, such as physiological and behavioural measures. These methods require proper study design and instruments.

7.6 Conclusion

The successful implementation and adoption of VR cannot disregard users trust. The belief that the system is functional, effective and reliable, therefore trustworthy, is fundamental to fully exploit the VR advantages compared to other technologies.

This research work contributed to address a gap in the literature regarding trust in VR by generating and validating a model of trust in VR systems. The model shows that well-known concepts in HCI have an impact on trust. Specifically, technology acceptance is the best predictor of trust, presence has a minor influence on trust and on technology acceptance, and usability has no direct influence on trust, but it is the best predictor of technology acceptance.

This model could be added to the frameworks on VR and increase the amount of information available for this technology. In addition, the confirmation of existing theories, such as the relationship between usability and technology acceptance, adds validity to the work that has already been done in literature about these two factors.

Furthermore, the model can be applied in industries to solve trust issues or to inform the design of new VR systems which will be perceived as more trustworthy. The model emphasises the importance of certain characteristics of VR, such as its usability, acceptance and the capability to give sense of presence and gives general guidelines on how to increase these factors. In addition, the inclusion of technology acceptance highlights the importance of the company strategy and the influence that users' motivation can have in the perception of trust in the system.

In future research, a more detailed investigation of the framework could add more factors and could measure more precisely the effect of each factor on trust. However, this model provides a basis upon which to start and to move toward a definitive model of trust in VR. Generally, this research could have a big impact in the improvement of VR: a technology which is growing and becoming used more widely, both in academia and in the private sector and could enhance its effectiveness and provide its correct adoption.

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9. Appendices

9.1 Questionnaires

9.1.1 Technology acceptance questionnaires

9.1.1.1 Technology acceptance questionnaire (Venkatesh and Davis, 2000 and Hernández-Ortega, 2011) used in the pilot study (chapter 3).

TAM Questionnaire

The following 36 statements are being used in literature to observe the Technology Acceptance of people, and the beliefs about the use of a specific technology. In that case, we will ask to you to answer the questions in relation to the use of the CAVE. Please follow the instructions and fill the questionnaire

Instructions: Please for each one of the statements on the left mark on the right one box that best describes your agreement from 1- Strongly disagree to 7-Strongly agree

(Participant ID *{researcher to complete}*: _____)

	Strongly Disagree						Strongly Agree
1. Assuming I have access to the system, I intend to use it.	☐	☐	☐	☐	☐	☐	☐
2. Given that I have access to the system, I predict that I would use it.	☐	☐	☐	☐	☐	☐	☐
3. Using the system improves my performance in my job.	☐	☐	☐	☐	☐	☐	☐

4. Using the system in my job increases my productivity.	☐	☐	☐	☐	☐	☐	☐
5. Using the system enhances my effectiveness in my job.	☐	☐	☐	☐	☐	☐	☐
6. I find the system to be useful in my job.	☐	☐	☐	☐	☐	☐	☐
7. My interaction with the system is clear and understandable.	☐	☐	☐	☐	☐	☐	☐
8. Interaction with the system does not require a lot of my mental effort.	☐	☐	☐	☐	☐	☐	☐
9. I find the system to be easy to use.	☐	☐	☐	☐	☐	☐	☐
10. I find it easy to get the system do what I want to do.	☐	☐	☐	☐	☐	☐	☐

	Strongly Disagree						Strongly Agree
11. People who influence my behaviour think that I should use the system.	☐	☐	☐	☐	☐	☐	☐
12. People who are important to me think that I should use the system.	☐	☐	☐	☐	☐	☐	☐
13. My use of the system is voluntary.	☐	☐	☐	☐	☐	☐	☐

14. My supervisor does not require me to use the system.	☐	☐	☐	☐	☐	☐	☐
15. Although it might be helpful, using the system is certainly not compulsory in my job.	☐	☐	☐	☐	☐	☐	☐
16. People in my organization who use the system have more prestige than those who do not.	☐	☐	☐	☐	☐	☐	☐
17. People in my organization who use the system have a high profile.	☐	☐	☐	☐	☐	☐	☐
18. Having the system is a status symbol in my organization.	☐	☐	☐	☐	☐	☐	☐
19. In my job, usage of the system is important.	☐	☐	☐	☐	☐	☐	☐
20. In my job, usage of the system is relevant.	☐	☐	☐	☐	☐	☐	☐
21. The quality of the output I get from the system is high.	☐	☐	☐	☐	☐	☐	☐
22. I have no problem with the quality of the output of the system.	☐	☐	☐	☐	☐	☐	☐

23. I have no difficulty telling others about the results of using the system.	☐	☐	☐	☐	☐	☐	☐
24. I believe I can communicate to others the consequences of using the system.	☐	☐	☐	☐	☐	☐	☐
25. The results of using the system are apparent to me.	☐	☐	☐	☐	☐	☐	☐
	Strongly Disagree						Strongly Agree
26. I would have difficulty explaining why using the system may or may not be beneficial.	☐	☐	☐	☐	☐	☐	☐
27. The system is compatible with our business value and results.	☐	☐	☐	☐	☐	☐	☐
28. The system is compatible with our business culture.	☐	☐	☐	☐	☐	☐	☐
29. The system is compatible with our preferred work practice.	☐	☐	☐	☐	☐	☐	☐
30. It is faster to performing tasks with the system.	☐	☐	☐	☐	☐	☐	☐
31. The system increases the productivity of performing tasks.	☐	☐	☐	☐	☐	☐	☐

32. The system reduces the costs of performing tasks.	☐	☐	☐	☐	☐	☐	☐
33. The performance of the firm in conducting its tasks due to the system has been satisfactory.	☐	☐	☐	☐	☐	☐	☐
34. I will use the system on a regular basis in the future.	☐	☐	☐	☐	☐	☐	☐
35. I will frequently use the system in the future.	☐	☐	☐	☐	☐	☐	☐
36. It is likely that I will continue to use the system.	☐	☐	☐	☐	☐	☐	☐

Adapted from Venkatesh and Davis, 2000 and Hernández-Ortega (2011)

Please, live us a note if there is something you would like to add or if there are some questions that you think do not fit the experiment you just take part in.

