User experience of 360° video: the development of a conceptual framework

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User Experience of 360° video: The development of a conceptual framework

A thesis submitted to Middlesex University
in partial fulfilment of the requirements for the degree of
Doctor of Philosophy

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July 2022

Abstract

Instead of just viewing a single screen containing the content determined by the creator, viewers of 360° video, using smart phones and Virtual Reality (VR) Head Mounted Devices (HMD), have the freedom to look around 360° and view the video in any direction as though they were actually at the location where the video was made. 360° video therefore changes the rules for both video producers and consumers, giving rise to the need to understand User Experience (UX) of 360° video to inform content producers and assist HCI researchers in their investigations.

The aim of this research was to investigate the participants' experience of 360° video in order to develop a conceptual framework of user experience of 360° video. The user experience of 360° video was investigated via a series of three user studies and one case study using a range of viewing platforms, namely VR HMDs, smart phones, flat screens and a CAVE (CAVE Automatic Virtual Environment).

After viewing a 360° video, participants took part in semi-structured interviews and shared their experience in their own words. Through thematic analysis of the transcribed interviews, prominent components of UX and their relationships with each other were derived and explored. The results of these studies were then synthesised into a conceptual framework, the UX360 framework, which aims to provide understanding of the user experience of 360° video to guide HCI researchers and 360° video content creators.

The UX360 framework could be used to guide future HCI research on the user experience of 360° video by identifying the relationships between elements of the framework and the effects that they have on the user's experience. It could also provide understanding for 360° video content creators by identifying how the manipulation of specific elements of the framework could affect the user experience; assisting their creative decisions to produce the desired user experience.

Acknowledgements

Firstly, I would like to thank my wonderful wife, Mehrnaz, for her continued support, motivation, and encouragement throughout this research.

Secondly, thanks to my Director of Studies Dr. Peter Passmore for keeping me on track and providing so much knowledge, support and motivation which helped me to get through the project. Also, thanks to Dr. Bob Fields, my second supervisor, for all of his knowledge, help and support throughout the project.

Finally, thanks to: Milad for the discussions and taking part in the user study, all of the collaborators, participants of the user studies, colleagues and staff at Middlesex University who assisted in the administration of the thesis, particularly Mark Springett and Xiaohong Gao.

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Chapter 1 Introduction

1.1 Introduction and background

1.1.1 Virtual Reality

Over the past five years or so, Virtual Reality (VR) has become a commercially available technology. Interest has grown exponentially with the development of more affordable devices such as the Oculus Quest 2, Playstation VR, and the Valve Index (Figure 1.1). This has been largely attributed to Palmer Luckey, a young man who experimented with making Head Mounted Display (HMD) prototypes in his parents' garage. Frustrated with the problems associated with VR HMDs such as high latency, low contrast, high cost, low field-of-view, and extreme bulk and weight, Luckey developed a compact HMD which was capable of lower latency and increased Field of View (FoV) at an affordable price. Following a Kickstarter campaign, which raised $2.4 million in September 2012, the Oculus Rift looked set to be the first of its kind (Kickstarter, PBC, 2012). In March 2013, the Oculus Rift Development Kit 1 (DK1) was released and made VR something which was accessible to developers and hobbyists alike.

The term Virtual Reality was coined and popularised by Jaron Lanier in 1987 while conducting research for his company, VPL (Virtual Programming Languages) Research. Lanier and VPL Research, pioneered research into VR and 3D graphics and also sold the first VR hardware such as VR glasses, data gloves, and the full data suit (VRS, 2017). A VE was defined by Ellis, (1994) as "interactive, virtual image displays enhanced by special processing and by non-visual display modalities, such as auditory and haptic, to convince users that they are immersed in a synthetic space." (Ellis, 1994, p. 17). While immersed in a synthetic space, the user may, or may not, interact with their surroundings and, may or may not, become engaged with the VE in some way.

Figure 1.1: The Oculus Quest 2 (left) and the Valve Index (right) (Facebook Technologies, LLC, 2021; Valve Corporation, 2021).

1.1.2 The current state of the Virtual Reality market

Along with the increased accessibility to devices with which to experience VR came an increase in the development of VR content. This included games, videos and what are commonly known, or referred to, as experiences. The focus of such content is on entertainment and to provide the user with an enjoyable, and unique, experience. Over the past couple of years, VR headsets have not impacted the mainstream as was forecast, though have been selling steadily and somewhat sedately. In January 2020, Sony Interactive Entertainment said that its PlayStation VR headset had sold an impressive 5 million units to date (Lang, 2020). According to research firm IHS Markit, "the global consumer VR headset installed base reached 28 million at the end of 2017, but by 2021 that number will rise to 75.7 million." (IHS Markit, 2018). More recently, VR HMDs have increased in popularity and appear to be shifting more towards the mainstream. The online game platform Steam, by Valve Corporation, has seen increased online play using VR headsets over the past couple of years. As can been seen in Figure 1.2, the number of connected VR headsets has been growing steadily with a record peak of 2.8 million in January 2021 (Lang, 2021a).

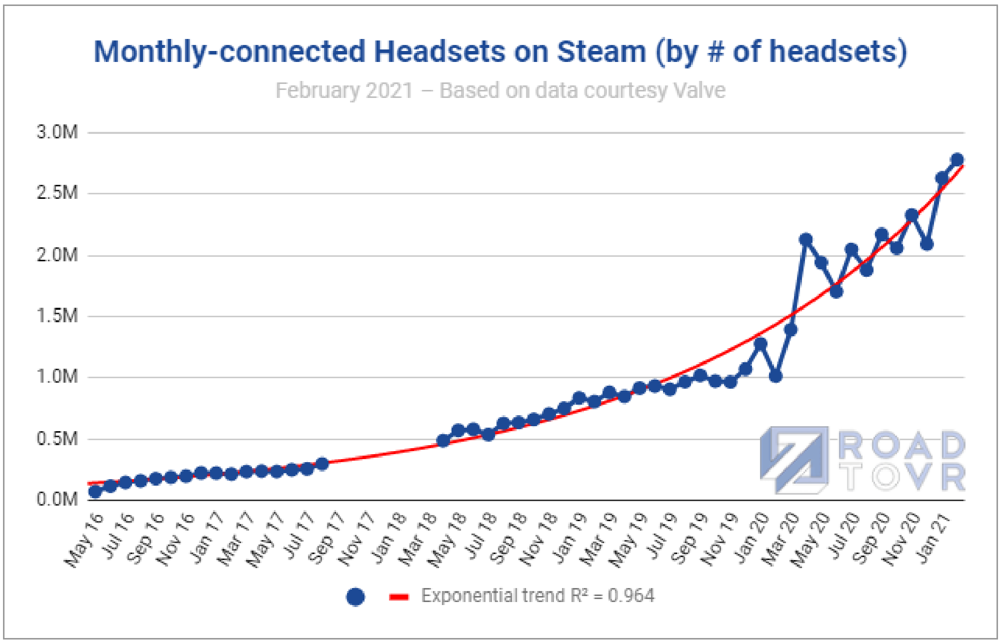


Figure 1.2: Monthly-connected Headsets on Steam (Lang, 2021a; Valve, 2021).

Additionally, on March 30th 2021, Facebook Reality Labs Vice President, Andrew Bosworth, said that "The fact that Oculus Quest 2 - in just a few months on the market - has outsold not just its predecessor, but all of its predecessors combined, is a tremendous indicator that we are now at that point where we have broken through from the early adopter crowd to an increasingly mainstream crowd." (Lang, 2021b). This is evident in the steam headset vendor market share from February 2021 in Figure 1.3.

Conversely, several large companies have abandoned VR projects, including Google, who have halted sales of its Daydream View headsets and admitted that it does not see a future for smartphone-based VR, and the BBC who have disbanded the team it created to make VR content, saying its funding had ended (BBC, 2019; Roettgers, 2019). Regardless, the overall forecast for market size and growth rate, from several market research companies, is a predicted rise over the next 5 – 7 years with an expected market size value of $62.1 billion in 2027 (Grand View Research, Inc, 2020; IDC, 2020; Markets and Markets Research Private Ltd, 2019).

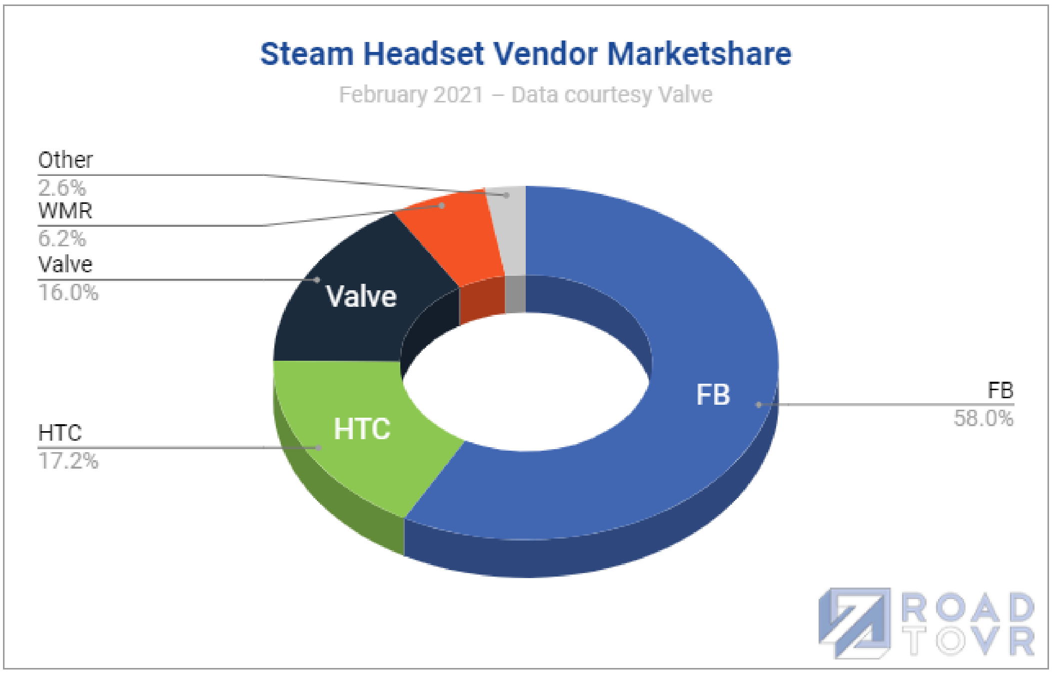


Figure 1.3: Steam Headset Vendor Market share (Lang, 2021a; Valve, 2021).

1.1.3 VR Concepts

VR has brought with it an increased interest in a number of experiential concepts which, in terms of user experience, were not so prominent when experiencing non-VR content; concepts such as presence, immersion, engagement and embodiment. There is a wide range of work and literature which investigates the aforementioned VR concepts and phenomena in various Virtual Environments (VE), including Computer-Generated Imagery (CGI) VEs and Augmented Reality (AR) (Schubert et al., 2001; Slater and Sanchez-Vives, 2014; Slater and Wilbur, 1997). Much of the research focuses on presence, as it is a concept which is at the centre of the VR experience. Presence is essentially the feeling of 'being there' in a VE, is arguably the most important concept when considering VR, and has been the subject of much research in the VR realm. However, many other concepts and phenomena contribute to the overall UX of VR.

VR concepts and phenomena can all affect how, and to what extent, a user engages with the VE; resulting in engagement existing as an important concept of user experience (UX) in VEs. Users are attracted to digital environments for differing reasons e.g., to learn, to be entertained, to share content etc. and for various periods of time in order to achieve their desired, specific outcome. The period of time that a user sustains engagement can be affected by their motivation for the engagement and, very importantly, the content, presentation of and interest in the content (O'Brien et al., 2018). Naturally, if a person has an interest in the subject material, whether that is a video, web page or piece of software, it can be expected that they would engage with that material for more than a brief moment. UX and engagement are often closely associated with each other. However, a great user experience may not generate an engaging experience, just as meaningful engagement does not assure a great user experience.

1.1.4 360° video

Along with the popularisation of VR and devices with which to view VR content, 360° video, also known as panoramic video, a relatively young medium, has been emerging into the mainstream over the past five to ten years or so. 360° video has been applied to, and created for, various areas such as education, medical treatment and entertainment (Feurstein, 2018; Herault et al., 2018; MacQuarrie and Steed, 2017; Theelen et al., 2019). A 360° video is created by making a video recording using a dedicated 360° video camera. Originally, 360° video was recorded by using a rig consisting of several individual cameras; this is not so common now due to the advance of technology. The videos were then synchronised in time and joined, or stitched, together frame by frame using specialised software to create a spherical view. More recently, some single lens 360° video cameras automatically stitch the footage in-camera and remove the requirement of post stitching. However, the high-end professional cameras have multiple lenses and often feature manual and automatic post stitching. Following the stitching process a completed spherical (equirectangular) video is produced and when viewed using a HMD, the viewer is situated in the centre of the sphere and can look around the full 360 degrees (Afzal et al., 2017). 360° video can be viewed using several different devices – a monitor/laptop screen, smart phone, HMD or even a C.A.V.E (Cave Automatic Virtual Environment), each providing a unique experience and methods of interaction with the video.

Interaction with 360° video has been somewhat limited to viewing the video by looking in various directions using gaze as the primary way to interact. In terms of what the user experiences, this could be regarded as quite a passive experience. However, some content producers have experimented with other interaction techniques such as looking at a particular selectable icon for a set period of time until the selection is complete or using tangible buttons/areas on device headsets or remote controls while looking at a particular menu item, icon or 'hot spot'. This method appeared in a short film series entitled *Gone* created by author, writer, and director JT Petty and produced for Samsung Milk VR, a premium VR content service. A trailer for the video can be viewed via the reference (Roettgers, 2015).

1.1.5 User Experience

When watching a 360° video for entertainment purposes, the user's experience is at the heart of this activity. UX is of great interest to the HCI field and has been researched in depth for the past 15 – 20 years. Donald Norman coined the term 'User Experience' in 1993 for his group at Apple Computers. However, the field is older than the term. Before user experience design there was "user-centered design"; a term which first appeared in Norman's book, *The Design of Everyday Things*, first published in 1988. This shift from the previous term "user centered system design" no longer focused on the system itself and the aesthetics of the interface, instead, Norman concentrated on the needs of the user (Norman, 1988, p. 187).

It wasn't until the early 90s when Norman joined Apple Computer first as a fellow and then as a "user experience architect" that the identifier made its way into a job title. In an interview in 2008 with Peter Merholzt, Donald Norman is quoted from an email that he had sent as a reply to peter in 1998:

> I invented the term because I thought human interface and usability were extremely good. I wanted to cover all aspects of the person's experience with the system including industrial design graphics, the interface, the physical interaction, and the manual. Since then the term has spread widely, so much so that it is starting to gain its meaning (Clagnut, 2016).

With no consensus on the definition of UX, the term is used in many different ways. However, there is a common understanding that UX is a complex concept and cannot simply pertain to usability or user interface. There is lots more to consider where UX is concerned such as values, emotions, expectations, and prior experience as well as aesthetics, challenge and stimulation. This emphasis on experiential factors has brought about more research into what UX actually is and how to evaluate it (Stage, 2006; Vermeeren et al., 2010). Research into UX of 360° video is currently quite sparse and has been increasing in recent years with some interesting studies such as those from Fonseca and Kraus, (2016), Passmore et al. (2016), Philpot et al. (2017), and Broeck et al. (2017). These studies all focused on viewing 360° video.

1.1.6 User Experience of 360° video

Creating 360° video content was an unchartered landscape for many 360° video content producers and filmmakers alike, and much discussion concerning techniques which should be used to create films and videos in 360 degrees was generated following the increased accessibility of VR viewing devices. The established rules of filmmaking and cinematography techniques do not apply to 360° video and many new elements had to be considered. It is said that 360° film making requires a new language to be developed for film makers to tell stories in 360 degrees. Along with learning a new language to create their films, additional challenges for 360° video content creators included how to engage the viewer to make sure that they were following the narrative of the story and were looking in the correct direction of where the action is taking place. Wisdom amassed over the last few years has been embodied in guidelines or recommendations (Facebook, 2016; Jaunt, 2018). However, although some exist, not many empirical studies have been conducted to ratify or challenge such guidelines (Fearghail et al., 2018; Gödde et al., 2018).

360° videos are, arguably, optimally viewed using a VR device, usually a HMD, though can be viewed on a flat screen or mobile phone/tablet. The level of engagement and presence, along with many other established VR concepts and phenomena, are often increased by viewing using a HMD. A number of studies have been carried out which have investigated viewing video in various formats and using a multitude of viewing platforms (Broeck et al., 2017; Fonseca and Kraus, 2016; MacQuarrie and Steed, 2017; Passmore et al., 2016; Philpot et al., 2017). When viewing 360° video using a HMD, users have reported high levels of presence and immersion and have been highly engaged with the video. However, other devices, such as smart phones, have also returned interesting results where presence and immersion is concerned (Passmore et al., 2016; Philpot et al., 2017; Rupp et al., 2016).

This thesis presents research which aims to develop a further understanding of the UX of 360° video via a series of user studies. The overarching research question was 'what are the components of the UX of 360° video and how does platform and content affect the UX of 360° video?'. The components of the UX of 360° video will be investigated by looking at how users experience 360° video using a variety of viewing devices (research questions 1, 2 and 4). The research also considers how users understand 360° video in terms of cinematic literacy and film sensemaking (research question 3). The focus of the research is on entertainment, as opposed to other topics common to VR research such as education, training or medical applications.

A conceptual framework of the UX of 360° video in VR was to be developed which would attempt to provide a deeper understanding of what affects the UX of 360° video when viewed primarily in VR using a HMD (research question 5). This framework could be used by 360° video content producers to inform them of what elements of a user's experience of 360° video can be affected by the choices that they make in their content creation. It could assist them in their filmmaking planning and execution and their understanding of the UX of 360° video. The framework and results of the studies could also be used by researchers in order to further their research by providing valuable information concerning the UX of 360° video when viewed using various viewing platforms.

1.2 Research questions

1. How does platform affect the user experience of 360° video when viewing a 360° video on a PC, phone, or VR headset?

This question is addressed in user study one (Chapter 3).

2. How does platform affect the user experience of 360° video when viewing a 360° video on a VR headset or in a CAVE?

This question is addressed in user study two (Chapter 4).

3. What can be inferred about 360° cinematic literacy following user studies one (Chapter 3) and two (Chapter 4)?

This question is addressed in the case study in (Chapter 5).

4. Does quantitative measurement of presence support the results returned from the methods used in the qualitative studies – user study one (Chapter 3) and user study two (Chapter 4)?

This question is addressed in user study three (Chapter 6).

5. Can a model or conceptual framework of user experience of 360° video be developed in order to inform content creators and researchers?

This question is addressed in Chapter 7.

1.3 Research objectives

To begin with, a review of the literature was required to ascertain an understanding of VR, VR concepts, such as presence and immersion, 360° video, engagement and cinematic and filming techniques, both traditional and what was being used in relation to 360° video. A basic understanding of cinematic and filming terms and techniques was required by the thesis, therefore, research into cinematic and filming techniques was not extensive. However, adequate understanding was gained through a combination of previous experience, the literature review, and some analysis.

Having identified, from the literature review, that presence was at the centre of the VR experience, it became apparent that one must be engaged in the subject of the experience in order to feel a greater sense of presence. Therefore, presence and engagement became the focus of the research in relation to viewing 360° video.

The next research objective was to gather some qualitative data with which to investigate and analyse the UX of 360° video when viewed with various devices. This was to be achieved via a series of user studies which would ask participants to watch a 360° video on various devices and to report back their experience via semi-structured interviews and some direct questions.

Presence, engagement, and other experiential factors have been researched for a number of years via several methods. However, the most common method for VR, and in particular presence, were questionnaires. Following some investigation and as a result of one paper specifically by Slater and Garau, (2007), where the use of questionnaires and the Likert scale to measure presence was questioned, it was decided to not rely upon such questionnaires as the main form of gathering data. As a result, it was decided to start from scratch as it were, and gather the information in the participants' own words (Slater and Garau, 2007). More information regarding this can be found in Chapter 6, section 6.2.1.

Two studies were conducted whereby 360° video was viewed using various devices and qualitative data was gathered and analysed using Braun and Clarke's thematic analysis method (Braun and Clarke, 2006); the methodology and results of which can be found in Chapters 3 and 4 respectively. In order to ascertain whether quantitative and qualitative measures of presence and engagement could be compared, a third user study, found in Chapter 6, was conducted which followed the same method as user studies one and two, but this time introduced a quantitative measure namely the iGroup Presence Questionnaire (IPQ); details of which can be found in Chapter 2, section 2.14.4 (Schubert et al., 2001). In between user study two and three, a case study of filming literacy was carried out which took into account the first two user studies and investigated how the user experience was affected by 360°video, found in Chapter 5.

The next objective was to take everything that had been learned and understood from the user studies and develop a conceptual framework. Therefore, research was to be carried out into models and frameworks which have been created in the HCI domain and, more specifically, frameworks and models of UX in HCI; the findings would be applied to the creation and development of the conceptual framework. The proposed conceptual framework would be used to inform 360° video content producers and researchers about what affects the UX of 360° video in VR. Using the results of the studies, the conceptual framework would attempt to provide understanding by highlighting the most significant concepts which affect the user experience of 360° video, which other concepts they affect and their relationships with each other (Chapter 7).

1.4 Contribution to knowledge

The research carried out during this thesis has produced four published conference papers:

Passmore, P.J., Glancy, M., Philpot, A., Roscoe, A., Wood, A., Fields, B., 2016. Effects of Viewing Condition on User Experience of Panoramic Video (Passmore et al., 2016).

Philpot, A., Glancy, M., Passmore, P.J., Wood, A., Fields, B., 2017. User Experience of Panoramic Video in CAVE-like and Head Mounted Display Viewing Conditions (Philpot et al., 2017).

Philpot, A., 2017. Effects of Camera Position on Perception of Self In 360 Degree Video and Virtual Environments (Philpot, 2017).

Passmore, P.J., Glancy, M., Philpot, A., Fields, B., 2017. 360 Cinematic literacy: A case study (Passmore et al., 2017).

Three of the aforementioned papers are featured in this thesis, Effects of Viewing Condition on User Experience of Panoramic Video is in Chapter 3, User Experience of Panoramic Video in CAVE-like and Head Mounted Display Viewing Conditions is in Chapter 4, and Cinematic literacy: A case study is in Chapter 5. The results of Chapters 3 – 6 were synthesised into the UX360 conceptual framework and accompanying word model, presented in Chapter 7, section 7.4. Each respective paper can be found in Appendix A.

The UX360 framework and word model assist in the understanding of the user experience of the relatively new media of 360° video. By understanding which elements of UX are affected by particular choices made in 360° video production, content creators can tailor their choices in filming techniques to achieve particular effects on specific experiential elements. For the researcher, the UX360 framework and word model provide knowledge within the domain and opportunity to further investigate the concepts and filming components and the effects that they have on each other, according to the framework.

1.5 Thesis overview

This chapter has provided a general introduction to the research area of this thesis. The motivation for the research which has been carried out in this thesis has been presented through the research questions and objectives. Finally, the contribution to knowledge has been stated.

Chapter 2 is a literature review of the main concepts and technology covered in this research thesis. The content covers many of the most prominent topics concerning the user experience of 360° video, including user experience, presence, and film literacy. The chapter aims to provide the reader with the background knowledge required to understand the scope of the thesis.

Chapter 3 presents the first user study. Participants watched a 360° video on two of three devices (a HMD, a mobile phone and a flat screen) and took part in interviews and a questionnaire following each viewing. The results of the thematic analysis identified seven themes which contributed to a 360° video viewer response profile.

Chapter 4 presents the second user study. Participants watched a 360° video on two devices (a HMD and a CAVE) and took part in interviews and a questionnaire following each viewing. The results of the thematic analysis identified some discriminating themes, which were unique to the CAVE, additional to the seven established themes from study one. The result was a framework which identified clusters of themes that influence the user experience particularly presence; the central theme of the HMD and CAVE user experience of 360° video.

Chapter 5 presents a case study of cinematic literacy and 360° video. Cinematic filming techniques used in the 360° video from the first two user studies are discussed in relation to the interview results from the first two user studies. Results from these two studies provided elements of presence experienced, classic film literacy elements which are missing from 360° video, and new 360° literacy elements. A model is presented which attempts to depict how user experience and sensemaking play out for 360° video viewing using a HMD.

Chapter 6 presents the third user study. Participants watched a 360° video on two devices (a HMD and a mobile phone) and took part in interviews and filled out the iGroup Presence Questionnaire (IPQ), following each viewing. The questionnaire was introduced in order to collect some meaningful quantitative data in contrast to the qualitative data that had been gathered thus far in the research. The same protocols and analysis methods were followed as were executed in user study one in order to investigate any similarities or differences in responses, and to discover if what viewers said in their interviews was consistent with their questionnaire results.

Chapter 7 presents the UX360 conceptual framework development and begins with a brief analysis of UX models and frameworks. The initial UX360 conceptual framework is presented in detail; some development is then discussed. The final UX360 conceptual framework is presented with discussion, along with a word model; which is an explanation of the elements of the UX360 conceptual framework. The chapter rounds out with proposed uses of the framework and some considerations for content producers and researchers concerning how to make use of the framework.

Chapter 8 presents the conclusion of the thesis with previous chapter summaries and a discussion of future work.

Appendix A contains a collection of published work which was carried out throughout the research for the thesis. The full texts from four international conferences are presented.

Appendix B contains the documents used in user study one which include a screening questionnaire, a consent form, a participation information sheet, interview questions and questionnaire and a debriefing sheet.

Appendix C contains the documents used in user study two which include a screening questionnaire, a consent form, a participation information sheet, interview questions and questionnaire and a debriefing sheet.

Appendix D contains the documents used in user study three which include a screening questionnaire, a consent form, a participation information sheet, interview questions and questionnaire and a debriefing sheet.

Appendix E contains the IPQ, a questionnaire used to measure presence (igroup.org, 2016).

Chapter 2 Background and related work

2.1 User Experience

Within the HCI community, the term user experience (UX – as it is often referred to) – is a "combination of user's perceptions and responses that result from the use and/or anticipated use of a system, product or service". Furthermore, "Users' perceptions and responses include the users' emotions, beliefs, preferences, perceptions, comfort, behaviours, and accomplishments that occur before, during and after use." (ISO 9241-110:2020, 2020). UX is an extremely popular concept and has been the focus of research in academia and industry for many years. Work in UX examines products, systems and services and the relationships that humans develop with such technologies as they become integrated into their lives in meaningful ways (O'Brien, 2011). The user experience contains three defining characteristics – a user is involved, that user is interacting with a system, product or interface and the user's experience is of interest and is observable and/or measurable. UX broadly looks at a user's interaction with the system, product or interface as well as the feelings, perception and thoughts which arise from that interaction (Albert et al., 2013). Due to the fluctuation of the internal and emotional state of a person and differences in circumstances during and after an interaction, UX is generally understood to be inherently dynamic (Hassenzahl, 2008; Law et al., 2009). Therefore, a thorough understanding of a user's experience, be it positive or negative, before, during and after the interaction can be observed and measured with arguably equal importance (Vermeeren et al., 2010).

UX emerged in the early to mid-2000s as a buzzword in HCI and interaction design. Adopted by the HCI community, both researchers and practitioners, UX became a counter movement to the task and work-related usability paradigm, which was dominant in the field. In an attempt to advance the understanding of UX, Hassenzahl and Tractinsky, (2006), aimed to encourage scientists and practitioners to engage in empirical UX research. They proposed that UX consisted of three perspectives, or threads, namely beyond the instrumental, emotion and affect and the experiential (Figure 2.1). According to Hassenzahl and Tractinsky, (2006) "one thread predominantly deals with addressing human needs beyond the instrumental; a second thread stresses affective and emotional aspects of the interaction; and a third thread deals with the nature of experience." (Hassenzahl and Tractinsky, 2006, p. 92).

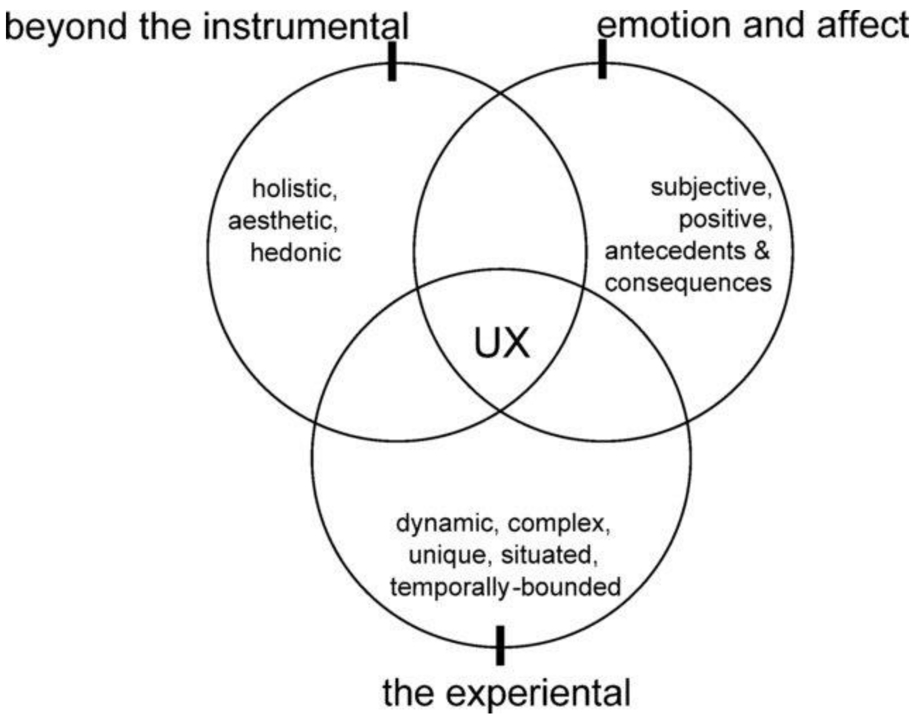


Figure 2.1: Facets of UX (Hassenzahl and Tractinsky, 2006).

Two types of qualities of UX can be distinguished: instrumental and non-instrumental. According to Mahlke and Thüring, (2007):

Instrumental qualities concern the experienced amount of support the system provides and the ease of its use. Features, such as the controllability of the system behaviour and the effectiveness of its functionality, fall into this category. Non-instrumental qualities, on the other hand, concern the look and feel of the system. Features, such as visual aesthetics or haptic quality, belong to this class (Mahlke and Thüring, 2007, p. 916).

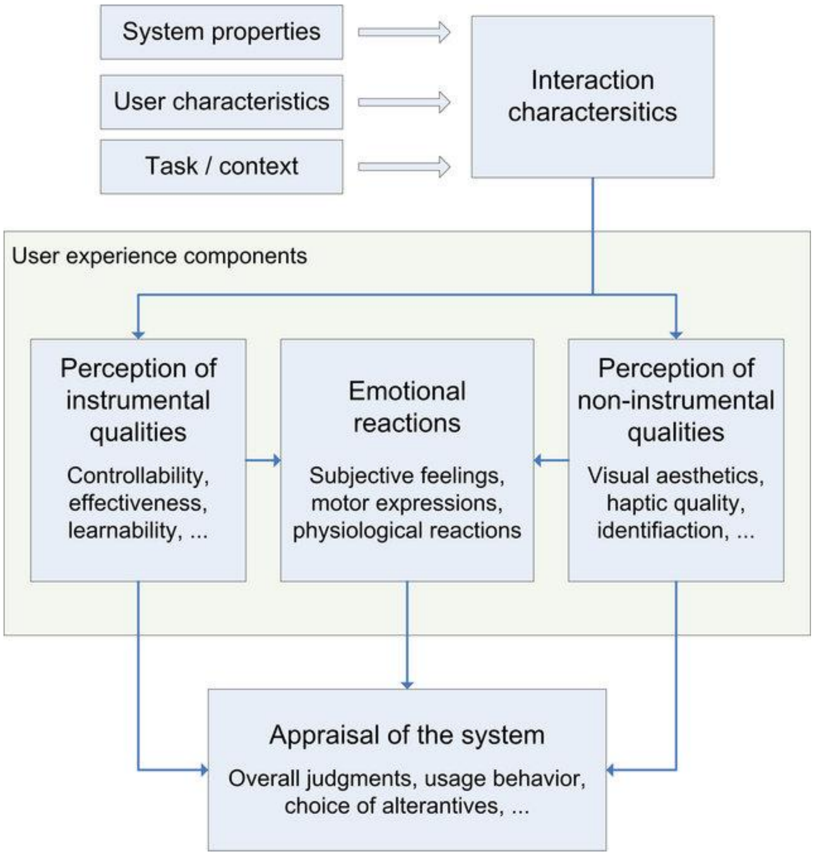


Figure 2.2: Components of User Experience (CUE model) (Mahlke and Thüring, 2007).

The Components of User Experience (CUE) model was proposed by Mahlke and Thüring, (2007). A number of theories and approaches are integrated into the model. The model distinguishes between the perception of instrumental and non-instrumental qualities (Figure 2.2). The model also assumes that emotions mediate between both types of perceptions and influence the consequences of usage (e.g., overall judgment, acceptance, and intention to use).

Minge et al. (2017) further developed the CUE model (Figure 2.3). The CUE model was the basis of the meQUE questionnaire; a standardised measurement of UX which addresses all key components of UX in a unified way (Minge et al., 2017).

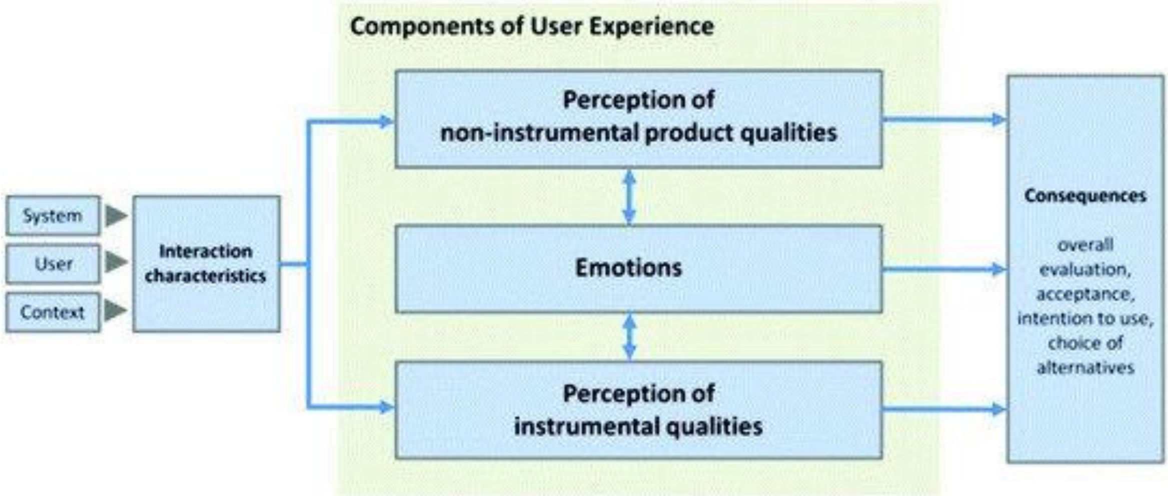


Figure 2.3: Components of User Experience (CUE model) (Minge et al., 2017).