9.1.1.2 Technology acceptance questionnaire used in the boot study (chapter 4) and final study (Chapter 6)

TAM Questionnaire

The following 19 statements are being used in literature to observe the Technology Acceptance of people, and the beliefs about the use of a specific technology. In that case, we will ask to you to answer the questions in relation to the use of the CAVE. Please follow the instructions and fill the questionnaire

Instructions: Please for each one of the statements on the left mark on the right <u>one</u> box that best describes your agreement from 1- Strongly disagree to 7-Strongly agree

	Strongly Disagree						Strongly Agree
1. **Assuming I have access to the system, I intend to use it.**	☐	☐	☐	☐	☐	☐	☐
2. **Given that I have access to the system, I predict that I would use it.**	☐	☐	☐	☐	☐	☐	☐
3. **Using the system improves my performance in my job.**	☐	☐	☐	☐	☐	☐	☐
4. **Using the system in my job increases my productivity.**	☐	☐	☐	☐	☐	☐	☐
5. **Using the system enhances my effectiveness in my job.**	☐	☐	☐	☐	☐	☐	☐
6. **I find the system to be useful in my job.**	☐	☐	☐	☐	☐	☐	☐

7. **My interaction with the system is clear and understandable.**	☐	☐	☐	☐	☐	☐	☐
8. **Interaction with the system does not require a lot of my mental effort.**	☐	☐	☐	☐	☐	☐	☐
9. **I find the system to be easy to use.**	☐	☐	☐	☐	☐	☐	☐
10. **I find it easy to get the system do what I want to do.**	☐	☐	☐	☐	☐	☐	☐
	Strongly Disagree						Strongly Agree
11. **The system is compatible with our business culture.**	☐	☐	☐	☐	☐	☐	☐
12. **The system is compatible with our preferred work practice.**	☐	☐	☐	☐	☐	☐	☐

13. **It is faster to performing tasks with the system.**	☐ ☐ ☐ ☐ ☐ ☐ ☐
14. **The system increases the productivity of performing tasks.**	☐ ☐ ☐ ☐ ☐ ☐ ☐
15. **The system reduces the costs of performing tasks.**	☐ ☐ ☐ ☐ ☐ ☐ ☐
16. **The performance of the firm in conducting its tasks due to the system has been satisfactory.**	☐ ☐ ☐ ☐ ☐ ☐ ☐
17. **I will use the system on a regular basis in the future.**	☐ ☐ ☐ ☐ ☐ ☐ ☐
18. **I will frequently use the system in the future.**	☐ ☐ ☐ ☐ ☐ ☐ ☐
19. **It is likely that I will continue to use the system.**	☐ ☐ ☐ ☐ ☐ ☐ ☐

9.1.2 System usability scale (SUS) used in the pilot study (chapter 3), Flight simulator and Desktop VR studies (chapter 4) and the final study (chapter 6)

System Usability Scale

The following 10 statements are being used in literature to observe the Perceived Usability of a system. In this case, we will ask to you to answer the questions in relation to the use of the Virtual Buck. Please follow the instructions and fill the questionnaire.

	Strongly Disagree						Strongly Agree
1. **I think that I would like to use this system frequently**	☐	☐	☐	☐	☐	☐	☐
2. **I found the system unnecessarily complex**	☐	☐	☐	☐	☐	☐	☐
3. **I thought the system was easy to use**	☐	☐	☐	☐	☐	☐	☐

4. I think that I would need the support of a technical person to be able to use this system	☐ ☐ ☐ ☐ ☐ ☐ ☐
5. I found the various functions in this system were well integrated	☐ ☐ ☐ ☐ ☐ ☐ ☐
6. I thought there was too much inconsistency in this system	☐ ☐ ☐ ☐ ☐ ☐ ☐
7. I would image that most of the people would learn to use the system very quickly	☐ ☐ ☐ ☐ ☐ ☐ ☐
8. I found the system very cumbersome to use	☐ ☐ ☐ ☐ ☐ ☐ ☐

9. **I felt very confident using the system**	☐ ☐ ☐ ☐ ☐ ☐ ☐
10. **I needed to learn a lot of things before I could get going with this system**	☐ ☐ ☐ ☐ ☐ ☐ ☐

9.1.3 Presence questionnaires

9.1.3.1 ITC- Sense of Presence Questionnaire, used in the pilot study (chapter 3)

ITC SOPI

Please read the instructions below before continuing

Instructions:

We are interested in finding out what you feel about the experience you have just had in the 'DISPLAYED ENVIRONMENT'. We use the term 'displayed environment' here, and throughout this questionnaire, to refer to the film, video, computer game or virtual world that you have just encountered. Some of the questions refer to the 'CONTENT' of the displayed environment. By this we mean the story, scenes or events, or whatever you could see, hear, or sense happening within the displayed environment. The displayed environment and its content (including representations of people, animals, or cartoons, which we call 'CHARACTERS') are different from the 'REAL WORLD': the world you live in from day-to-day. Please refer back to this page if you are unsure about the meaning of any question.

There are two parts to this questionnaire, PART A and PART B. PART A asks about your thoughts and feelings once the displayed environment was over. PART B refers to your thoughts and feelings while you were experiencing the displayed environment. Please do not spend too much time on any one question. Your first response is usually the best. For each question, choose the answer CLOSEST to your own.

Please remember that there are no right or wrong answers – we are simply interested in YOUR thoughts and feelings about the displayed environment. Please do not discuss the questionnaire with anyone who may also complete it as this may affect your answers or theirs. We should be grateful if you would also complete the 'Background Information' overleaf.

All of your responses will be treated confidentially.

ITC
Independent Television Commission

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ITC-SOPI

i2 media research

PART A

Please indicate HOW MUCH YOU AGREE OR DISAGREE with each of the following statements by circling just ONE of the numbers using the 5-point scale below.