As the interest and research into UX grew over the next few years, so did the interest and research into methods of measuring UX. There have been several subjective and objective metrics proposed to measure UX. Subjective measures such as talk-aloud/talk-after protocols, psychometric scales, and interviews are widely used due to the fact that UX is concerned with a user's perceptions (Jacques et al., 1995; O'Brien and Toms, 2008; Webster and Ho, 1997). Data collection techniques such as these are useful for capturing the beliefs, motivations and attitudes of users, however, they may be susceptible to self-report bias. Additionally, questionnaires can create measurement bias as they are not always extensively evaluated for reliability and validity (O'Brien and Lebow, 2013). Nevertheless, several questionnaires have been developed which capture different aspects of UX. For example, the AttrakDiff by Hassenzahl et al. (2003) and the User Experience Questionnaire (UEQ) by Laugwitz et al. (2008), measure product perceptions on diverse dimensions which address hedonic and pragmatic qualities (Hassenzahl et al., 2003; Laugwitz et al., 2008).

Objective measures of UX can be physiological or behavioural. Behavioural data can be captured using several measures such as task completion time, error rate, and the System Usability Scale (SUS) (Brooke, 1996). These can be achieved via observation, interview, or questionnaire. Physiological measures include heart rate, electromyogram (EMG), respiration and electrodermal activity (EDA). Such measures have been employed in HCI research in order to detect physiological responses while users interact with digital artefacts. For example, video games (Mandryk and Atkins, 2007) or various versions of a mobile phone interface (Mahlke and Minge, 2008). According to O'Brien and Lebow, (2013), the behavioural and physiological measures address the "what," but not the "why". The subjective, self-report measures, such as questionnaires administered directly after an interaction, probe the user's preferences, motivations, and attitudes, but some users may under- or over-report their experiences. Therefore "the complexity of human information experiences necessitates a mixed-methods approach to measurement." (O'Brien and Lebow, 2013, p. 1545).

2.2 Engagement

Today's technology is used to derive pleasure through the user experience. Whether the user is browsing websites, online shopping, watching a film or studying online, the success of their interaction is related to performance outcomes, system usability and their level of engagement. Users of technology have personal motivations and objectives for using, and continued usage of, the chosen technology. Whether a hand held device, personal computer or VR HMD, the success of the human-computer experience can be defined by whether those motivations and/or objectives are met; this success is linked to a user's level of engagement (O'Brien and McLean, 2009).

In the past 30 years or so, and especially the past decade, User Engagement (UE) has grown to be one of the buzzwords in a variety of domain and application areas, ranging from video games, search engines and mobile apps, to training, VR, and education. Considering the attention that the concept of engagement is receiving within industry and academia, it has become apparent that UE is, without a doubt, a vital part of a user's interaction with technology. However, something which is not clear is what is actually meant by the term engagement (in the realm of HCI) (O'Brien, 2016).

Previously, definitions of engagement were not consistent and were defined narrowly as attention and intrinsic motivation (Jacques, 1996); motivation (Makkonen, 1997); perceived control (Jacques et al., 1995) or the observable - physical interaction between the user and the system (Hutchins et al., 1985). It has also been suggested that "continued use" is indicative of being engaged (Jacques, 1996; O'Brien and McLean, 2009). It is not desired to arrive at one single definition of engagement, rather to present several definitions and interpretations, each of which may have both similarities and differences, but overall shed light on engagement in the HCI overall. Attfield et al. (2011) defined user engagement as "the emotional, cognitive and behavioural connection that exists, at any point in time and possibly over time, between a user and a resource." (Attfield et al., 2011, p. 2). Following work by, chiefly, O'Brien and collaborators Toms and Cairns (O'Brien and Cairns, 2016, 2015; O'Brien and Toms, 2008), O'Brien defines user engagement as "a quality of user experience characterized by the depth of an actor's cognitive, temporal, affective and behavioural investment when interacting with a digital system." (O'Brien et al., 2018, p. 29).

Engagement has been viewed in the past "as both an outcome of experience and a process during an interaction" (O'Brien and McLean, 2009, p. 2). A user may discuss aspects of an experience and possibly say that it was engaging; engagement can also be, and has been, described as a process. O'Brien, with several other researchers, has constructed a theoretical framework of engagement over the past decade or so which has somewhat unified the research in the area of engagement. Attributes of engagement have been empirically tested and, as a result, six core dimensions of engagement have been identified, namely: aesthetic appeal, focused attention, novelty, perceived usability, felt involvement, and endurability. Additionally, O'Brien and Toms' theory of engagement articulates five distinct stages: a point of engagement that initiates the engaging episode, a period of sustained engagement, disengagement, nonengagement, and, potentially, re- engagement) (O'Brien, 2008; O'Brien and Toms, 2008). O'Brien and Toms' proposed model of engagement can be viewed in Figure 2.4.

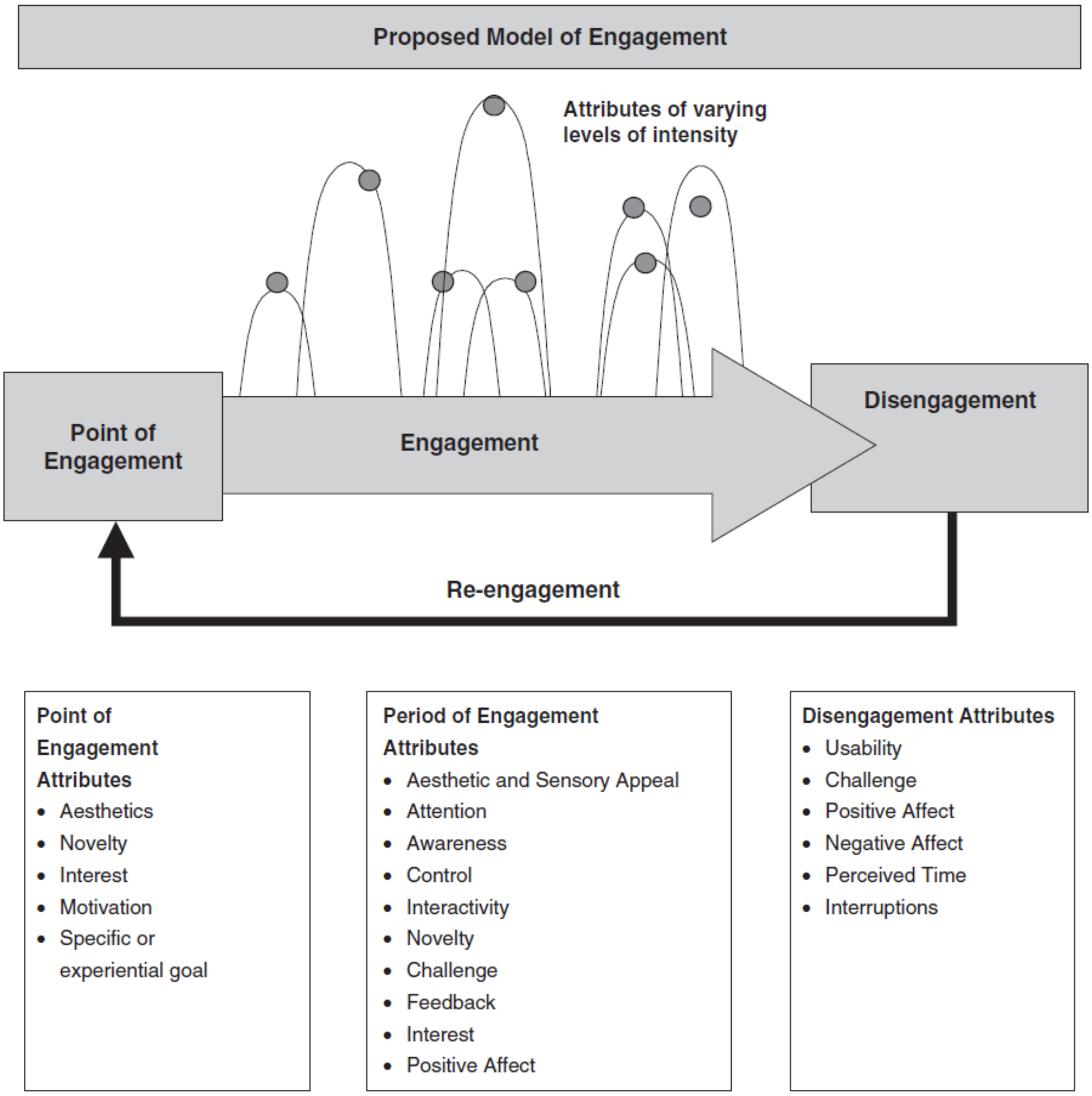


Figure 2.4: O'Brien and Toms' proposed model of engagement and its attributes (O'Brien and Toms, 2008).

According to O'Brien and Toms, engagement is a process, the process is defined by the presence of multiple attributes that vary in intensity depending on a combination of user and system attributes that emerge during the interaction. This model defines which attributes of engagement are most prominent during each phase in the engagement process. The four stages or phases of the process are: Point of Engagement, Engagement, Disengagement and Re-engagement. The stages of the process correspond to McCarthy and Wright's threads of experience as they contain emotional, compositional, sensory and spatiotemporal elements (McCarthy and Wright, 2004; O'Brien and Toms, 2008).

McCarthy and Wright, (2004) characterised their four threads of experience, not as fundamental elements of experience, but rather as ideas to help people think more clearly about technology as experience. "They provide ways of talking about technology that heighten sensibility to people's experience of it." (McCarthy and Wright, 2004, p. 80). The four threads are the sensual (i.e., behavioural e.g., interactivity) and cognitive (e.g., problem solving components of the experience), the emotional (e.g., fatigue, pleasure), the compositional (i.e., beginning, middle, and end), and the spatiotemporal (i.e., the subtasks which are performed as a part of a participant's use of an application, such as browsing, searching, comparing information, and communication with others, also their awareness of their environments and themselves, and characteristics of the technology) (McCarthy and Wright, 2004; O'Brien and Toms, 2008).

There is a myriad of VR and AR content available for use with a wide range of devices from dedicated VR HMDs to laptops and smart phones. The user engages with the content in several ways – passively watching, interacting with the viewing position by moving their head or swiping the screen with their finger, gazing in particular directions at specific areas of the screen for specific periods of time or physically interacting with the device while gazing at a specific area to make selections. All of these various methods of engagement provide the user with an experience of varying levels of difficulty and satisfaction. The experience has been measured using various tools and scales over the years in order to ascertain whether the particular game, software or website (to name but a few) provide an engaging and pleasant user experience.

O'Brien and Toms' UES was used to evaluate an internet shopping website based upon their 14 factors. Other questionnaires, include the Game User Experience Satisfaction Scale (GUESS), a game satisfaction questionnaire by Phan et al. (2016) which measures video game satisfaction based on key factors identified using an Exploratory Factor Analysis (Phan et al., 2016), the Game Engagement Questionnaire (GEQ) developed by Brockmyer et al. (2009) "a psychometrically strong measure of levels of engagement specifically elicited while playing video games" (Brockmyer et al., 2009, p. 624), and the Engagement Sample Questionnaire (ESQ) developed by Schoenau-Fog, whereby the Player Engagement Process framework (PEP) and in-game evaluation methods, such as the GEQ, were combined with inspiration from Csikszentmihalyi's work with the Experience Sampling Method (Csikszentmihalyi, 1990; Schoenau-Fog, 2011a). The ESQ was described by Schoenau-Fog as an intrusive method of inquiry with online surveys, in order to evaluate continuation desire as an aspect of engagement in interactive narratives (Schoenau-Fog, 2011b).

2.3 Existing Attributes of Engagement

Following a review and analysis of the existing measures, scales and questionnaires used to measure engagement, there are several common attributes or factors which are apparent in some shape or form and are considered at varying levels of importance. These are presented in several ways, for example as descriptive words, labels, tags, or key words. However, it has been decided to present the following attributes from O' Brien and Toms', (2010) definition of the attributes of engagement, directly quoted.

Table 2.1 is a non-exhaustive list of common attributes and their definitions which were also derived from the review of the literature pertaining to engagement (by the author). These attributes were chosen as they adequately summarise the most common attributes which occurred during the literature review where user engagement was concerned (O'Brien and Cairns, 2015; O'Brien et al., 2018; O'Brien and Toms, 2010a).

Additional to the attributes in Table 2.1, an 'Engagement' attribute exists which incorporates "items that pertained to engagement but did not correspond to an attribute (e.g., "Application x was engaging to use.")." (O'Brien and Toms, 2010a, p. 54). Further to the definitions in Table 2.1, what follows is some additional information to assist in the understanding of the attributes.

Aesthetics – This attribute applies to the visual appearance of whatever the subject of the study may be e.g., an interface, a device, a video etc. The user would generally have an overall aesthetic impression of the subject's attractiveness and sensory appeal (O'Brien and Toms, 2010a, p.57). In a world where appearance is so prominent, this can contribute to the quality of experience that a user has with the subject and is therefore an important attribute to consider.

Affect – This attribute applies to personal feelings and motivations which influence a user's impressions of the subject of the study e.g., an interface, a device, a video etc. Emotion is embedded throughout all stages of the user experience which supports the view that computer-user interactions involve more than just behaviour and cognition (Nahl, 2007). According to Forlizzi and Battarbee, "emotion affects how we plan to interact with products, how we actually interact with products, and the perceptions and outcomes that surround those interactions." (Forlizzi and Battarbee, 2004, p. 163).

Attribute	Definition
Aesthetics	Visual beauty or the study of natural and pleasing (or aesthetic) computer-based environments (Jennings, 2000).
Affect	“The emotional investment a user makes in order to be immersed in an environment and sustain their involvement in the environment” (Jennings, 2000); “The user’s emotional response to the system” (Stone et al., 2005).
Focused Attention	The concentration of mental activity; concentrating on one stimulus only and ignoring all others (Matlin, 1994).
Challenge	The amount of effort experienced by the participant in performing an online task.
Control	How “in charge” users feel over their experience with the technology.
Feedback	Response or reaction from the task environment or system that communicates the appropriateness of the users past actions or demonstrates progress toward a specific goal; serves as a basis for future action (Reber and Reber, 2001); “Information that is sent back to the user about what action has been done or what result has been accomplished” (Stone et al., 2005)
Interest	The “feeling that accompanies or causes special attention to an object or class of objects” (Webster, 2020).
Motivation	Elements that bring about focus or a desire to proceed with an activity (Jennings, 2000).
Novelty	Variety of sudden and unexpected changes (visual or auditory) that cause excitement and joy or alarm (Aboulafia and Bannon, 2004); Features of the interface that that “users find unexpected, surprising, new, and unfamiliar” (Huang, 2003).
Perceived Time	Users’ perception of estimated time spent on task.

Table 2.1: Definition of the attributes of engagement (O’Brien and Toms, 2010a, p. 51).

Focused Attention – This attribute relates to a user's perception of time passing and their degree of awareness regarding what was taking place outside of what they were interacting with e.g., an interface, a device, a video etc. Other elements such as flow state and the user's ability to lose themselves in the experience and become absorbed in the activity which they are undertaking are considered here (O'Brien and Toms, 2010a).

Challenge – This attribute relates to the user's perceived effort required to complete a task, whether the user feels that they can perform the required task and whether the user can actually accomplish the required task when using an interface, using a device, watching a video etc. (O'Brien and Toms, 2010a).

Control – This attribute applies to how much control and influence a user feels when undertaking a task, when interacting with an interface, a device, technology etc. Feeling in control of the situation and being able to influence what is happening is an important element of user experience (O'Brien and Toms, 2010a).

Feedback – This attribute refers to any responses or reactions from the interface, device, video etc. to the user which indicates that the user is making progress in their intentions or specific goal. For example, a user watching a video will receive feedback from the video in the form of following a narrative and understanding what is happening in the video. Alternatively, a user who is interacting with a shopping website will receive feedback when they have successfully added an item to their shopping basket – via a notification (O'Brien and Toms, 2010a).

Interest – This attribute applies to a user's interest and motivation to use or to continue to use the application, interface, device etc. Personal interest, involvement, and fun have an influence on the user's experience and are an important consideration (O'Brien and Toms, 2010a).

Motivation – This attribute refers to the user's reasons for using the application, interface, device etc. and why they are spending time on the particular activity. There is usually a reason for interacting with the technology, interface, video etc. and can be a number of things such as enjoyment or necessity (O'Brien and Toms, 2010a).

Novelty – This attribute applies to the unexpected or unknown features of a device, interface, video etc. The novelty value can increase interest and has the potential to sustain a user's attention and can have a positive effect on the user's experience (Pace, 2004).

Perceived Time – This attribute relates to how much time a user believes they have spent on a task. This can be influenced by elements including interest and whether the user is in a flow state (O'Brien and Toms, 2010a).

2.4 Flow

The concept of 'flow' has been present in HCI for decades and is the term used to describe the feelings of enjoyment that occur when a balance between skill and challenge is achieved in the process of performing an intrinsically rewarding activity (Csikszentmihalyi and Csikszentmihalyi, 1988; Moneta and Csikszentmihalyi, 1999, 1996). The likelihood of flow is increased when a user has a specific goal, and an immediate performance feedback structure exists. A basic example is a video game where the goal is to complete the level and the feedback is the number of points that are accumulated while playing. Additionally, learning appears to be enhanced while in a flow state (Csikszentmihalyi and LeFevre, 1989; Moneta and Csikszentmihalyi, 1999). Flow states include being one with the activity, a feeling of being in control and experiencing time distortions such as losing track of time while watching a video or playing video games; such characteristics are often reported by committed video game players (Brockmyer et al., 2009).