(Strongly disagree)	(Disagree)	(Neither agree nor disagree)	(Agree)	(Strongly agree)
1	**2**	**3**	**4**	**5**

<u>AFTER</u> MY EXPERIENCE OF THE DISPLAYED ENVIRONMENT…

1. I felt sad that my experience was over 1 2 3 4 5

2. I felt disorientated 1 2 3 4 5

3. I had a sense that I had returned from a journey..1 2 3 4 5

4. I would have liked the experience to continue 1 2 3 4 5

5. I vividly remember some parts of the experience......................................1 2 3 4 5

6. I'd recommend the experience to my friends. 1 2 3 4 5

PART B

Please indicate HOW MUCH YOU AGREE OR DISAGREE with each of the following statements by circling just ONE of the numbers using the 5-point scale below.

(Strongly disagree)	(Disagree)	(Neither agree nor disagree)	(Agree)	(Strongly agree)
1	**2**	**3**	**4**	**5**

<u>DURING</u> MY EXPERIENCE OF THE DISPLAYED ENVIRONMENT…

1. I felt myself being 'drawn in'. 1 2 3 4 5
2. I felt involved (in the displayed environment). 1 2 3 4 5
3. I lost track of time. 1 2 3 4 5
4. I felt I could interact with the displayed environment 1 2 3 4 5
5. The displayed environment seemed natural. 1 2 3 4 5
6. It felt like the content was 'live'. 1 2 3 4 5
7. I felt that the characters and/or objects could almost touch me 1 2 3 4 5
8. I enjoyed myself. 1 2 3 4 5
9. I felt I was visiting the places in the displayed environment 1 2 3 4 5
10. I felt tired. 1 2 3 4 5

(Strongly disagree)	(Disagree)	(Neither agree nor disagree)	(Agree)	(Strongly agree)
1	**2**	**3**	**4**	**5**

<u>DURING</u> MY EXPERIENCE OF THE DISPLAYED ENVIRONMENT…

11. The content seemed believable to me.	1	2	3	4	5
12. I felt I wasn't *just* watching something.	1	2	3	4	5
13. I had the sensation that I moved in response to parts of the displayed environment	1	2	3	4	5
14. I felt dizzy.	1	2	3	4	5
15. I felt that the displayed environment was part of the real world.	1	2	3	4	5
16. My experience was intense.	1	2	3	4	5
17. I paid more attention to the displayed environment than I did to my own thoughts (e.g., personal preoccupations, daydreams etc.).	1	2	3	4	5
18. I had a sense of being in the scenes displayed	1	2	3	4	5
19. I felt that I could move objects (in the displayed environment).	1	2	3	4	5
20. The scenes depicted could really occur in the real world	1	2	3	4	5
21. I felt I had eyestrain.	1	2	3	4	5
22. I could almost smell different features of the displayed environment.	1	2	3	4	5

ITC-SOPI

(Strongly disagree)	(Disagree)	(Neither agree nor disagree)	(Agree)	(Strongly agree)
1	**2**	**3**	**4**	**5**

<u>DURING</u> MY EXPERIENCE OF THE DISPLAYED ENVIRONMENT…

23. I had the sensation that the characters were aware of me..........................1 2 3 4 5

24. I had a strong sense of sounds coming from different directions within the displayed environment...1 2 3 4 5

25. I felt surrounded by the displayed environment 1 2 3 4 5

26. I felt nauseous. 1 2 3 4 5

27. I had a strong sense that the characters and objects were solid.................1 2 3 4 5

28. I felt I could have reached out and touched things (in the displayed environment)..1 2 3 4 5

29. I sensed that the temperature changed to match the scenes in the displayed environment...1 2 3 4 5

30. I responded emotionally 1 2 3 4 5

31. I felt that *all* my senses were stimulated at the same time.........................1 2 3 4 5

32. The content appealed to me. 1 2 3 4 5

33. I felt able to change the course of events in the displayed environment. ...1 2 3 4 5

(Strongly disagree)	(Disagree)	(Neither agree nor disagree)	(Agree)	(Strongly agree)
1	**2**	**3**	**4**	**5**

<u>DURING</u> MY EXPERIENCE OF THE DISPLAYED ENVIRONMENT…

34. I felt as though I was in the same space as the characters and/or objects...	1	2	3	4	5
35. I had the sensation that parts of the displayed environment (e.g. characters or objects)were responding to me.	1	2	3	4	5
36. It felt realistic to move things in the displayed environment.....................	1	2	3	4	5
37. I felt I had a headache.	1	2	3	4	5
38. I felt as though I was participating in the displayed environment.	1	2	3	4	5

<u>If there is anything else you would like to add, please use the space below:</u>

<u>PLEASE CHECK THAT YOU HAVE ANSWERED ALL THE QUESTIONS</u>

<u>THANK YOU VERY MUCH FOR YOUR TIME AND PARTICIPATION</u>

9.1.3.2 Witmer and Singer (1998) Presence Questionnaire (PQ) as used in the Boot study (chapter 4) and final study (chapter 6).

Presence Questionnaire

Characterize your experience in the environment, by marking an "X" in the appropriate box of the 7-point scale, in accordance with the question content and descriptive labels. Please consider the entire scale when making your responses, as the intermediate levels may apply. Answer the questions independently in the order that they appear. Do not skip questions or return to a previous question to change your answer.

	Strongly Disagree						Strongly Agree
1. **How much were you able to control events?**	☐	☐	☐	☐	☐	☐	☐
2. **How responsive was the environment to actions that you initiated (or performed)?**	☐	☐	☐	☐	☐	☐	☐
3. **How natural did your interactions**	☐	☐	☐	☐	☐	☐	☐

with the environment seem?	
4. How much did the visual aspects of the environment involve you?	☐ ☐ ☐ ☐ ☐ ☐ ☐
5. How natural was the mechanism which controlled movement through the environment ?	☐ ☐ ☐ ☐ ☐ ☐ ☐
6. How much did your experiences in the virtual environment seem consistent with your real-world experiences?	☐ ☐ ☐ ☐ ☐ ☐ ☐
7. How compelling was your sense of moving around	☐ ☐ ☐ ☐ ☐ ☐ ☐

inside the virtual environment?	
8. How compelling was your sense of moving around inside the virtual environment?	☐ ☐ ☐ ☐ ☐ ☐ ☐
	Strongly Disagree … Strongly Agree
9. How well could you examine objects from multiple viewpoints?	☐ ☐ ☐ ☐ ☐ ☐ ☐
10. How involved were you in the virtual environment experience?	☐ ☐ ☐ ☐ ☐ ☐ ☐
11. How much delay did you experience between your actions	☐ ☐ ☐ ☐ ☐ ☐ ☐

and expected outcomes?	
12. How proficient in moving and interacting with the virtual environment did you feel at the end of the experience?	☐ ☐ ☐ ☐ ☐ ☐ ☐
13. How much did the visual display quality interfere or distract you from performing assigned tasks or required activities?	☐ ☐ ☐ ☐ ☐ ☐ ☐
14. How much did the control devices interfere with the performance of assigned	☐ ☐ ☐ ☐ ☐ ☐ ☐

tasks or with other activities?	

Original version : Witmer, B.G. & Singer. M.J. (1998). Measuring presence in virtual environments: A presence questionnaire. Presence : Teleoperators and Virtual Environments, 7(3), 225-240. The factor structure of the Presence Questionnaire. Presence, 14(3) 298-312. Revised factor structure: Witmer, B.J., Jerome, C.J., & Singer, M.J. (2005). The factor structure of the Presence Questionnaire. Presence, 14(3) 298- 312.

9.1.4 Witmer and Singer (1998) Presence Questionnaire (PQ) as used in the presence study (chapter 5)

PRESENCE QUESTIONNAIRE
(Witmer & Singer, Vs. 3.0, Nov. 1994)*
Revised by the UQO Cyberpsychology Lab (2004)

Characterize your experience in the environment, by marking an "X" in the appropriate box of the 7-point scale, in accordance with the question content and descriptive labels. Please consider the entire scale when making your responses, as the intermediate levels may apply. Answer the questions independently in the order that they appear. Do not skip questions or return to a previous question to change your answer.

WITH REGARD TO THE EXPERIENCED ENVIRONMENT

1. How much were you able to control events?

|________|________|________|________|________|________|________|
NOT AT ALL SOMEWHAT COMPLETELY

2. How responsive was the environment to actions that you initiated (or performed)?

|________|________|________|________|________|________|________|
NOT RESPONSIVE MODERATELY RESPONSIVE COMPLETELY RESPONSIVE

3. How natural did your interactions with the environment seem?

|________|________|________|________|________|________|________|
EXTREMELY ARTIFICIAL BORDERLINE COMPLETELY NATURAL

4. How much did the visual aspects of the environment involve you?

|________|________|________|________|________|________|________|
NOT AT ALL SOMEWHAT COMPLETELY

5. How natural was the mechanism which controlled movement through the environment?

|________|________|________|________|________|________|________|
EXTREMELY ARTIFICIAL BORDERLINE COMPLETELY NATURAL

6. How compelling was your sense of objects moving through space?

|________|________|________|________|________|________|________|

NOT AT ALL — MODERATELY COMPELLING — VERY COMPELLING

7. How much did your experiences in the virtual environment seem consistent with your real world experiences?

|________|________|________|________|________|________|________|

NOT CONSISTENT — MODERATELY CONSISTENT — VERY CONSISTENT

8. Were you able to anticipate what would happen next in response to the actions that you performed?

|________|________|________|________|________|________|________|

NOT AT ALL — SOMEWHAT — COMPLETELY

9. How completely were you able to actively survey or search the environment using vision?

|________|________|________|________|________|________|________|

NOT AT ALL — SOMEWHAT — COMPLETELY

10. How compelling was your sense of moving around inside the virtual environment?

|________|________|________|________|________|________|________|

NOT COMPELLING — MODERATELY COMPELLING — VERY COMPELLING

11. How closely were you able to examine objects?

|________|________|________|________|________|________|________|

NOT AT ALL — PRETTY CLOSELY — VERY CLOSELY

12. How well could you examine objects from multiple viewpoints?

|________|________|________|________|________|________|________|

NOT AT ALL — SOMEWHAT — EXTENSIVELY

13. How involved were you in the virtual environment experience?

|________|________|________|________|________|________|________|

NOT INVOLVED — MILDLY INVOLVED — COMPLETELY ENGROSSED

14. How much delay did you experience between your actions and expected outcomes?

|________|________|________|________|________|________|________|

NO DELAYS — MODERATE DELAYS — LONG DELAYS

15. How quickly did you adjust to the virtual environment experience?

|________|________|________|________|________|________|________|

NOT AT ALL — SLOWLY — LESS THAN ONE MINUTE

16. How proficient in moving and interacting with the virtual environment did you feel at the end of the experience?

|________|________|________|________|________|________|________|

NOT PROFICIENT — REASONABLY PROFICIENT — VERY PROFICIENT

17. How much did the visual display quality interfere or distract you from performing assigned tasks or required activities?

|________|________|________|________|________|________|________|

NOT AT ALL — INTERFERED SOMEWHAT — PREVENTED TASK PERFORMANCE

18. How much did the control devices interfere with the performance of assigned tasks or with other activities?

|________|________|________|________|________|________|________|

NOT AT ALL — INTERFERED SOMEWHAT — INTERFERED GREATLY

19. How well could you concentrate on the assigned tasks or required activities rather than on the mechanisms used to perform those tasks or activities?

|________|________|________|________|________|________|________|

NOT AT ALL — SOMEWHAT — COMPLETELY

IF THE VIRTUAL ENVIRONMENT INCLUDED SOUNDS:

20. How much did the auditory aspects of the environment involve you?

|________|________|________|________|________|________|________|
NOT AT ALL SOMEWHAT COMPLETELY

21. How well could you identify sounds?

|________|________|________|________|________|________|________|
NOT AT ALL SOMEWHAT COMPLETELY

22. How well could you localize sounds?

|________|________|________|________|________|________|________|
NOT AT ALL SOMEWHAT COMPLETELY

IF THE VIRTUAL ENVIRONMENT INCLUDED HAPTIC (SENSE OF TOUCH):

23. How well could you actively survey or search the virtual environment using touch?

|________|________|________|________|________|________|________|
NOT AT ALL SOMEWHAT COMPLETELY

24. How well could you move or manipulate objects in the virtual environment?

|________|________|________|________|________|________|________|
NOT AT ALL SOMEWHAT EXTENSIVELY

Last version : March 2013

*Original version : Witmer, B.G. & Singer. M.J. (1998). Measuring presence in virtual environments: A presence questionnaire. *Presence : Teleoperators and Virtual Environments*, *7*(3), 225-240. Revised factor structure: Witmer, B.J., Jerome, C.J., & Singer, M.J. (2005). The factor structure of the Presence Questionnaire. *Presence, 14*(3) 298-312.