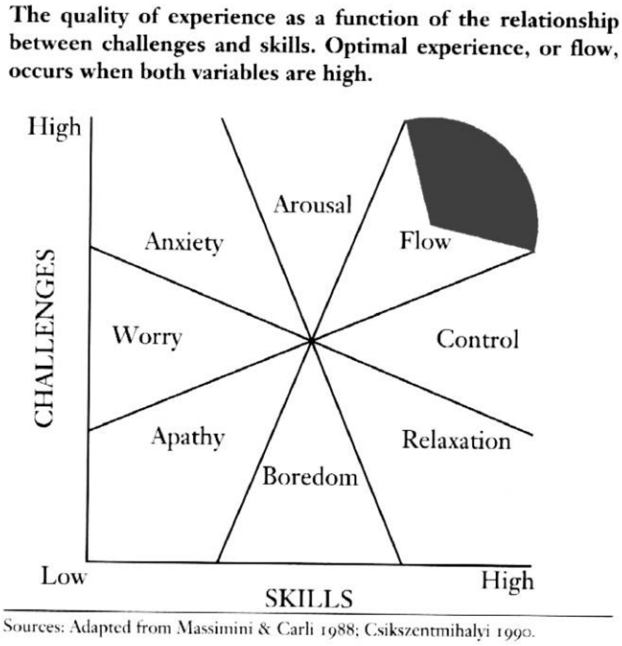


Figure 2.5: The quality of experience (Csikszentmihalyi, 1997, p. 31).

Csikszentmihalyi's work on flow produced the graph in Figure 2.5 which is now synonymous with the concept of flow. According to Csikszentmihalyi, (1997), "flow tends to occur when a person's skills are fully involved in overcoming a challenge that is just about manageable." (Csikszentmihalyi, 1997, p. 30). A fine balance between an ability to act and the available opportunities is usually involved when considering a person's optimal experiences. A person becomes frustrated, then worried and eventually anxious if the challenges are too high. Conversely, if the challenge is too low, relative to a person's skills, that person will become relaxed, then bored. A person would feel apathetic if both skills and challenges are perceived to be low. However, when high skills are matched with high challenges, a deep involvement which sets flow apart from ordinary life is very likely to occur. For example Csikszentmihalyi states "The climber will feel it [flow] when the mountain demands all his strength, the singer when the song demands the full range of her vocal ability" (Csikszentmihalyi, 1997, p. 30).

Over the years, flow has been measured by a number of brief, un-standardised questionnaires, along with better-researched techniques. One such brief questionnaire was a six-item questionnaire developed by Choi and Kim, (2004), which they used to measure what they conceptualised as flow while playing online computer games. The six questions assess the game's intrinsic interest, the player's sense of immersion and control and the player's sense of curiosity about the game. However, the questions appeared to only assess a few aspects of what is traditionally considered flow (Choi and Kim, 2004).

From their summary of several studies, Novak and Hoffman, (1997) identified three major approaches to measuring flow. These included narrative description followed by survey completion, retroactive survey completion, and experience sampling (Novak and Hoffman, 1997). The most used approach was developed by Csikszentmihalyi and Csikszentmihalyi, (1988) and is the Experience Sampling Method. Day-to-day activities were sampled randomly across the course of a week. Participants, when contacted, would complete the Experience Sampling Form to measure aspects of flow which included challenges and skills, motivation and mood, all of which were associated with the current situation (Csikszentmihalyi and Csikszentmihalyi, 1988). Earlier work by Csikszentmihalyi, (1975) was the Flow Questionnaire, wherein participants read descriptive statements of the flow experience such as 'I am so involved in what I am doing, I don't see myself as separate from what I am doing', and then respond to a series of questions. The respondents would firstly indicate whether they had previous, similar flow experiences and would then rate their flow activities on 12 dimensions e.g., 'I get involved' and 'I feel self-conscious' (Csikszentmihalyi, 1975).

2.5 Virtual Environments

A VE was defined by Ellis, (1994) as "interactive, virtual image displays enhanced by special processing and by non-visual display modalities, such as auditory and haptic, to convince users that they are immersed in a synthetic space." (Ellis, 1994, p. 17). Although it is common to associate a VE with CGI, Ellis, (1991) mentions that the fascination of humans with vicarious experiences in imagined environments originates with the earliest human cave art and can also be found in literature such as Lewis Carroll's *Through the Looking Glass*, and Aldous Huxley's *Brave New World* where people use a cinema which provides a sensory experience beyond sight and sound (Ellis, 1991).

A VE can be experienced via two types of viewpoints, egocentric and exocentric, explained here according to Ellis, (1991):

> Egocentric viewpoints, in which the sensory environment is constructed from the viewpoint actually assumed by the user, and exocentric viewpoints in which the environment is viewed from a position other than that where the user is represented to be (Ellis, 1991, p. 325).

Each viewpoint requires a different form of tracking in order for the user to track a target and to provide a realistic visual representation of their view of the VE. Egocentric viewpoints require compensatory tracking, and exocentric viewpoints require pursuit tracking. Current technology allows for an efficient tracking system, in most cases, which accurately and adequately provides realistic visual representations which correspond to head movements. This can seriously affect a user's experience of a VE, sometimes making the difference between a good and bad experience (Ellis, 1991). It is fair to assume that most people have experienced a VE in some form or another whether it be in a video game, a VR experience using a HMD or using AR to augment the actual world by adding virtual objects.

As well as the term virtual environment, it is common to encounter the term Virtual World (VW). These terms have been used interchangeably in the past, however, Schroeder, (2008) sought to define the two as very different "Virtual worlds are persistent virtual environments in which people experience others as being there with them - and where they can interact with them." (Schroeder, 2008, p. 2). The term virtual world has been applied to persistent online social spaces, for example, a VE which has a large population that people experience as ongoing over time which is experienced together with others as a world for social interaction. A VW should not be confused with online gaming and Massively Multiplayer Online Roleplaying Games (MMORPGs). Although they are similar, online games are sociable and can be used for socialising purposes, the activity in the games revolve around gaming activities such as accumulating points, reaching new levels etc., whereas social spaces are not focussed on such things (Axelsson and Regan, 2006; Schroeder, 2008). Therefore, a VW is a place where users experience other participants in a shared VE as being present in the same environment and interacting with them or 'being there together' (Schroeder, 2006).

According to Sivunen and Hakonen, (2011), "VEs can be defined as communication systems in which multiple interactants share the same three-dimensional digital space despite occupying remote physical locations; interactants can navigate, manipulate objects, and interact with one another via avatars" (Sallnäs, 2005; Sivunen and Hakonen, 2011; Yee and Bailenson, 2007). The differences between a Virtual World and a VE have also been investigated. Bell (2008) explored several definitions of Virtual Worlds and sought to combine them into one definition. The result was "A synchronous, persistent network of people, represented as avatars, facilitated by networked computers." (Bell, 2008). VEs have become more common in everyday life over the past couple of decades. Second Life became quite popular in the mid to late 2000s which provided millions of users with a 3D VE which resembled the actual world and allowed daily interaction (Sivunen and Hakonen, 2011). VEs have also extended into multiple disciplines and fields such as education and medical training (Bouras and Tsiatsos, 2006; Cowan, 2014; Ketelhut et al., 2010).

2.6 Presence

Essentially, presence is the sensation of 'being there' in the virtual world/environment and is arguably the most researched phenomenon in relation to VR. There have been numerous user studies, investigations and research into what presence is and how it can be measured by members of the VR and HCI community over the years (Lombard and Ditton, 2006; Schubert et al., 2001; Schuemie et al., 2001; Slater and Wilbur, 1997; Witmer and Singer, 1998).

More recently, there has been a focus on to what extent people respond realistically to the illusion of being in a place, place illusion (PI), and experiencing/responding to events as if they were real, plausibility illusion (Psi) (Slater and Sanchez-Vives, 2014). This has led to VR being used in professional services fields such as medical, military, police, and fire services. For example, VR has been used to assist patients with rehabilitation (Schultheis and Rizzo, 2001), treat phobias (Garcia-Palacios et al., 2002), and train people to perform high risk procedures and surgeries (Khor et al., 2016). It can be argued that such application of VR in meaningful and consequential real-life scenarios has assisted the increase of popularity and awareness with professionals, consumers and the general public.

Presence, as a concept, is highly relevant in the design and evaluation of entertainment media products e.g., movies, television programs, and video games, telecommunications such as videoconferencing and computer-based collaborative work, education e.g., on-line education, virtual campuses, and simulation training, and health care such as telemedicine and telesurgery. The attention paid to presence by computer scientists, psychologists and HCI experts alike has grown exponentially with the increasing sophistication and availability of VR technology. Consequently, presence is a central concept in the theorising and UX of VR systems (Biocca, 1997; Lombard and Ditton, 1997; Sheridan, 1995; Slater and Sanchez-Vives, 2014; Witmer and Singer, 1998).

Presence has been referred to in the past as telepresence, virtual presence, or mediated presence. However, it has become widely used in its simple form of just presence and in this thesis, the word presence is used simply meaning the feeling of being in the VE. According to Heeter, (1992):

> The basic premise is that experiencing your own presence in VR is like the process of discerning and validating the existence of self in the natural world (which humans have engaged in since birth). A sense of presence in a virtual world derives from feeling like you exist within but as a separate entity from a virtual world that also exists (Heeter, 1992, p. 262).

Heeter went on to define three dimensions of presence which are largely still used today. They are personal presence, social presence, and environmental presence. Personal presence is the extent to which you feel you are in a virtual world. Factors which contribute to the feeling of personal presence in a virtual world include partial or full representation of oneself, the extent of sensory channels engaged, and the perceptual realism of the virtual environment, others and objects in the virtual world. Social presence is the extent to which other living or synthetic beings coexist and react to you in the virtual world. Interaction with, and simply the existence of, other real human or computer-generated social entities inside the virtual world can contribute to the feeling of social presence. In turn, the feeling of social presence can provide the person with strong evidence of both their existence in, and the existence of, the virtual world. Finally, the extent to which a VE appears to know and react to your existence is referred to as environmental presence. A virtual world can provide stronger feelings of environmental presence by being more responsive to user input through interaction with the environment (Heeter, 1992; Lee, 2004; Slater et al., 2009).

Biocca, (1997, 2001) identified three types of presence; they were physical, social and self-presence. Physical presence refers to the sense of being physically located in a VE. Biocca proposed that when using technology, at any given moment a user could feel as though they were present in only one of the following three places: a physical environment, a virtual environment, or in the imaginal environment – dreaming or daydreaming. This definition of physical presence, as a subjective feeling of being in a VE, emphasised the user's transportation into a VE from the actual physical environment as an integral part of physical presence (Biocca, 1997). Social presence was defined by Biocca et al. (2001) as "the sense of 'being together with another' and mental models of other intelligences (i.e., people, animals, agents, gods, etc.) that help us simulate 'other minds'" (Biocca et al., 2001, p. 2). Social presence is here defined as simulation, as the simulation occurs even when the perceived intelligence is another human or nonhuman intelligence, such as an artificial being which may or may not have real intelligence. For example, even simple moving objects such as boxes or lines could be perceived as having purpose and intention and could contribute to one's sense of social presence (Biocca, 1997; Biocca et al., 2001). Finally, self-presence refers to a user's mental model of them self or the awareness inside a virtual world of self-identity. The close mapping of a user's actual physical body to a virtual body inside the VE may influence the user's body schema or image. Biocca also notes that there can be a discrepancy between a user's virtual and actual body in terms of social role or meaning (Biocca, 1997).

Following a review of the then current literature in 2004, Lee presented three definitions of three types of presence – physical, social, and self-presence. These were based on the three domains of virtual experience and although they are the same terms that Biocca, (1997) used, Lee states that each type of presence is substantially different from those of Biocca. Firstly, physical presence is defined as "a psychological state in which virtual (para-authentic or artificial) physical objects are experienced as actual physical objects in either sensory or non-sensory ways." Social presence is defined as "a psychological state in which virtual (para-authentic or artificial) social actors are experienced as actual social actors in either sensory or non-sensory ways." Finally, self-presence is defined as "a psychological state in which virtual (para-authentic or artificial) self/selves are experienced as the actual self in either sensory or non-sensory ways." (Lee, 2004, pp. 37, 44 and 46).

Virtual worlds can seem very 'real' with some appearing more believable than others. Pan and Hamilton, (2018) mentioned that it seems impossible that people would believe the virtual world to be the real thing. Although current VR systems can provide a strong sense of place and presence, the differences are substantial to the actual world. Pan and Hamilton (2018) reported that no participants of their studies were confused between the two (p. 35). This is expanded upon by Slater, (2018) who proposes that presence is an illusion and is not about belief. For example, when somebody is standing by a virtual precipice, their heart racing and experiencing a feeling of great anxiety, they never believe in the reality of what they are perceiving. According to Slater:

> The whole point of presence is that it is the illusion of being there, notwithstanding that you know for sure that you are not. It is a perceptual but not a cognitive illusion, where the perceptual system, for example, identifies a threat (the precipice) and the brain-body system automatically and rapidly reacts (this is the safe thing to do), while the cognitive system relatively slowly catches up and concludes 'But I know that this isn't real'. But by then it is too late, the reactions have already occurred (Slater, 2018, p. 432).

2.7 Immersion

There was once a fine line between presence and immersion until Slater and Wilber, (1997) made an important distinction and proposed that immersion "can be objectively assessed as the characteristics of a technology, and has dimensions such as the extent to which a display system can deliver an inclusive, extensive, surrounding and vivid illusion of virtual environment to a participant" whereas presence "is a state of consciousness", and "that participants who are highly present should experience the VE as more the engaging reality than the surrounding physical world, and consider the environment specified by the displays as places visited rather than as images seen." (Slater and Wilbur, 1997, pp. 1 and 4). According to Schuemie, (2001), immersion is "the extent to which the senses are engaged by the mediated environment" (Schuemie et al., 2001, p. 184). The level of immersion that a person experiences when entering a VE is dependent on a number of aspects. According to Slater and Wilbur, (1997), the aspects of immersion, which are mentioned in their definition, are:

- Inclusive (I) which indicates the extent to which physical reality is shut out.
- Extensive (E) which indicates the range of sensory modalities accommodated.
- Surrounding (S) which indicates the extent to which this virtual reality is panoramic rather than limited to a narrow field.
- Vivid (V) which indicates the resolution, fidelity, and variety of energy simulated within a particular modality (for example, the visual and colour resolution). Vividness is concerned with the richness, information content, resolution and quality of the displays (Slater and Wilbur, 1997, p. 3).

Furthermore, Slater and Wilbur identified several other aspects which can have an effect on a user's immersion in a VE. Matching – there should be a match between a user's proprioceptive feedback concerning body movements and the information generated on the display. For example, a turn of the head should have a corresponding change to the visual display and auditory display i.e., sound direction is invariant to the orientation of the head. A self-representation or a Virtual Body (VB) in the VE - the VB is both a part of the perceived environment and also represents the being that is actually perceiving. Perception in the VE is centred on the position in virtual space of the VB. For example, the visual perception should be from the viewpoint of the eyes in the head of the VB (egocentric as opposed to exocentric) (Ellis, 1991; Slater and Wilbur, 1997).

Visual immersion is just one part of the overall level of immersion which has many components. In the following, non-exhaustive, list from Bowman and McMahan, (2007), it is apparent that both software and hardware can play a role in determining the level of immersion:

- field of view (FoV)—the size of the visual field (in degrees of visual angle) that can be viewed instantaneously
- field of regard (FoR)—the total size of the visual field (in degrees of visual angle) surrounding the user
- display size
- display resolution
- stereoscopy—the display of different images to each eye to provide an additional depth cue
- head-based rendering—the display of images based on the physical position and orientation of the user's head (produced by head tracking)
- realism of lighting

- frame rate
- refresh rate (Bowman and McMahan, 2007, p. 38).

Subsequently, it has been found that there is not a straightforward link between presence and immersion, though immersion can affect presence in a number of ways, some of which can be detrimental to the users experience within a VE (Mania, 2004). Other factors which may affect immersion include Spatial Presence (SP), the relation between the VE as a space and the own body; Involvement (INV), the attention devoted to the VE; and Realness (REAL), the sense of reality attributed to the VE (Schubert et al., 2001). These factors appear in the Igroup Presence Questionnaire (IPQ) which is a scale for measuring the sense of presence experienced in a VE (igroup.org, 2016). More details of the IPQ can be found in Chapter 2, section 2.14.4.

2.8 Embodiment and Agency

In many VEs and experiences, the user takes part by assuming the role of a character and is often represented within the virtual world by an avatar. The user can usually control this avatar by use (or combination) of a mouse, the keyboard, control pad or other novel form of controller. The undertaking of the avatar as the representation of the user within the VE is commonly known as embodiment. When a user is embodied within the avatar, a psychological link between the user's physical body and that of the avatar within the VE varies from user to user due to a number of attributes such as realism of the avatar, appearance etc. The user has control over the avatar and directly controls the motion and behaviour of the avatar, providing input via the chosen form of controller and viewing the results of their actions within the environment (Bailenson et al., 2003; Biocca, 1997).