9.1.4.1 Slater, Usoh and Steed (1994) questionnaire on presence, used in the presence study (chapter 5)

Slater, Usoh and Seed questionnaire of Presence

1. Please rate the extent to which you were aware of background sounds in the laboratory in which this experience was actually taking place. Rate this on the following scale from 1 to 7 (where for example 1 means that you were hardly aware at all of the background sounds):

During the experience I was aware of background sounds from the laboratory:	**Please tick against your answer**
1. not at all	1
2.	2
3.	3
4.	4
5.	5
6.	6
7. very much	7

2. Please rate *your sense of being in the* car, on the following scale from 1 to 7, where 7 represents your *normal experience of being in a car*.

I had a sense of "being there" in the car:	**Please tick against your answer**
1. not at all	1
2.	2
3.	3
4.	4
5.	5
6.	6
7. very much	7

3. To what extent were there times during the experience when the street was the reality for you?

There were times during the experience when the street was the reality for me...	**Please tick against your answer**
1. at no time	1
2.	2
3.	3
4.	4
5.	5
6.	6
7. almost all of the time	7

4. When you think back about your experience, do you think of the street was more as *images that you saw*, or more as *somewhere that you visited*?

The street seems to me to be more like...	**Please tick against your answer**
1. images that I saw	1
2.	2
3.	3
4.	4
5.	5
6.	6
7. somewhere that I visited	7

5. During the time of the experience, which was strongest on the whole, your sense of being in the car, or of being elsewhere?

I had a stronger sense of...	**Please tick against your answer**
1. being elsewhere	1
2.	2
3.	3
4.	4
5.	5
6.	6
7. being in the car space	7

6. Consider your memory of being in the street. How similar in terms of the *structure of the memory* is this to the structure of the memory of other *places* you have been today? By 'structure of the memory' consider things like the extent to which you have a visual memory of the field, whether that memory is in colour, the extent to which the memory seems vivid or realistic, its size, location in your imagination, the extent to which it is panoramic in your imagination, and other such *structural* elements.

I think of the street as a place in a way similar to other places that I've been today...	**Please tick against your answer**
1. not at all	1
2.	2
3.	3
4.	4
5.	5
6.	6
7. very much so	7

7. During the time of the experience, did you often think to yourself that you were actually in the car?

During the experience I often thought that I was really in the car...	**Please tick against your answer**
1. not very often	1
2.	2
3.	3
4.	4
5.	5
6.	6
7. very often	7

8. Further Comments

Please write down any further comments that you wish to make about your experience. In particular, what things helped to give you a sense of 'really being' in the car, and what things acted to 'pull you out' of this?

9.1.5 Trust questionnaire (McKnight et al., 2011) used in all the experiments

Trust in Technology

The following 10 statements have been used in literature to observe the trust of people about the use of a specific technology. In that case, we will ask to you to answer the questions in relation to the use of the system you just used. Please follow the instructions and fill the questionnaire.

After the 10 statements there is going to be an open question, we strongly encourage you to answer this question with your personal opinions. Instructions: Please for each one of the statements on the left mark on the right one box that best describes your agreement from 1- Strongly disagree to 7-Strongly agree.

Participant ID *{researcher to complete}*:

	Strongly Disagree						Strongly Agree
1. **The system is a very reliable piece of technology.**	☐	☐	☐	☐	☐	☐	☐
2. **The system does not fail me**	☐	☐	☐	☐	☐	☐	☐
3. **The system is extremely dependable.**	☐	☐	☐	☐	☐	☐	☐
4. **The system does not malfunction me**	☐	☐	☐	☐	☐	☐	☐

5. The system has the functionality I need.	☐	☐	☐	☐	☐	☐	☐
6. The system has the features required for my tasks.	☐	☐	☐	☐	☐	☐	☐
7. The system has the ability to do what I want it to do.	☐	☐	☐	☐	☐	☐	☐
8. The system supplies my need for help through a help function.	☐	☐	☐	☐	☐	☐	☐
9. The system provides competent guidance (as needed) through a help function.	☐	☐	☐	☐	☐	☐	☐

10. **The system provides very sensible and effective advice, if needed.**	☐ ☐ ☐ ☐ ☐ ☐ ☐

Is there any other aspect of trust in the technologies on which you would like to comment? (Something not addressed in the questionnaire that you think influenced/can influence your perception of trust in this particular system).

Please, give us a note if there is something you would like to add or if there are some questions that you think do not fit the experiment you just take part in.

9.1.6 Simulator Sickness Questionnaire (Kennedy et al., 1993) used in all the experiments.

No_______________ Date______________________

SIMULATOR SICKNESS QUESTIONNAIRE

Kennedy, Lane, Berbaum, & Lilienthal (1993)***

Instructions : Circle how much each symptom below is affecting you <u>right now</u>.

1. General discomfort	None	Slight	Moderate	Severe
2. Fatigue	None	Slight	Moderate	Severe
3. Headache	None	Slight	Moderate	Severe
4. Eye strain	None	Slight	Moderate	Severe
5. Difficulty focusing	None	Slight	Moderate	Severe
6. Salivation increasing	None	Slight	Moderate	Severe
7. Sweating	None	Slight	Moderate	Severe
8. Nausea	None	Slight	Moderate	Severe
9. Difficulty concentrating	None	Slight	Moderate	Severe
10. « Fullness of the Head »	None	Slight	Moderate	Severe
11. Blurred vision	None	Slight	Moderate	Severe
12. Dizziness with eyes open	None	Slight	Moderate	Severe
13. Dizziness with eyes closed	None	Slight	Moderate	Severe
14. *Vertigo	None	Slight	Moderate	Severe
15. **Stomach awareness	None	Slight	Moderate	Severe
16. Burping	None	Slight	Moderate	Severe

* Vertigo is experienced as loss of orientation with respect to vertical upright.

** Stomach awareness is usually used to indicate a feeling of discomfort which is just short of nausea.

Last version : March 2013

***Original version : Kennedy, R.S., Lane, N.E., Berbaum, K.S., & Lilienthal, M.G. (1993). Simulator Sickness Questionnaire: An enhanced method for quantifying simulator sickness. *International Journal of Aviation Psychology, 3*(3), 203-220.

9.1.7 Pre-interaction trust questionnaire (McKnight et al., 2011), used in the pilot study (chapter 3), presence study (chapter 5) and final study (chapter 6)

Trust in Technology

The following 15 statements are been used in literature to observe the general trust of people about the use of technologies. In that case, we will ask to you to answer the questions in relation to the use of Virtual Reality and general technology. Please follow the instructions and fill the questionnaire

Instructions: Please for each one of the statements on the left mark on the right one box that best describes your agreement from 1- Strongly disagree to 7-Strongly agree.

	(Participant ID *{researcher to complete}*: _____)						
	Strongly Disagree						Strongly Agree
1. I am totally comfortable working with virtual reality products.	☐	☐	☐	☐	☐	☐	☐
2. I feel very good about how things go when I use virtual reality products.	☐	☐	☐	☐	☐	☐	☐
3. I always feel confident that the right things will happen when I use	☐	☐	☐	☐	☐	☐	☐

virtual reality products.							
4. It appears that things will be fine when I utilize virtual reality products.	☐	☐	☐	☐	☐	☐	☐
5. I feel okay using virtual reality products because they are backed by vendor protections.	☐	☐	☐	☐	☐	☐	☐
6. Product guarantees make it feel all right to use virtual reality systems.	☐	☐	☐	☐	☐	☐	☐
7. Favorable-to-consumer legal structures help me feel safe working with virtual reality products.	☐	☐	☐	☐	☐	☐	☐
8. Having the backing of legal statutes and processes makes me feel secure in using	☐	☐	☐	☐	☐	☐	☐

virtual reality products.							
9. I believe that most technologies are effective at what they are designed to do.	☐	☐	☐	☐	☐	☐	☐
10. A large majority of technologies are excellent.	☐	☐	☐	☐	☐	☐	☐
	Strongly Disagree						Strongly Agree
11. Most technologies have the features needed for their domain.	☐	☐	☐	☐	☐	☐	☐
12. I think most technologies enable me to do what I need to do.	☐	☐	☐	☐	☐	☐	☐
13. My typical approach is to trust new technologies until they prove to me that I shouldn't trust them.	☐	☐	☐	☐	☐	☐	☐

14. I usually trust a technology until it gives me a reason not to trust it.	☐	☐	☐	☐	☐	☐	☐
15. I generally give a technology the benefit of the doubt when I first use it.	☐	☐	☐	☐	☐	☐	☐

Please, give us a note if there is something you would like to add or if there are some questions that you think do not fit the experiment you just take part in.

9.1.8 Demographic questionnaire, used in all the experiments.

Background information

*Partecipant ID {research to comlpete}*______

Section 1: Demographic Information and History

Please delete as applicable

1. Sex: Male / Female

2. Age: ....

3. Occupation ....

4. Are you presently in your normal state of health? Yes / No

If not, please state why ....

5. Are you left or right handed? Left / Right

6. Do you regard yourself as susceptible to motion sickness?

Not at all **Slightly** **Moderately**

Very much so

Section 2: Visual Characteristics

The following questions ask you about your eyesight. Please delete as appropriate

1. Do you wear glasses? Yes / No

If yes, please state when ....

2. Do you wear contact lenses? Yes / No

If yes, please state when ....

3. If you wear glasses or contact lenses, are you predominately long or short sighted? Long / Short

4. Are you colour blind? Yes / No

5. Have you ever had a squint? Yes / No

If yes, please state in which eye Left / Right

6. Do you have any other visual impairments? Yes / No

If yes, please give details ....

Section 3: Experience/Knowledge of VR

Please tick the ONE statement from the following list which most applies to you:

I have never heard of Virtual Reality □

I have heard of Virtual Reality but do not know what it is □

I have some idea what Virtual Reality is □

I know what Virtual Reality but have never seen or used it □

I have seen a Virtual Reality system in use □

I have used a Virtual Reality system once or twice ☐

I have often used Virtual Reality ☐

I use Virtual Reality almost every day ☐

If you are a frequent user of VR, please describe below where you have used it (e.g. for leisure, in your work, as part of an educational programme)

....
....

9.2 Recruitment posters

9.2.1 Presence study recruitment poster

CALL FOR PARTICIPANTS!!!!

WHAT FOR?

The experiment aims to investigate some factors of Virtual Reality

WHAT WILL I DO?

If you decide to take part you will experience a race simulator, with the possibility to use the Oculus Rift! (Duration: 30-45 minutes)

£5 voucher are going to be paid if you complete the study!

WHERE?
Building n° 30 on the Map
Usability Lab, Human Factors Research Group (B03) @ Innovation Technology Research Centre, University Park

ARE THERE SPECIAL REQUIREMENTS?

Yes, you SHOULD NOT suffer or have suffered from:

- *Migraine*
- *Recurring headache*
- *Back pain or back problems*
- *Neck or shoulder strain*
- *Heart condition*
- *Asthmatic or respiratory disorder*
- *Epilepsy (photosensitive or other)*
- *Problems with depth perception*

WHO?
To Participate please contact Davide Salanitri (ezxds2@exmail.nottingham.ac.uk)
With:

1. Your name
2. Your tel. number
3. Your preferred day/hour

- *Other serious injury or illness*

Moreover you SHOULD NOT be Pregnant

Note: Heart rate and Skin Conductance are going to be measured during the experiment. The measures are going to be in a complete non-invasive way.

9.2.2 Final experiment recruitment poster.

CALL FOR PARTICIPANTS!!!!

WHAT FOR?