There has been much research and numerous studies in the VR field which investigate the psychological link between the user's physical body and the avatar's body as well as body perception in the VE (Biocca, 1997; Blanke and Metzinger, 2009; Fong and Mar, 2015; Ogawa et al., 2017; Ratan et al., 2020; Schroeder, 2002). In some instances, a user can become responsive to the actions and reactions of the avatar in the VE for example physically moving one's head if a projectile in the VE is heading towards the avatar's head. This phenomenon has been exemplified in a now classical experiment explained by Kilteni et al. (2012):

> The participant sits comfortably at a table with his or her left hand resting on it. A left rubber hand is put on a table aligned with and close to the real one. An occluding screen prevents the sight of the real left hand and arm. Both the rubber hand and corresponding real hand receive synchronous tactile stimulation from two paintbrushes at the same relative positions. After a few seconds of such synchronous stimulation, the participant will probably experience a profound illusion known as the rubber hand illusion (RHI)—the rubber hand feels as if it were his or her real hand (Botvinick and Cohen, 1998) (Kilteni et al., 2012, p. 373).

Kilteni et al. (2012) proposed a definition for the Sense of Embodiment (SoE) in order to avoid confusion in the research community. The term Sense of Embodiment is used to "refer to the ensemble of sensations that arise in conjunction with being inside, having, and controlling a body especially in relation to virtual reality applications." (Kilteni et al., 2012, p. 374). A 'body', used here, is a container which could be any kind of object in VR. However, the definition proposed by Kiltini et al. (2012) is concerned with the representation of the biological body in a VE and its relation to the actual biological body. According to de Vignemont, (2011), an object "E is embodied if and only if some properties of E are processed in the same way as the properties of one's body." (de Vignemont, 2011, p. 3). This definition is in congruence with that of Blanke and Metzinger,

(2009) who state that embodiment includes the "subjective experience of using and 'having' a body." (Blanke and Metzinger, 2009, p. 7). Consequently, the definition of SoE is thus "SoE toward a body B is the sense that emerges when B's properties are processed as if they were the properties of one's own biological body." (Kilteni et al., 2012, p. 375).

The term embodiment is often associated with the concepts of sense of self-location (Arzy et al., 2006), the sense of agency (Newport et al., 2010), and the sense of body ownership (Lopez et al., 2008). Therefore, one could consider the properties of one's biological body being described under the conceptual umbrella of these three terms. These three terms are explained according to Kilteni et al. (2012):

> Self-location is a determinate volume in space where one feels to be located. Normally self-location and body-space coincide in the sense that one feels self-located inside a physical body (Lenggenhager et al., 2009). The sense of self-location refers to one's spatial experience of being inside a body and it does not refer to the spatial experience of being inside a world (with or without a body) (Kilteni et al., 2012, p. 375).

The sense of agency refers to the sense of having "global motor control, including the subjective experience of action, control, intention, motor selection and the conscious experience of will" (Blanke and Metzinger, 2009, p. 7). Agency is present in active movements. When the predicted consequences of the action and the actual consequences of actions match by, for example, the presence of synchronous visuomotor correlations under active movement, one feels oneself to be the agent of those actions. The development of agency depends on the synchronicity of visuomotor correlations. Several studies have shown that discrepancies between the visual feedback of the action and the actual movement negatively affect the feeling of agency. In the study of Franck et al. (2001), a discrepancy of more than

150 ms was found to reduce agency (Blakemore et al., 2002; Franck et al., 2001; Sato and Yasuda, 2005).

Body ownership refers to one's self-attribution of a body (Gallagher, 2000; Tsakiris et al., 2006). It has a possessive character, and it implies that the body is the source of the experienced sensations. For example, body ownership is disturbed in patients with somatoparaphrenia who deny the ownership of their limb (Vallar and Ronchi, 2009). The sense of body ownership, according to Kilteni et al. (2012):

> The sense of body ownership has been proposed to emerge from a combination of bottom-up and top-down influences (Tsakiris, 2010; Tsakiris and Haggard, 2005). Here, bottom-up information refers to the afferent sensory information that arrives to our brain from our sensory organs; for example, visual, tactile, and proprioceptive input, whereas top-down information consists of the cognitive processes that may modulate the processing of sensory stimuli; for example, the existence of sufficient human likeness to presume that an artificial body can be one's body (Kilteni et al., 2012, p. 377).

Concerning 360° video, the viewer may feel a sense of embodiment relative to the placement of the camera, regardless of the presence of an avatar or body representation (Philpot, 2017). For example, a camera placed between a person and a table on which the person is performing some task, via a shot which is similar to a first person point-of-view (POV), may give the viewer the impression that they are carrying out that task (Passmore et al., 2016). Alternatively, as in a VR experience directed by Guy Shelmerdine and produced by produced by Chris Milk entitled Catatonic, the camera is placed in a wheelchair with a person and the viewer may perceive the body to be that of their own when looking down. To add to the experience, the viewer was strapped into a wheelchair rig which was equipped with a 'Buttkicker', a vibrating device which was built into the base of the wheelchair (Dark Corner Studios, 2015; Watercutter, 2015). Gimmicks such as this are quite common in VR experiences and are designed to increase one's immersion into the VE, video, or experience.

2.9 C.A.V.E

A C.A.V.E (Cave Automatic Virtual Environment), or CAVE, is a projection-based immersive VR display which consists of a number of rear projection screens (typically 3 but can be more) or walls with a downward projection onto the floor. The size is generally 10' x 10' x 10' which is enough space to house several people at once allowing a shared experience. The images are usually projected in stereo and viewers wearing stereo glasses can see images in true three-dimensional space. Only one user has the correct perspective and their position and orientation is tracked by an electromagnetic tracking system, which allows the rendering of the environment in a correct, viewer-centred perspective. Navigation in the VE is usually via a controller, such as a Microsoft Xbox controller, and this is also used by the primary user. The glasses and Xbox controller have markers on them which detect the position and facing direction of the user. This allows the VE to adjust according to the user's head movements. The CAVE setup including glasses, and Xbox controller can be seen in Figure 2.6 (Cruz-Neira et al., 1993; Disz et al., 1996; Matsentidou and Poullis, 2014).

More recently, the CAVE 2, a near-seamless flat-panel-based, surround-screen immersive system, was produced by Febretti et al. (2013). The CAVE2 is referred to as a Hybrid Reality Environment (HRE) and is a cylindrical system of 24 feet in diameter and 8 feet tall, and consists of 72 near-seamless, off-axis optimised passive stereo LCD panels, creating an approximately 320 degree panoramic environment, and can be seen in Figure 2.7 (Febretti et al., 2013). CAVEs have been used for a wide range of purposes in research and industry ranging from various types of training such as forklift truck operation (Yuen et al., 2010) and the training and enhancement of social skills for children with autism (Matsentidou and Poullis, 2014) to visualising and assessing hypotheses for marine archaeology (Katsouri et al., 2015), entertainment and leisure (Jacobson and Hwang, 2002; Lutz and Weintke, 1999) and treating phobias and other medical applications (Gromer et al., 2018; Zhang et al., 2001).

Figure 2.6: A VR CAVE, glasses and Xbox controller (Matsentidou and Poullis, 2014).

Figure 2.7: The CAVE2 Hybrid Reality Environment (Febretti et al., 2013).

2.10 360° Video

360° video, also known as panoramic video, is a relatively young medium and has been emerging into the mainstream over the past seven years or so. This has been parallel to the earlier mentioned availability of VR devices. 360° video, and its uses, have been the subject of much research and it has been experimented with in various areas such as education, medical treatment and entertainment (Feurstein, 2018; Herault et al., 2018; MacQuarrie and Steed, 2017; Theelen et al., 2019). As previously mentioned, the focus of this research is 360° video in the realm of entertainment, as this is an area which has a relatively low amount of published research; according to the literature review carried out by the author.

When this research began in 2015, a 360° video was created by making a video recording using a rig consisting of several individual cameras (Figure 2.8). The videos were then, if required, synchronised in time, and joined, or stitched, together frame by frame using specialised software in order to create a spherical view (Figure 2.9). The spherical coordinates were then converted into a rectangular format, creating an equirectangular 360° video which can be compared to flattening the globe of the Earth into a 2-dimensional map. The un-rendered, equirectangular footage can be viewed on any device, however, to fully appreciate the video, a 360° video player or HMD should be used. When the 360° video is viewed using a HMD, the viewer is situated in the centre of the sphere and can look around the full 360° (Figure 2.10) (Afzal et al., 2017). 360° video can be viewed using a number of different devices – a monitor/laptop screen, a smart phone, a HMD or even in a CAVE, each providing a different and somewhat unique experience and methods of interaction with the video.

Figure 2.8: A pre-made 360RIZE Pro10B Plug-n-Play 360° rig containing 7 GoPro Hero cameras (360Rize, 2019).

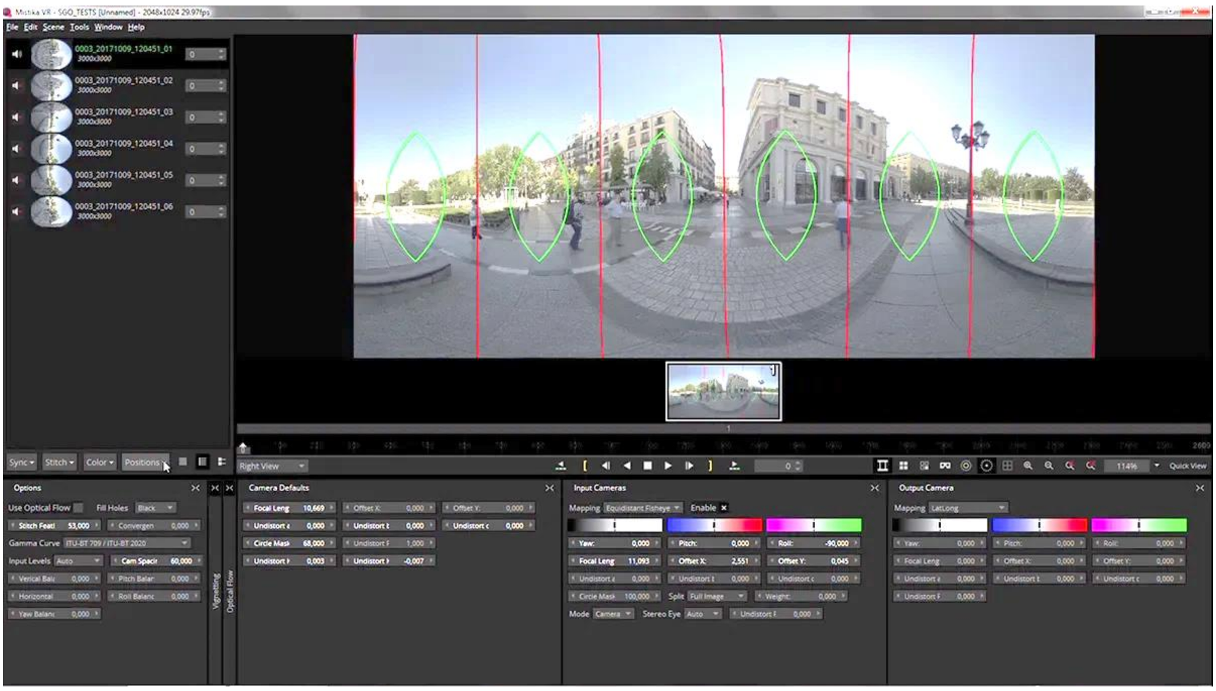


Figure 2.9: SGO Mistika-VR 360° video stitching software (SGO, 2022).

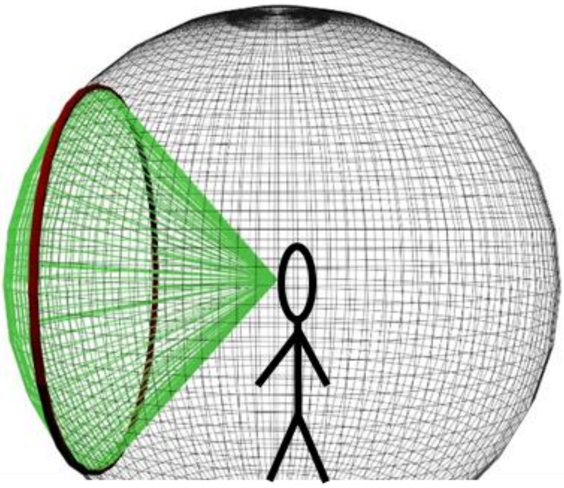


Figure 2.10: The position of the viewer in the 360° video sphere (Weiß, 2017).

However, using the rig of cameras is now a somewhat primitive method of recording the 360° video footage. Sophisticated cameras are now available that can auto stitch the recorded footage with some allowing both auto stitching and manual stitching in order to provide more creative control. The auto stitching is commonly executed via proprietary software, however, some cameras, such as the 360RIZE 360Penguin Panoramic Camera (Figure 2.11), automatically stitch the footage in-camera and output in 2:1 equirectangular format (360Rize, 2021). 360° video currently has two formats: monoscopic and stereoscopic, which are very different to each other.

Figure 2.11: The 360RIZE 360Penguin Panoramic Camera (360Rize, 2021).

2.11 Monoscopic 360° video

Monoscopic 360° videos are the most common type of 360° videos as they are easy for novice users to capture and produce with widely available hardware and software. The video footage can be captured from multiple regular cameras which are mounted in a custom-built or pre-made rig (Figure 2.8) or using a dedicated 360° video camera such as a GoPro Max (Figure 2.13). These are the amateur devices which would produce some good quality videos.

However, for professionals, such as Hollywood film producers, there have been some very high end, expensive cameras such as the Eye camera, a rig holding 42 cameras with 24 microphones and 225megapixel resolution, and the Jaunt One which has 24 integrated cameras. Both were marketed at the professional and carried multi thousand-dollar price tags. These two models are outdated now and are no longer available. One of the more recent professional models is the insta360 Titan which has impressive specifications such as post-processing stitching and resolutions of 10560 x 5280 @30fps (11K 2D) and 9600 x 9600 @30fps (10K 3D) (Figure 2.12).

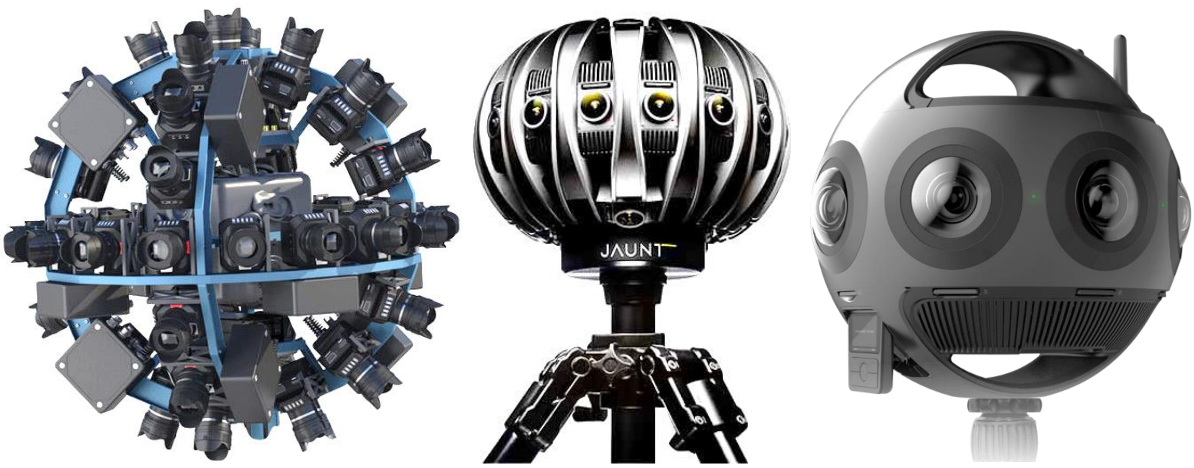


Figure 2.12: The Eye professional VR camera (left), the Jaunt One VR camera (centre) and the insta360 Titan (right) (Affinity Media Inc, 2016; insta360.com, 2022; Meyer, 2017).

While watching a monoscopic video using a HMD, the same content, a single image, is rendered for both eyes. As this is not how a human views the real world, the result is a lack of three-dimensional (3D) depth. The majority of 360° videos currently available are monoscopic and have been produced using the aforementioned technique utilising a flat equirectangular spherical video format. This is mainly due to the efficient and inexpensive devices and software which are used to capture, edit, and produce the footage (Figure 2.13). Although the viewer can experience presence and have an enjoyable virtual experience with monoscopic video, it will always be a two-dimensional (2D) world without the feeling of 3D depth which is experienced in the actual world.

Monoscopic 360° videos are limited in their responses to head movement; they can only respond to rotational motion of the head. Most VR HMDs support full 6 degree-of-freedom (DOF) head tracking which includes not only the rotational motion, but also the translational motion of the head. This limited DOF of the monoscopic 360° video viewing experience is arguably less engaging and immersive when compared to other full 3D VR content such as games (Roettl and Terlutter, 2018; Schild et al., 2012). However, in relation to presence, there is also evidence which suggests that there is no difference in experience between 2D and 3D games and no significant difference in experience between 2D and 3D 360° videos (Bessa et al., 2016; Huang et al., 2017; Williams, 2014).

Figure 2.13: The GoPro Max an affordable, high quality consumer 360° camera (GoPro Inc, 2020).

2.12 Stereoscopic 360° Video

Stereoscopic video differs from monoscopic video such that it is recorded using two separate lenses for each FoV (Figure 2.14). There are many cameras available which are capable of recording both monoscopic and stereoscopic 360° videos (Figure 2.15). Stereoscopic video cameras are, of course, more expensive than monoscopic video cameras and the editing and stitching of the video is a lot more challenging. Flaws in the stitching can be magnified when viewing in 3D and can ultimately lead to a very poor viewer experience. The difference between the devices is evident by the existence of lens pairs or two cameras for each field of view (Figure 2.16). Each lens provides a slightly different view which is equivalent to the human eyes viewing from 2 different angles. Recording using stereoscopic cameras creates a sense of 3D depth in 360° videos, with objects appearing nearer or further away, by mimicking human eye positions (Figure 2.17). When viewing the same scene from two different eye positions, depth can be calculated by the brain. This leads to a more realistic viewing experience, using a HMD, which is much closer to viewing objects and video in the actual world.

Figure 2.14: Monoscopic and stereoscopic 360° cameras differences (VRdirect, 2019).

Figure 2.15: The Vuze XR, a 360° camera capable of both monoscopic and stereoscopic 360° video capture (human-eyes, 2020).

Figure 2.16: A dedicated stereoscopic 360° camera (Samsung, 2020).

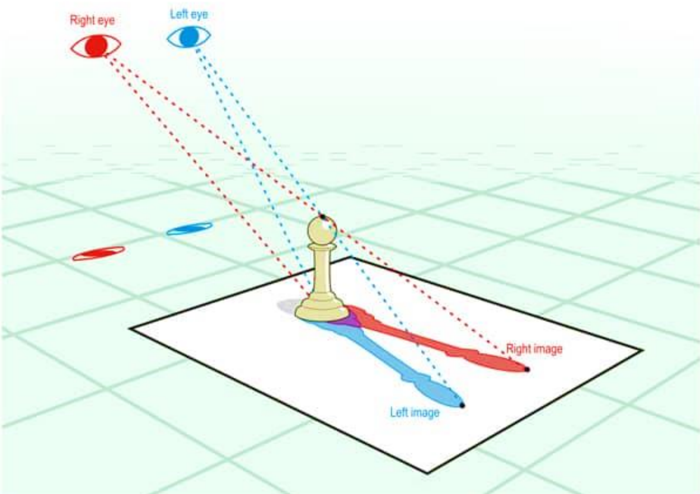


Figure 2.17: Recording using two lenses creates depth perception, the same as the human eyes (Immersion VR, n.d).

As the technology has improved and progressed, camera rigs and cameras such as the Jaunt One have been succeeded by more compact and powerful professional cameras such as the Z CAM V1 Pro Cinematic VR Camera which retails at $33,800 (at the time of writing June 2021). The Z CAM V1 Pro Cinematic VR Camera has 9 fisheye lenses, 4 Directional Mono Microphones and boasts the following spherical resolution - Mono 8K @30fps / 4K @60fps, Stereo 7K @30fps / 4K @60fps post stitching output (Shenzhen ImagineVision and Technology Limited, 2021) (Figure 2.18).

Figure 2.18: The Z CAM V1 Pro Cinematic VR Camera (B & H Foto & Electronics Corp, 2021).

2.13 Cinematic literacy, narrative, and filming techniques

Most people have watched films and or television programmes for much of their lives and are accustomed to the typical viewing situation using a flat screen, projection onto a flat surface or at the cinema. Before 360° video appeared, the cinematic techniques used for filming and editing were well established and generally followed by film makers. This includes types of shots such as close-ups, long-shots and pull back shots, camera movements such as panning, zooming and tracking and transitions between scenes such as jump cuts, flash backs and fade in/out. Most viewers are accustomed to such techniques and are able to follow a narrative or story and make sense of a film or programme via the techniques used.

Typically, the film maker uses the language of film making, which is composed of lower syntactic elements, such as the aforementioned shots, transitions and sequences etc., in order to tell a story which is embodied in a film. When watching the film, the viewer will use a viewing platform, e.g., a television or a VR HMD, and this will provide an experience which they will need to make sense of in order to understand the story. For most experienced literate viewers, it can be considered that experiential factors require minimal attention and that they more or less directly make sense of the film.

It can be said that 360° video has brought with it a requirement for a new language of film production. Many of the traditional filming techniques are not suitable for use in 360° video production due to the cameras recording the full 360 degrees. This method would also capture film crew, microphones, lighting and other equipment, props etc. which may not be desired to be visible in the scene. As a result of this, several guidelines and recommendations for producing 360° video have been made by companies such as Jaunt, the BBC, and Facebook (BBC, 2022; Facebook, 2016; Jaunt, 2018).

These guides are not very specific and are somewhat generic in their content. However, the BBC article does provide some additional information specific to elements such as framerate, editing and the stitch line. According to Jaunt, in regard to 'The Cinematic VR Field Guide' by Jaunt, "We are not, however, trying to produce an exhaustive text on the entirety of filmmaking but rather trying to cover the additional complexities and challenges that come with shooting in VR." (Jaunt, 2018). It appears that Jaunt started a series with part one "This is part one of a four part series on best practices for shooting 360 video for VR." (Jaunt, 2018). However, the subsequent parts cannot be found and may not have been published. An excerpt from the 'FaceBook Better Practices for 360' blog states for example:

Honor the Horizon Line

> When there is a horizon line, keep it steady. This manages the viewer's equilibrium, shifting it around can give the feeling of being on a boat and can make one sick (Facebook, 2016).

Furthermore, when comparing stereoscopic to monoscopic VR, an excerpt from 'The Cinematic VR Field Guide' by Jaunt states:

> Most cameras have a minimum distance to subject that you must respect in order to get a quality stitch and these distances are generally greater when stitching in 3D. If you need to get very close to a subject it may be better to go the mono route (Jaunt, 2018).

Finally, the 'How do I make 360 videos?' article from the BBC includes:

> Higher framerates are normally reserved for fast-moving subjects or slow motion, but when shooting 360, a high frame rate is very important … Aim for at least 60fps if you intend to have the content viewable on a VR headset. If you can, push for more than that.

Evidently, the advice, guidance and better practices which are offered are helpful, but not exhaustive or comprehensive. As far as the author is aware, there have not been many empirical studies conducted to ratify or challenge these guidelines and recommendations. In the early days of 360° video production, it was very much a trial-and-error process which resulted in many experimental techniques. Some of which were good and, of course, some of which were bad. Regardless of the techniques used, most 360° videos have a narrative which the viewer is required to follow and understand in order to make sense of the video and to have a positive or pleasant experience.

When viewing classical narrative media, such as film or television, the viewer is passive, whereas viewing VR using a HMD, the viewer is an active agent, involved in the unfolding narrative. This has presented 360° video creators with several challenges when considering user immersion and/or interaction with the 360° video. It appears that there is still no single approach or fully established screen grammar associated with 360° video production or 360° video narrative. According to Jerald, (2015), "in any field, no single design process is appropriate for every project. This is even truer of VR, for multiple reasons… there are not yet (and there may never be) standardized processes to follow" (Dooley, 2017; Jerald, 2016).

2.14 Questionnaires

There are various quantitative and qualitative research methodologies which are commonly used in the realm of HCI. These include, but are not limited to, surveys, interviews, focus groups, user studies, case studies, statistical analysis and experiments (Lazar, 2017). In this sub-section, six predominant questionnaires in the domain are presented.

2.14.1 The presence questionnaire, Witmer and Singer

Although the Presence Questionnaire (PQ) by Witmer and Singer is from the late nineties, its relevance is still very prominent in VR research. The initial version of the PQ and the Immersive Tendencies Questionnaire (ITQ) were developed in 1992 and were refined up until the 1998 version. Both questionnaires rely upon self-report information and use a seven-point Likert scale. The scale has anchors, based on the content of the question, at each end using opposing descriptors, and also uses a midpoint anchor. An 'X' is placed in the appropriate box by participants of the survey. Figure 2.19 displays a question from the PQ.

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

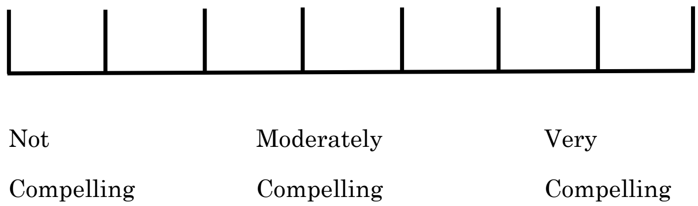


Figure 2.19: An exemplar from the Presence Questionnaire (Witmer and Singer, 1998).

Previous to the development of the PQ, a few researchers had attempted to measure presence and relate it to contributing factors (Barfield and Hendrix, 1995; Prothero and Hoffman, 1995). Witmer and Singer based the factors used in the PQ upon those identified by Sheridan, (1992) and Held and Dulach, (1992) (Held and Durlach, 1992; Sheridan, 1992). The questions, or items, in the survey are categorised by these major factors: CF = Control Factors, SF = Sensory Factors, DF = Distraction Factors, RF = Realism. Each item is also associated with a subscale which was "loosely based on the content of the questionnaire items in their cluster" (Witmer and Singer, 1998, p. 236). The subscales are: INV/C = Involvement/Control, NAT = Natural, AUD = Auditory, HAPTC = Haptic, RES = Resolution, IFQUAL = Interface Quality. For a detailed explanation of the factors and subscales, please refer to the literature (Witmer and Singer, 1998).

Following the completion of the questionnaire, each question is scored based on where the 'X' is situated in the scale from 1 – 7 for each question. The sum of the scores is the presence score for each participant; a higher score suggests a higher sense of presence. Though this was a very popular method to measure presence in

VR for some time, the PQ did receive criticism from some leading researchers in the VR field (Slater, 2004; Usoh et al., 2000).

2.14.2 The Game User Experience Satisfaction Scale

The Game User Experience Satisfaction Scale (GUESS) is a game satisfaction questionnaire devised by Phan et al. (2016), which measures video game satisfaction based on nine key factors identified using an Exploratory Factor Analysis (EFA). The questionnaire uses a 7-point Likert scale with response anchors which from left to right are 'strongly disagree, disagree, somewhat disagree, neither agree nor disagree, somewhat agree, agree, and strongly agree'. At the end of the scale is an N/A option for when a statement does not apply to a particular video game. The nine key factors which comprise the GUESS are made up of varying numbers of statements; these can be seen in Figure 2.20.

Factor 1: Usability/Playability	11
Factor 2: Narratives	7
Factor 3: Play Engrossment	8
Factor 4: Enjoyment	5
Factor 5: Creative Freedom	7
Factor 6: Audio Aesthetics	4
Factor 7: Personal Gratification	6
Factor 8: Social Connectivity	4
Factor 9: Visual Aesthetics	3

Figure 2.20: The nine key factors which comprise the GUESS (Phan et al., 2016).

Several common attributes exist between watching 360° video and video game satisfaction (found from the early user study carried out by the author), hence the interest in the GUESS (Passmore et al., 2016; Philpot et al., 2017). These attributes include engagement, immersion, presence, and flow.

When undertaking exploratory studies with a view to measure an attribute using a scale or collection of factors/attributes, a factor analysis is considered to be one of the best methods for both the development and validation. Experts strongly advise that all new scales undergo an Exploratory Factor Analysis (EFA) followed by a Confirmatory factor analysis (CFA) (Cabrera-Nguyen, 2010; Hinkin, 1995; Worthington and Whittaker, 2006). According to Phan et al. (2016), "Both EFA and CFA are complex and iterative procedures that require clear justification and documentation for each major analytic decision (e.g., which extraction method and why)." (Phan et al., 2016, p. 7). One method which appears to be suitable is that carried out by Phan et al. (2016) in their development and validation of the Game User Experience Satisfaction Scale (GUESS). "The aim of this study was to develop and psychometrically validate a new instrument that comprehensively measures video game satisfaction based on these key factors." (Phan et al., 2016, p. 8).

They used a mixed method design which consisted of the following five steps:

1. Item pool generation: Multiple resources (e.g., past established scale and heuristics) were drawn upon to generate an item pool for the scale.

2. Expert review of item pool: The item pool was presented to a panel of eight experts with expertise in video games and/or questionnaire design.

3. Questionnaire pilot study: The scale was piloted with 16 participants from four groups of self-identified gamers (i.e., newbie/novice, casual, midcore/core, and hardcore/expert).

4. EFA: The questionnaire was distributed to different gamers in an online survey (N = 629). EFA was performed to identify the underlying factors and reduce the number of items on the scale.

5. CFA: Another independent sample of video game players (N = 771) was surveyed using the revised scale from the EFA. Additionally, CFA was conducted to further validate the scale (Phan et al., 2016, pp. 8 and 9).

2.14.3 The User Engagement Scale

The User Engagement Scale (UES) was initially developed by O'Brien and Toms in 2008 and presently exists in two forms, the UES and the User Engagement Scale Short Form (UES SF). The UES-SF was developed in 2018 by O'Brien, Cairns and Hall. The UES is a tool which was developed to measure UX, and has been administered in various digital domains including information search, online news, online video, education, and consumer applications, haptic technologies, social networking systems, and video games (O'Brien et al., 2018; O'Brien and Toms, 2010b). The original UES consists of 31-items and measures six dimensions of engagement. These are Aesthetic Appeal (AE), Focused Attention (FA), Novelty (NO), Perceived Usability (PU), Felt Involvement (FI), and Endurability (EN). The 31 items were categorised into the six dimensions using the abbreviations in parentheses (O'Brien and Toms, 2010a, 2008). Some example statements from the UES include: 'I was so involved in this experience that I lost track of time' [FA.2], and 'My experience was rewarding' [RW.4] (O'Brien et al., 2018).

The six dimensions of engagement were arrived at following an initial EFA, which was used to examine the construct validity and multidimensionality of the UES in its early form. Structural Equation Modeling (SEM), which combines CFA, was carried out in order to assess whether or not the factor structure of data from a study carried out by O'Brien and Toms, Study 1, was comparable to a second study carried out by O’Brien and Toms, Study 2. Additionally a Path Analysis (PA), which examines the predictive relationships among the resulting factors was performed (O’Brien and Toms, 2010a).

Although evidence suggests that the UES is a valid and reliable means of capturing subjective user engagement, some findings have questioned its effectiveness; reported in a paper by O’Brien entitled ‘Translating theory into medical practice’ (O’Brien, 2016). These findings suggest flaws in the ways that the UES has been administered and analysed in practice. It has been found that few researchers have used the UES in its entirety (all 31 items). According to O’Brien, 2018, “This makes it difficult to assess its factor structure and robustness over time and across different digital applications.” (O’Brien et al., 2018, p. 29). By not using all 31 items of the UES, pragmatic issues of using the UES in a study (i.e., length), or poor documentation regarding how to adapt, implement, and make meaning from the measurement tool arise (O’Brien et al., 2018). According to O’Brien, (2018), the ways in which the UES has been implemented in such studies “suggests there may be a need for a briefer version of the questionnaire and more effective documentation to guide its use and analysis.” (O’Brien et al., 2018, p. 28).

For a number of reasons, O’Brien et al. (2018), decided to re-evaluate the original UES data to confirm a four or six factor structure, and determine how the 31 original UES items were grouped together. A second goal was to use the resulting knowledge of the validated factor structure to propose a short-form of the UES. According to O’Brien et al. (2018):

> First, the widespread use of the UES in various HCI domains suggested that there was a need for an instrument to capture UE from the users’ perspective, and that the UES’s conceptualization of UE as a multi-dimensional construct resonated within the community. Second, the four-factor structure that emerged in those studies that used the UES in its

entirety indicated the need to look closely at the dimensions of the UES and either confirm the six-factor structure or propose and validate a new four-factor scale. Third, the use of select items or subscales rather than the entire UES signalled that the questionnaire may be too lengthy for some research contexts and a briefer version was warranted (O'Brien et al., 2018, p. 31).

Code	Category	No. of Qs
FA	Focused Attention	3
PU	Perceived Usability	3
AE	Aesthetic Appeal	3
RW	Reward Factor	3

Table 2.2: The UES SF categories and respective number of questions per category (O'Brien et al., 2018).

The result was a revised UES Long Form (UES-LF) and the UES-SF. The UES-SF consists of 12 statements divided into 4 categories, uses a 5-point Likert scale and contains responses from 'strongly disagree' to 'strongly agree'. Following completion, each statement is scored 1 – 5 from left to right on the Likert scale, PU-S1, PU-S2, and PU-S3 are reverse scored. Some sample statements are: "I lost myself in this experience" [FA-S1] and "I felt interested in this experience" [RW-S3] (O'Brien et al., 2018). The categories and respective number of questions can be seen in Table 2.2.

2.14.4 The IPQ

The iGroup Presence Questionnaire (IPQ) is a scale which is used for measuring the sense of presence experienced in a VE (see appendix E). It is comprised of 14 statements and questions which are divided into 4 categories, see Table 2.3. The four categories are General (G), the general ‘sense of being there’, Spatial Presence (SP), the relation between the VE as a space and the own body; involvement (INV), the attention devoted to the VE; and Realism (REAL), the sense of reality attributed to the VE. Some sample statements and questions include: ‘I felt present in the virtual space’ [SP5], ‘I still paid attention to the real environment’ [INV3], and ‘How much did your experience in the virtual environment seem consistent with your real-world experience?’ [REAL2] (igroup.org, 2016; Schubert et al., 2001).

	Category	No. of Qs
G	Presence	1
SP	Spatial Presence	5
INV	Involvement	4
REAL	Realism	4

Table 2.3: The IPQ categories and respective number of questions (igroup.org, 2016).

The questionnaire uses a 7-point Likert scale scored from 0-6 and consists of various responses to the 14 statements and questions such as: ‘Not at all – Very much’ and ‘Fully disagree – Fully agree’. The use of various general scale anchors and more precise anchors were used in order to make the scale less boring (Schubert et al., 2001). Once completed, scores are attributed to each statement from 0 – 6. The left endpoint of the scale is always 0, the right endpoint is always 6. However, the scores for statements SP2, INV3, and REAL1 are reverse scored see Figure 2.21.

Figure 2.21: The scoring for the IPQ Likert scale.