The experiment aims to investigate some factors of Virtual Reality

WHAT WILL I DO?

If you decide to take part you will interact with some Virtual Environments using the Oculus Rift DK2. The experiment will be conducted in two sessions 1 week apart. The total duration will be 120min

20£ Amazon voucher are going to be paid for your time!

ARE THERE SPECIAL REQUIREMENTS?

Yes, you SHOULD NOT suffer or have suffered from

- *Migraine*

WHERE?
Building n° 38 on the Map
Usability Lab, Human Factors Research Group (B03) @ Innovation Technology Research Centre, University Park.

- *Recurring headache*
- *Back pain or back problems*
- *Neck or shoulder strain*
- *Heart condition*
- *Asthmatic or respiratory disorder*
- *Epilepsy (photosensitive or other)*
- *Problems with depth perception*
- *Other serious injury or illness*

Moreover you SHOULD NOT be Pregnant

WHO?
To Participate please use this doodle:
http://doodle.com/poll/wrqivt6g9a639gty

Remember to book also the second session and to leave your email.

9.3 Information sheets

9.3.1 Information sheets for the pilot study.

TRUST IN VIRTUAL REALITY

Participant Information Sheet

My name is Davide Salanitri and I am a first year PhD student at The University of Nottingham.

As part of my project work, I would like to invite you to take part in a research exercise. Before you start it is important for you to understand why the research is being done and what will be involved. Please take some time to read through this information sheet carefully and ask questions if anything is unclear or if you would like more information.

The project is co-founded by Jaguar Land Rover.

Purpose of the study

The purpose of this study is to investigate the factors influencing trust in Virtual Reality. Three aspects of the technology are going to be evaluated: Technology Acceptance, Presence and Usability. The aim of the study is to explore if those characteristics influence trust in Virtual Reality.

What will happen if I decide to take part?

You will fill some questionnaires before and after a practice (more or less 30 minutes) with the Jaguar Land Rover CAVE. During the practice you will ask to perform some tasks that are going to be explained at the beginning. All the practice part will be video-recorded for future analysis. The entire experiment would last more or less one hour.

If you agree to take part, we will provide you with full instructions. You will also be given the opportunity to ask any questions. You may ask questions at any time if you do not understand anything.

Potential side effects of using Virtual Reality (VR)

The possible risks associated with viewing virtual reality through a headset are outlined below. These risks are based on research reports to date. These effects may also be experienced when using VR on a monitor. The current position may be summarised as follows:

* Some people have reported side effects when using VR.
* Previous research suggests that between 10% and 70% of users may experience side effects.
* The most common reported side effects are dizziness, nausea, disorientation, and visual symptoms.
* For most people any side effects wear off soon after they have finished using VR.
* Many people report reduced levels of side effects on using VR for a second , third or fourth time.
* There is no reason to suppose that reported side effects have serious immediate or long term consequences in terms of work performance, user health and safety or personal distress.

People who suffer (or ever suffered) from:

* *Migraine*
* *Recurring headache*
* *Pregnancy*
* *Back pain or back problems*
* *Neck or shoulder strain*
* *Heart condition*
* *Asthmatic or respiratory disorder*
* *Epilepsy (photosensitive or other)*
* *Problems with depth perception*
* *Other serious injury or illness*

Should not take part in the study.

What will happen to my information?

All information provided will be captured electronically, and stored on a password protected computer. It will be destroyed seven years after any publication arising from the work, in accordance with the university data storage policy. Your name (i.e. signature on consent form) will be kept separate from your questionnaire responses. Consent forms will be stored in a locked filing cabinet for the duration mentioned above. All the registrations will be kept in a password protected Hard-Disk at the University of Nottingham, with limited access only for the people involved in the study.

The information that I collect during this project will be used to inform my design. Your name will not be used in association with the data. The information that we collect during this project may also be used for academic publications, for example as part of a journal article.

What will happen if I don't want to carry on with the study?

You can withdraw from the study at any time without having to provide a reason. If you do withdraw, any information that you have collected will be destroyed and will not be included in the study. You also do not have to answer any particular question.

Will my taking part in this study be kept confidential?

Yes.

Who is organising and funding the research?

This research is being conducted as a research project at The University of Nottingham with the collaboration of Jaguar Land Rover.

Who has reviewed the study?

This study has been approved by the ethical committee of the University of Nottingham.

Who do I contact if I have questions or require further information?

If you have any questions or concerns about the study, please contact:

Davide Salanitri, ezxds2@exmail.nottingham.ac.uk.

Supervisor:

Dr Glyn Lawson

Lecturer in Product Design and Manufacture

Human Factors Research Group

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9.3.2 Information sheet for the presence experiment (chapter 5)

PRESENCE AND VIRTUAL REALITY

Participant Information Sheet

My name is Davide Salanitri and I am a second year PhD student at The University of Nottingham.

As part of my project work, I would like to invite you to take part in a research exercise. Before you start it is important for you to understand why the research is being done and what will be involved. Please take some time to read through this information sheet carefully and ask questions if anything is unclear or if you would like more information.

The project is co-founded by Jaguar Land Rover.

Purpose of the study

The purpose of this study is to investigate the relationship between presence and trust in Virtual Reality (VR). Your sense of presence and your level of trust in VR are going to be evaluated

What will happen if I decide to take part?

You will fill some questionnaires before and after a practice (more or less 30 minutes) with a VR systems. You will be randomly assigned to one of two groups, one interacting with a desktop VR (Desktop group) and one interacting with the Head Mounted Display (HMD) Oculus Rift (HMD group). During the practice you will be asked to perform some tasks. All the practice part will be video-recorded for future analysis. Two Physiological measurements are going to be taken during the interactions: Skin Conductance and Heart Rate. The measurement is a completely non-invasive procedure. The entire experiment will last 30-45 minutes.

Note: The physiological measures are purely for research purpose not for diagnosis. The experimenter is not qualified to give any sort of medical interpretations of the data.

If you agree to take part, we will provide you with full instructions. You will also be given the opportunity to ask any questions. You may ask questions at any time if you do not understand something.

If you decide to take part and complete the procedure a £5 voucher will be given.