Once the questionnaires have been scored, the result is a number for each of the categories. The number is calculated by computing the mean values of each category. Once the mean values have been calculated, diagrams can be plotted, and data can be presented. The final mean values from each category can provide an indication of the subjective sense of presence experienced in a VE.

The IPQ was created and developed by Thomas Schubert, Frank Friedmann, and Holger Regenbrecht using a combination of items from existing presence questionnaires (Carlin et al., 1997; Ellis et al., 1997; Hendrix, 1994; Slater, 2004; Towell and Towell, 1997; Witmer and Singer, 1994), the authors' own research (Regenbrecht et al., 1998), and new items constructed using "a large pool of items and two survey waves with approximately 500 participants" (Regenbrecht and Schubert, 2002; Schubert et al., 2001, 1999; Schubert and Regenbrecht, 2002; Schubert, 2003). Exploratory factor analyses were then conducted on these items, resulting in the 14-item, 3-factor model of presence – the IPQ. The IPQ was found to be highly reliable in 2 preliminary studies (α=.85; α=.87), and confirmatory factor analysis of the 3-factor model provided evidentiary support of the measure's validity (Schubert et al., 2001). Further validity studies were carried out with positive results which demonstrated the IPQ to be a robust questionnaire with which to measure the sense of presence in VR studies (Schwind et al., 2019; Vasconcelos-Raposo et al., 2016).

2.14.5 The Game Engagement Questionnaire versions

There exist two questionnaires in the HCI realm which have the 'GEQ' acronym; namely the Game Engagement Questionnaire (GEQ[1]) and the Game Experience Questionnaire (GEQ[2]). These two questionnaires have been mistakenly cited by researchers in the past (Law et al., 2018). Law et al. (2018) conducted a systematic review and validation of the Game Experience Questionnaire due to its lack of a formal peer-reviewed publication, confusion over the 'manuscript in preparation' status, inconsistent reporting of psychometric properties, and the misleading citation practices with regards to the source (Law et al., 2018). Despite all of these concerns, the GEQ[2] has been widely applied in games research over the last decade or so, both in full and in part (Gajadhar et al., 2008; Kuikkaniemi et al., 2010; Nacke et al., 2010; Nebel et al., 2016; Ranasinghe et al., 2018).

2.14.6 The Game Engagement Questionnaire (GEQ[1])

The Game Engagement Questionnaire (GEQ[1]), developed by Brockmyer et al. (2009), was used to measure levels of engagement while playing video games. Following Rasch analyses, it was demonstrated that the GEQ[1] demonstrates "adequate separation, fit, rating scale functioning, and dimensionality, suggesting that one's tendency to become engaged in video game-playing is a quantifiable construct." (Brockmyer et al., 2009, p. 624). The Rasch model, taken from the Brockmyer et al. (2009) publication, is a "mathematical representation of how response data function when they satisfy the fundamental properties of measurement – the same properties found in physical measures such as height, weight, and temperature. These fundamental measurement properties include unidimensionality of the data, linearity, and invariance across samples of respondents and items." (Brockmyer et al., 2009, p. 627).

The GEQ[1] consists of 19 items and was measured using a 3-point scale with the anchors 'No', 'Sort of' and 'Yes'. The anchors were attributed with a score, 'No' [1], 'Sort of' [2] and 'Yes' [3], and the final score was achieved by calculating an average score of all 19 items. Example items from the GEQ[1] include: 'If someone talks to me, I don't hear them', 'I play longer than I meant to' and 'Time seems to kind of stand still or stop'. The items were also categorised and placed into one of four constructs, namely presence, flow, [psychological] absorption and immersion.

A high score would indicate that the person had experienced deeper levels of engagement, such as flow and psychological absorption whereas a low score would suggest that the person had experienced low engagement, such as immersion. According to Brockmyer et al. (2009), "The GEQ[1] provides a psychometrically strong measure of levels of engagement specifically elicited while playing video games", and "has the potential to identify different levels of engagement in playing video games in a cost-effective and efficient manner" (Brockmyer et al., 2009, pp. 624 and 633).

2.14.7 The Game Experience Questionnaire (GEQ[2])

The Game Experience Questionnaire (GEQ[2]) is a "self-report measure that aims to comprehensively and reliably characterise the multifaceted experience of playing digital games.", and was developed as a part of the FUGA (The fun of gaming) project by Poels et al. (2007) (Poels et al., 2007, p. 2). The 2007 version of the GEQ[2] (GEQv7) was further developed and was made available in 2013; hereby referred to as the GEQv13. The reason for this differentiation is that there are less items in the core module of the GEQv13 (33 items) than there were in the earlier GEQv7 core module (42 items). To avoid any confusion in relation to the identified issues with several versions, the version of the GEQ[2] which is referred to is the GEQv13 from the 2013 publication by IJsselsteijn et al. (2013).

The GEQv13 has a modular structure which consists of three modules, they are: Core Module, Post-game module, and the Social Presence Module; in addition, the In-game Module was developed. Each module is comprised of several statements, or items, with a scale which is made up of five anchors, shown in Figure 2.22. Each item in each module is numbered and can be referred to using a code. For example, item four from the Core Module is GEQ Core-4. The participant would indicate how they felt after finishing playing the game for each of the items by selecting an anchor and marking which applied to them. The items are distributed among several components which include Sensory and Imaginative Immersion, Flow, Competence, Positive Affect, Negative Affect, Tension/Annoyance, Challenge, Psychological Involvement – Empathy, Psychological Involvement – Negative Feelings, Behavioural Involvement, Positive Experience, Negative Experience, Tiredness and Returning to Reality.

not at all	slightly	moderately	fairly	extremely
0	1	2	3	4
< >	< >	< >	< >	< >

Figure 2.22: The scale used in the GEQv13 (IJsselsteijn et al., 2013).

The modules should be administered immediately after the game session has finished and in the following order:

1. The Core Module
2. The Social Presence Module
3. The Post-game Module

Each module consists of a number of components which contain a specified number of items. What follows is each module, their components, the number of items in each component and some examples of the items contained in that respective module.

The Core Module – seven components [Sensory and Imaginative Immersion, Flow, Competence, Positive Affect, Negative Affect, Tension/Annoyance, Challenge] [33 items] – ‘I was fully occupied with the game’, ‘I found it tiresome’, and ‘I was fast at reaching the game's targets’.

The Social Presence Module – three components [Psychological Involvement – Empathy, Psychological Involvement – Negative Feelings, Behavioural Involvement] - [17 items] – 'I found it enjoyable to be with the other(s)', What the other(s) did affected what I did', and 'When the other(s) was(were) happy, I was happy'.

The Post-game Module – [Positive Experience, Negative Experience, Tiredness and Returning to Reality] - [17 items] - 'I was interested in the game's story', 'I felt completely absorbed', and 'I found it impressive'.

The In-game Module - seven components [Sensory and Imaginative Immersion, Flow, Competence, Positive Affect, Negative Affect, Tension/Annoyance, Challenge] – [14 items] – 'I felt successful', 'I felt completely absorbed' and 'I forgot everything around me'.

The in-game module is used to assess game experience at multiple intervals during a game, or play-back session and has 14 items. These 14 items are extracted from the Core Module. The module consists of seven components and two items are used for each component (IJsselsteijn et al., 2013).

Each module in the GEQv13 is scored by component where the average score of each component's respective items is computed. A high score in a component would indicate a stronger reaction to that component. For example, a high score in Negative Experience would indicate that the participant had a negative experience, whereas a low score in Sensory and Imaginative Immersion would suggest that the participant did not experience very much immersion. Although some of the scores are easy to interpret, others are not so easy and, according to Law et al. (2018), these difficulties are potentially misleading which resulted in their conclusion that using the GEQv13 in its current form was not recommended (Law et al., 2018).

2.15 Summary

The literature review in this chapter has briefly introduced the prominent concepts, topics, and areas with which this research has been concerned. Although most have been briefly covered, this chapter can be used as a reference and should provide the reader with a reasonable understanding of these concepts and topics for when they are encountered again later in the thesis.

Chapter 3 User study one – The effect of viewing platform on the user experience: Phone vs HMD vs Flat Screen

To gather meaningful data from users of 360° video, the method by which the data would be gathered had to be determined. There were several options available and after some consideration it was decided that a series of user studies would be the best course of action. This chapter presents the first in a series of user studies which were undertaken in order to address the research objectives and research questions. Each study aimed to answer a specific research question and contribute information which could provide input to the conceptual framework. The series consists of three user studies and one case study and are presented in chronological order.

3.1 Research question

This user study addressed research question one: How does platform affect the user experience of 360° video when viewing a 360° video on a PC, phone, or VR headset?

The study was carried out as a collaborative study with members of the BBC Research and Development (R&D) team and an MSc student from the University of Bath who was working with the BBC R&D team. Ethical approval was applied for, and granted, at the BBC organisation by the BBC R&D team as well as from the Middlesex University Computer Science Research Ethics Committee.

3.1.1 Author's contribution

The author contributed to this study as part of the team and was involved from the beginning to end of the study in the following:

- Study protocol design – the order of events was proposed, the interview questions were produced.
- Application for ethical approval and preparation of all study documentation – this process was required by the university before the research could commence. All documentation was prepared and collated by the author before being submitted by the author.
- Recruitment of participants – this was carried out by the author via email and word of mouth on site at Middlesex University.
- Execution of the study protocol – the author set up the equipment, prepared the documentation, administered the demo of the equipment, carried out the interviews, questionnaires and debriefing for all participants of the study at the Middlesex University site.
- Design of the analysis methodology – analysis methods were researched and proposed by the author. The chosen methods were decided upon by the team and the author.
- Execution of the analysis – the analysis was carried out in the main by the author, along with some input from and consultation with the other members of the research team.

- Production of results – the results of the analysis were presented in the main by the author, along with some assistance from and consultation with the other members of the research team.
- Write up of the published paper – the write up of the study was a joint effort of the research team. The first and third authors of the paper (Passmore and Philpot) wrote the majority of the paper. The author reviewed what was written by the other team members and provided some suggestions and modifications.

3.2 Aim

To acquire information pertaining to user experience of viewing 360° video using three different viewing platforms i.e., devices: a HMD (VR), a flat screen and a smart phone.

3.3 Protocol

To begin, the potential participant read the Participant Information sheet (PIS) (see Appendix B, B.3), which outlined the study; what they would be doing, what was expected of them etc. A screening questionnaire was then filled out to ascertain whether the potential participant was suitable to take part in the study (see Appendix B, B.1). The screening questionnaire contained safety measures obtained from the Oculus health and safety warnings found online (Facebook Technologies, LLC, 2020). Upon successfully meeting the criteria, and signing the consent forms (Appendix B, B.2), the participant was assigned a viewing condition combination. The viewing conditions were arranged in an attempt to avoid ordering effects and were executed in the stated order. Two viewing conditions were chosen, and not all three to avoid undesirable learning and fatigue effects due to watching the same video three times, as opposed to twice. The viewing condition combinations were the following:

- Screen and Phone
- Screen and VR
- VR and Phone
- VR and Screen
- Phone and VR
- Phone and Screen

This study employed a within group design and was carried out in three separate locations, namely, Middlesex University and the BBC offices in London and Manchester. The screen condition comprised the 17-inch flat screen of an Apple MacBook pro which was used at all locations. The phone condition comprised a Samsung Galaxy Note 4 at Middlesex University or a Samsung Galaxy S6 in the studies executed at the BBC premises. A Samsung Gear VR was used in all locations for the VR condition. The Note 4 was inserted into the Gear VR at Middlesex University while the S6 was inserted into the Gear VR at the BBC premises. There was no difference in the display resolutions of the two Samsung phones. Both have main display resolutions of 2560 x 1440 (Quad HD) using Super AMOLED technology with a colour depth of 16 million. A pair of on ear headphones were worn by the participants in all viewing conditions, which provided the audio to the video.

The feature video, which was viewed by each participant twice – once using each prescribed condition, was an eight-minute monoscopic 360° video documentary profile of an artist, entitled 'The Resistance of Honey' (Figure 3.1). The video is a character led study of the artist's exploration of beekeeping, the recording of bees, and the subsequent production and performance of derived electronic music. The main character of the film was Bioni Samp, referred to as the 'Bee man' by many of the participants and is used for the purpose of analysis and throughout the thesis. In terms of the content of the video, it was shot in various locations including in a park, inside a small shed in the park, one shot was taken inside a simulated hive and the hive entrance was on the outside of the shed. One shot was taken of the Bee man standing in a polytunnel. Other shots were taken in the Bee man's studio room and outside the small shed.

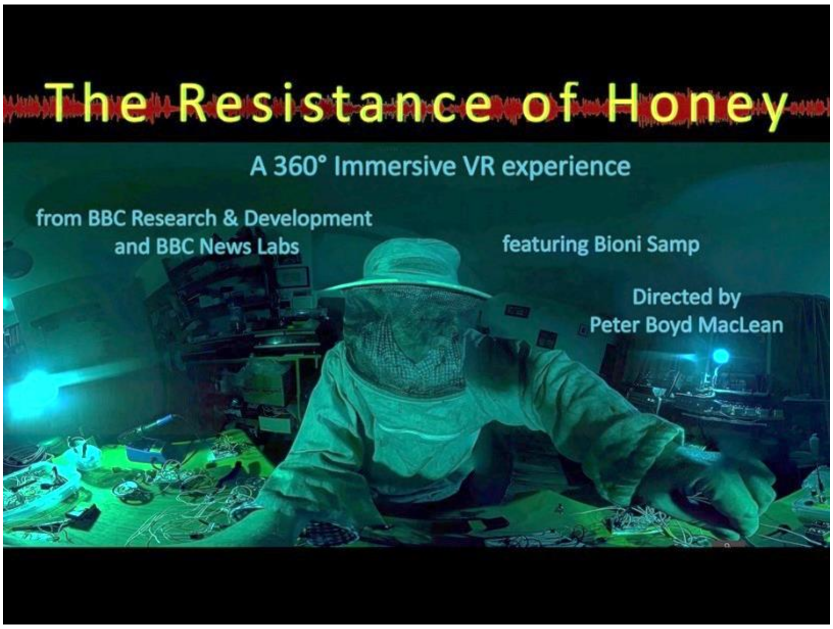


Figure 3.1: A flyer for the video used in the study 'The Resistance of Honey'.

The 360° video followed closely the tradition of continuity editing in sequentially portraying a number of scenes linked in both space and time. Secondly, the soundtrack, consisting of music, sound effects and intermittent narration by the Bee man, was continuous over the piece, uniting the shots. The piece was shot with the Bee man always in the front view, and he was generally the main moving object. Moreover, the narration was often used to steer viewer attention. Several shots were used in the video, some of which were specifically where the camera was placed. These included establishing shot, [camera] at head height, [camera] above head height, [camera] below head height and close-up shots. More detail of these shots and their effects on the viewing experience are discussed in Chapter 5, section 5.3.

For the purpose of the flat screen version of the video, the central twenty five percent of the equirectangular video was extracted in order to approximate a typical 16:9 view. A demonstration video about London's Chinatown was shown to participants who had been assigned the VR viewing condition and had not experienced VR, or used a HMD before, in order to familiarise them with HMD and 360° video navigation mechanisms such as moving the head to look in different directions etc. This was shown before the feature video, 'The Resistance of Honey', using the HMD.

Once assigned a viewing condition combination, the participant watched the feature video using the first viewing condition. Once the video had finished, the participant took part in a semi-structured interview comprising several questions (see Appendix B, B.4). The participant then watched the feature video using the second viewing condition and once completed, the same semi-structured interview was carried out and a questionnaire for each of the conditions was administered i.e., two questionnaires. The questionnaire had six questions in the form of a 5-point Likert scale for each condition undertaken. The questions referred to the participant's experience in relation to the device used (see Appendix B, B.5). While partaking in the interviews, each participant was video recorded to allow future transcription of the audio. Finally, a debriefing was provided to the participant, (see appendix B, B.6).

There were 24 participants, comprised of 13 males and 11 females aged 22 – 42, who took part in the study across the three locations. The study drew participants approximately evenly from Middlesex University (13 subjects) and the two BBC premises (11 subjects). The participants from Middlesex University either studied or worked in a computing discipline and the participants from the BBC had a diverse range of backgrounds in the research and development department. The participants were not asked about any disabilities or conditions beyond what was asked in the screening form. The semi-structured interviews from the 24 participants were transcribed and saved to a PC with the view to carry out a thematic analysis using NVIVO software following Braun and Clarke's method (more detail can be found in section 3.4.2) (Braun and Clarke, 2006). The results of the questionnaires were compiled into charts and are presented later in this section (section 3.5.3).

3.4 Analysis methods used for this study

The initial analysis method chosen for this study was Braun and Clarke's Thematic Analysis (Braun and Clarke, 2006). As the analysis progressed, and at a relatively early stage of the thematic analysis, while identifying key words and sentences and generating initial themes, another method of analysis arose, namely mind maps. The methods are presented along with the software which was used to perform the thematic analysis.

3.4.1 Thematic analysis

This first user study was of an exploratory nature and the data which was gathered from the interviews was qualitative. Therefore, a suitable methodology was required to apply to the data in order to deduce some useful results. Upon initial investigation of qualitative analytical methods, Grounded Theory was identified as suitable. However, further investigations discovered that Braun and Clarke's Thematic Analysis (Braun and Clarke, 2006), was slightly more flexible as it "does not require the detailed theoretical and technological knowledge of approaches, such as grounded theory" and "can offer a more accessible form of analysis, particularly for those early in a qualitative research career." (Braun and Clarke, 2006). The aim was not to build a theory or hypothesis at this time, therefore thematic analysis suited the broad research question, and would be suitable as a starting point for eliciting common information from the interview data. This method appeared to be adequate for what was desired to be achieved from this first user study.