Potential side effects of using Virtual Reality (VR)

The possible risks associated with viewing virtual reality through a headset are outlined below. These risks are based on research reports to date. These effects may also be experienced when using VR on a monitor. The current position may be summarised as follows:

* Some people have reported side effects when using VR.
* Previous research suggests that between 10% and 70% of users may experience side effects.
* The most common reported side effects are dizziness, nausea, disorientation, and visual symptoms.
* For most people any side effects wear off soon after they have finished using VR.
* Many people report reduced levels of side effects on using VR for a second , third or fourth time.
* There is no reason to suppose that reported side effects have serious immediate or long term consequences in terms of work performance, user health and safety or personal distress.

People who suffer (or ever suffered) from:

* *Migraine*
* *Recurring headache*
* *Back pain or back problems*
* *Neck or shoulder strain*
* *Heart condition*
* *Asthmatic or respiratory disorder*
* *Epilepsy (photosensitive or other)*
* *Problems with depth perception*
* *Other serious injury or illness*

And pregnant women

Should not take part in the study.

What will happen to my information?

All information provided will be captured electronically, and stored on a password protected computer. It will be destroyed seven years after any publication arising from the work, in accordance with the university data storage policy. Your name (i.e. signature on consent form) will be kept separate from your questionnaire responses. Consent forms will be stored in a locked filing cabinet for the duration mentioned above. All the registrations will be kept in a password protected Hard-Disk at the University of Nottingham, with limited access only for the people involved in the study.

The information that I collect during this project will be used for research purposes. Your name will not be used in association with the data. The information that we collect during this project may also be used for academic publications, for example as part of a journal article.

In case of publication, some pictures taken during the experiment could be published. The face will be masked and unrecognisable. If you do not wish to have any picture published please DO NOT tick the corresponded box in the consent form.

What will happen if I don't want to carry on with the study?

You can withdraw from the study at any time without having to provide a reason. If you do withdraw, any information that you have collected will be destroyed and will not be included in the study. You also do not have to answer any particular question.

Will my taking part in this study be kept confidential?

Yes.

Who is organising and funding the research?

This research is being conducted as a research project at The University of Nottingham with the collaboration of Jaguar Land Rover.

Who has reviewed the study?

This study has been approved by the ethics committee of the University of Nottingham.

Who do I contact if I have questions or require further information?

If you have any questions or concerns about the study, please contact:

Davide Salanitri, ezxds2@exmail.nottingham.ac.uk.

Supervisor:

Dr Glyn Lawson

Lecturer in Product Design and Manufacture

Human Factors Research Group

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9.3.3 Information sheet for the final validation study (chapter 6)

STUDY ON VIRTUAL REALITY

Participant Information Sheet

My name is Davide Salanitri and I am a third year PhD student at The University of Nottingham.

As part of my project work, I would like to invite you to take part in a research exercise. Before you start it is important for you to understand why the research is being done and what will be involved. Please take some time to read through this information sheet carefully and ask questions if anything is unclear or if you would like more information.

The project is co-founded by Jaguar Land Rover.

Purpose of the study

The purpose of this study is to investigate the factors influencing trust in Virtual Reality (VR) systems. During this experiment your perceived usability, presence, technology acceptance and system trust will be measured.

What will happen if I decide to take part?

If you decide to take part in the study, I will ask you to fill some questionnaires, than interact with 8 different virtual environments, where you will perform some tasks. The experiment will be divided in two sessions: one will take place today and the other one in exactly one week from now. Each session will have an approximate duration of 60 minutes (40 minutes of interaction with the VR system).

If you agree to take part, we will provide you with full instructions. You will also be given the opportunity to ask any questions. You may ask questions at any time if you do not understand something.

If you decide to take part a £20 voucher will be given.

Potential side effects of using Virtual Reality (VR)

The possible risks associated with viewing virtual reality through a headset are outlined below. These risks are based on research reports to date. These effects may also be experienced when using VR on a monitor. The current position may be summarised as follows:

Some people have reported side effects when using VR.

Previous research suggests that between 10% and 70% of users may experience side effects.

The most common reported side effects are dizziness, nausea, disorientation, and visual symptoms.

For most people any side effects wear off soon after they have finished using VR.

Many people report reduced levels of side effects on using VR for a second , third or fourth time.

There is no reason to suppose that reported side effects have serious immediate or long term consequences in terms of work performance, user health and safety or personal distress.

People who suffer (or ever suffered) from:

- *Migraine*
- *Recurring headache*
- *Back pain or back problems*
- *Neck or shoulder strain*
- *Heart condition*
- *Asthmatic or respiratory disorder*
- *Epilepsy (photosensitive or other)*
- *Problems with depth perception*
- *Other serious injury or illness*

And pregnant women

Should not take part in the study.

What will happen to my information?

All information provided will be captured electronically, and stored on a password protected computer. It will be destroyed seven years after any publication arising from the work, in accordance with the university data storage policy. Your name (i.e. signature on consent form) will be kept separate from your questionnaire responses. Consent forms will be stored in a locked filing cabinet for the duration mentioned above.

The information that I collect during this project will be used for research purposes. Your name will not be used in association with the data. The information that we collect during this project may also be used for academic publications, for example as part of a journal article. As the co-funding company, Jaguar Land Rover will have access only to anonymised data.

In case of publication, some pictures taken during the experiment could be published. The face will be masked and unrecognisable. If you do not wish to have any picture published please DO NOT tick the corresponded box in the consent form.

What will happen if I don't want to carry on with the study?

You can withdraw from the study at any time without having to provide a reason. If you do withdraw, any information that you have collected will be destroyed and will not be included in the study. You also do not have to answer any particular question.

Will my taking part in this study be kept confidential?

Yes.

Who is organising and funding the research?

This research is being conducted as a research project at The University of Nottingham with the collaboration of Jaguar Land Rover.

Who has reviewed the study?

This study has been approved by the ethics committee of the University of Nottingham.

Who do I contact if I have questions or require further information?

If you have any questions or concerns about the study, please contact:

Davide Salanitri, ezxds2@exmail.nottingham.ac.uk.

Supervisor:

Dr Glyn Lawson
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