According to Braun and Clarke, (2006), "Thematic analysis is a method for identifying, analysing, and reporting patterns (themes) within data. It minimally organizes and describes your data set in (rich) detail." (Braun and Clarke, 2006, p. 79).

There are six phases in Braun and Clarke's Thematic Analysis process which are exhibited in Table 3.1. Phase one, familiarising yourself with your data, is where the researcher usually transcribes the data from audio or video interviews. If this is performed by the researcher/s and not outsourced, it can be a very useful process (as was discovered by the author). By listening and typing/writing down what the participants have said, the familiarisation is very easy and effective. However, transcription is a very time intensive activity and can become tedious. During the transcription, recurrent themes begin to emerge and some initial ideas and possible codes are noted down (Braun and Clarke, 2006).

Phase two, generating initial codes, involves reading over the transcripts and data and coding interesting or remarkable features. The codes tend to build up quite fast at the beginning and once there are a reasonable number of codes, the collation of the data to each relevant code becomes systematic. It is important to not force data into codes and create new codes if required (Braun and Clarke, 2006).

Phase	Description of the process
1. Familiarising yourself with your data:	Transcribing data (if necessary), reading and re-reading the data, noting down initial ideas.
2. Generating initial codes:	Coding interesting features of the data in a systematic fashion across the entire data set, collating data relevant to each code.
3. Searching for themes:	Collating codes into potential themes, gathering all data relevant to each potential theme.
4. Reviewing themes:	Checking if the themes work in relation to the coded extracts (Level 1) and the entire data set (Level 2), generating a thematic 'map' of the analysis.
5. Defining and naming themes:	Ongoing analysis to refine the specifics of each theme, and the overall story the analysis tells, generating clear definitions and names for each theme.
6. Producing the report: The final opportunity for analysis.	Selection of vivid, compelling extract examples, final analysis of selected extracts, relating back of the analysis to the research question and literature, producing a scholarly report of the analysis.

Table 3.1: The six phases of Braun and Clarke's Thematic Analysis (Braun and Clarke, 2006).

Phase three, searching for themes, reviews the codes and associated data, and begins to generate potential themes. The themes are created relevant to the content of the data and the data is gathered together in each theme. Relationships between codes, themes and different levels of themes are considered some themes may be discarded at this stage (Braun and Clarke, 2006).

Phase four, reviewing themes, begins with a collection of candidate themes which are refined. There are two levels of review, level one involves reviewing the coded extracts. The researcher must read all of the collated extracts for each theme and consider whether they appear to form a coherent pattern. The must decide if the extracts warrant a new theme, if they suit a different theme, or if they are to be discarded. A candidate thematic map can then be created which is very similar to a mind map (see section 3.4.3).

Following the creation of the candidate thematic map, the level two review can begin. The level two review is very similar to the level one review; however, the entire data set is taken into consideration. The themes are reviewed, and it must be decided whether they accurately reflect the meanings evident in the data set as a whole. The entire data set should be re-read at this stage for two reasons –

> The first is to ascertain whether the themes 'work' in relation to the data set. The second is to code any additional data within themes that has been missed in earlier coding stages. The need for re-coding from the data set is to be expected as coding is an ongoing organic process (Braun and Clarke, 2006, p. 91).

If at this point the thematic map works, then it is time to move on to the next phase. If not, further review and refinement must be carried out bearing in mind that re-coding could be an infinite process and knowing when to stop re-coding and tinkering is very important. It is time to stop when the thematic map fits the data well and fine-tuning is occurring as opposed to re-coding (Braun and Clarke, 2006).

Phase five, defining and naming themes, is an iterative process whereby the 'essence' of what each theme is about is identified and what aspect of the data each theme captures via a 'define and refine' process. It is important not to attempt to get a theme to do too much, or to be too diverse and complex. This is achieved by going back to the collated data extracts for each theme and organising them into a coherent and internally consistent account, with an accompanying narrative. Themes should not overlap, and sometimes sub-themes are required in order to structure large, complex themes and to demonstrate the hierarchy of meaning within the data. The final theme names need to be "concise, punchy, and immediately give the reader a sense of what the theme is about" (Braun and Clarke, 2006, p. 93).

Phase six, producing the report, requires a fully worked out set of themes and involves a final analysis and the actual writing of a report. The purpose of the report is to tell the story of the data in a way which convinces the reader of the merit and validity of the analysis. According to Braun and Clarke, (2006), the report must provide "a concise, coherent, logical, non-repetitive and interesting account of the story the data tell - within and across themes." (Braun and Clarke, 2006, p. 93). Particularly vivid examples, or data extracts which capture the essence of the theme and point which is being demonstrated, without unnecessary complexity, should be presented in the report and the extract should be easily identifiable as an example of the theme or issue. The report should not just present the data, an analytic narrative which illustrates the story being told, regarding the data, needs to go beyond description of the data, and should make a compelling argument in relation to the research question/s (Braun and Clarke, 2006).

The interview transcripts from the user study were to be the basis of the thematic analysis and it was therefore decided to use a software to code the transcripts as opposed to hand coding them using for example coloured highlighter pens or written notes on colour coded pieces of paper or 'post it' notes which were methods traditionally used in the past when coding transcripts. To this end, NVIVO was chosen as the software of choice as the university had a license for the software.

3.4.2 Coding user responses

NVIVO is a computer program which is used for analysing qualitative and mixed methods data. There are several useful tools and ways that NVIVO can be utilised in the research process. In this research, NVIVO was used for coding the transcriptions of interviews from the user studies. Each code is automatically assigned a colour and the codes are easily viewable when reviewing the transcripts due to the colour strips which are associated with the codes. In Figure 3.2, the 'Attention' code has been selected by clicking it. This has highlighted the text in the transcript which had been coded 'Attention'. On the right of the transcript excerpt, several codes are present, each with their respective colour.

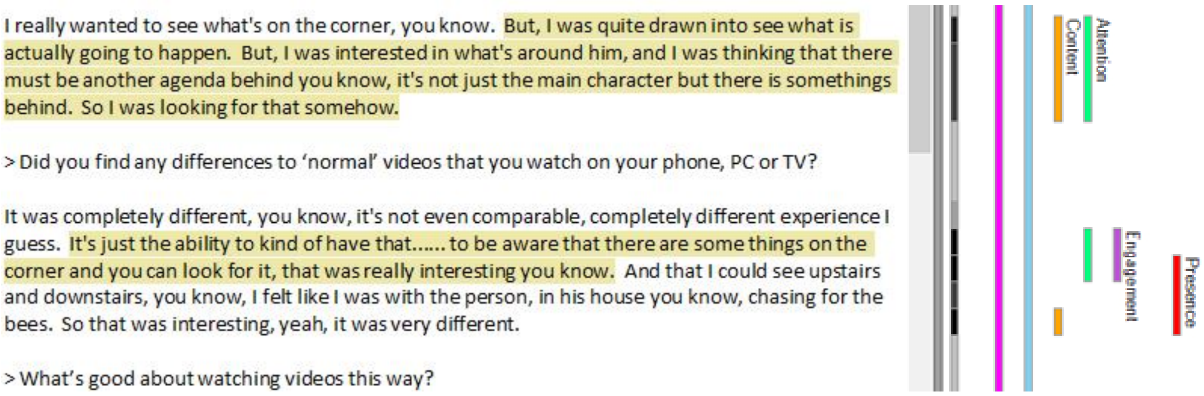


Figure 3.2: The colour strips used for codes in NVIVO.

Another useful NVIVO feature which was used throughout the analysis was the query tool. A query can be created to search for content based on how it is coded, frequently occurring terms, or intersections between two lists of items among other search terms. The content based on how it is coded option was used in the analysis in order to investigate theme frequency in relation to condition. For example, in this study a query configured to search for content based on how it is coded and to search for content coded at all these codes – Headset (VR) First and Presence, returned the following result: 13 references from 4 participants (Figure 3.3). The particular references could then be viewed and further analysed.

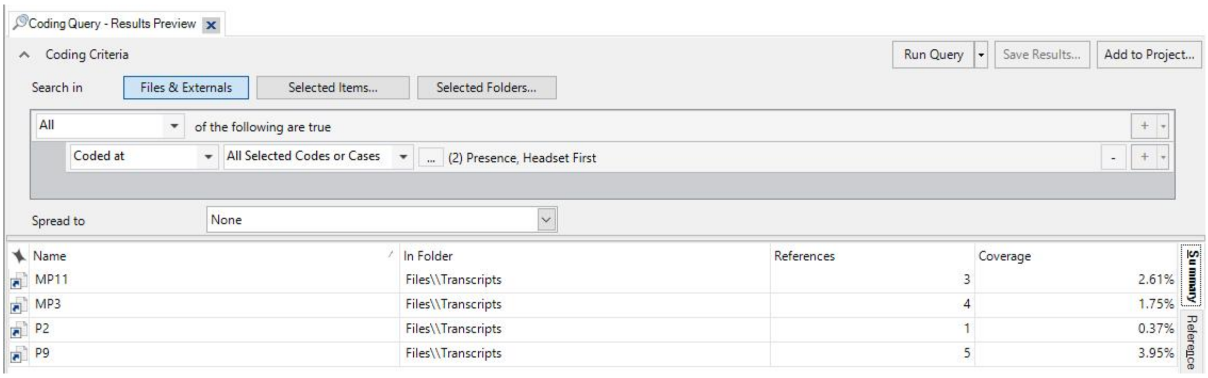


Figure 3.3: The query results in NVIVO.

NVIVO proved to be a very useful piece of software and was convenient to use, as the interview transcripts were typed using a PC. Although investigated, many of the analytical tools present in NVIVO were not employed in this research project as they were unnecessary (QSR International, 2021).

3.4.3 Mind maps

Mind maps are used quite widely in various scenarios and fields such as writing, project organisation, brainstorming ideas, meetings, list making, presentations, general note taking and self-improvement (Wycoff, 1991).

Buzan, (2005) emphasises four important features of mind maps:

- Attention to the subject is provided by a picture at the centre of the mind map.
- Main themes of the subject are formed thanks to the branches related with the picture at the centre.
- Branches state a key picture or keyword on the connected lines.
- Branches have a structure which is related to each other (Buzan, 2005).

Mind maps were a suitable choice for this research as they allowed the collection and organisation of quotes into groups which had a common theme. The quotes were connected via branches and related to the common, central theme. Although an image or images/symbols were not used, the main ethos of the technique was employed throughout the analysis (Erdem, 2017).

3.5 Results and analysis

This section presents the results and analysis of the user study.

3.5.1 Analysis method

Firstly, the analysis of the study began with transcriptions of each interview using the video recording of the semi-structured interviews. Each transcription was then scrutinised and coded using open coding via the NVIVO software. While reading the text, a 'node' (as it is termed in NVIVO) or theme, was created and separate words and/or sentences were assigned to the node. The nodes were created spontaneously according to the judgement of the author and refined and modified during the coding process. Subsequent words or sentences were allocated to the newly formed nodes, with new nodes created as and when the author felt they were required.

At this point, there were 49 nodes/themes, each with a number of words and sentences allocated to them. The themes were reviewed by two of the members of the group and all themes and coding was agreed upon with some minor discrepancies. This process was undertaken to test the reliability of the coding due to it being a subjective process and was carried out solely by the author (Miles and Huberman, 1994). At this point some additional nodes were added in order to assist the determining of which condition was being referred to. The nodes which were added were: headset first, headset second, phone first, phone second, screen first and screen second. This allowed queries such as ‘presence and phone first’ to be run in NVIVO using the query tool.

The initial identified themes were reviewed, in some cases amalgamated, and then clustered into universal themes. These were very broad and contained large numbers of nodes/themes. This process was repeated several times which resulted in various themes being created and tested for suitability of ‘fit’. The process concluded with the choice of the following initial general themes: content, space, attention, interaction, viewpoint, physical, psychological, and miscellaneous. To assist in the process of amalgamating and clustering themes another method was employed, namely mind mapping.

The mind maps were made up of particular quotes and observations/statements inferred from the transcripts which were coded with the specific central theme or themes which belonged to that theme cluster along with a specific viewing condition. Figure 3.4, for example, shows the mind map for Headset and Attention. In some instances, quotes and statements were allocated to branches of the mind map such as ‘positive’ or ‘negative’, ‘ways to navigate’, ‘looking for information’ or other descriptively labelled branches (Figure 3.4). Using the mind map method, quotes were categorised and arranged according to several themes or descriptors.

Figure 3.4: The Headset and Attention mind map.

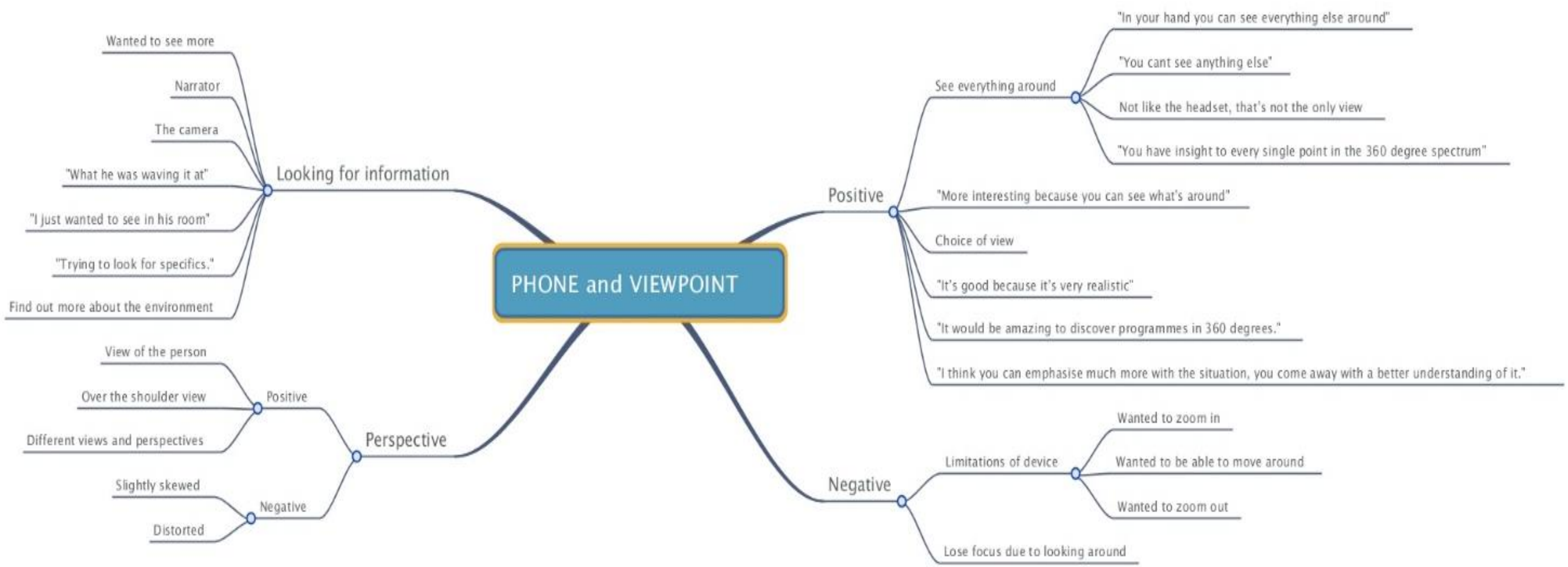


Figure 3.5: The Phone and Viewpoint mind map.

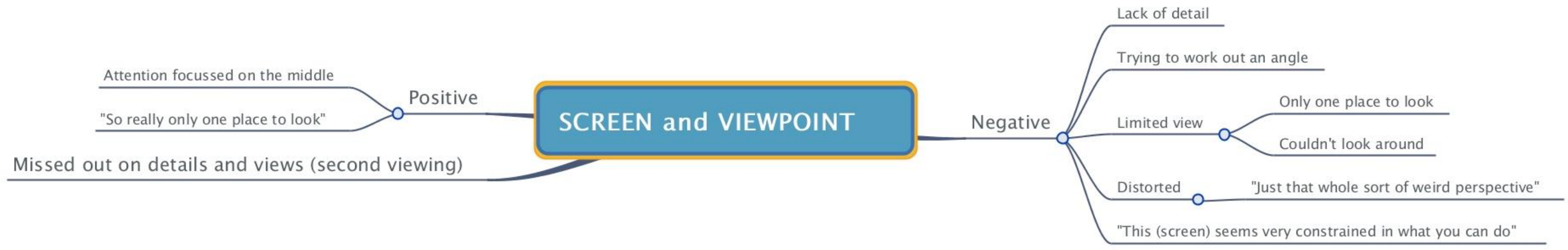


Figure 3.6: The Screen and Viewpoint mind map.

A large number of smaller mind maps were produced for the various theme and condition combinations throughout the iterative refinement process. Along with three 'mega mind maps' which are a series of very large mind maps, one for each viewing condition. Figure 3.5 and Figure 3.6 show some more examples of the various mind maps which were produced.

Following on from the mind mapping stage, an initial thematic map was created based upon the initial general themes (Figure 3.7). The thematic map structuring, from the thematic analysis process, was combined with the mind map ethos in order to create a hybrid diagram of the mind map and thematic map which brought together the main themes derived from the mind mapping process. The quotes were condensed into shorter sentences or descriptive themes. The central themes had been iteratively refined into 4 main themes: Freedom of View, Technical/Device/Physical Limitations and Issues, Presence and Disembodiment and Focus and Attention. The final thematic maps for each viewing condition can be seen in Figure 3.8, Figure 3.9, and Figure 3.10 respectively.

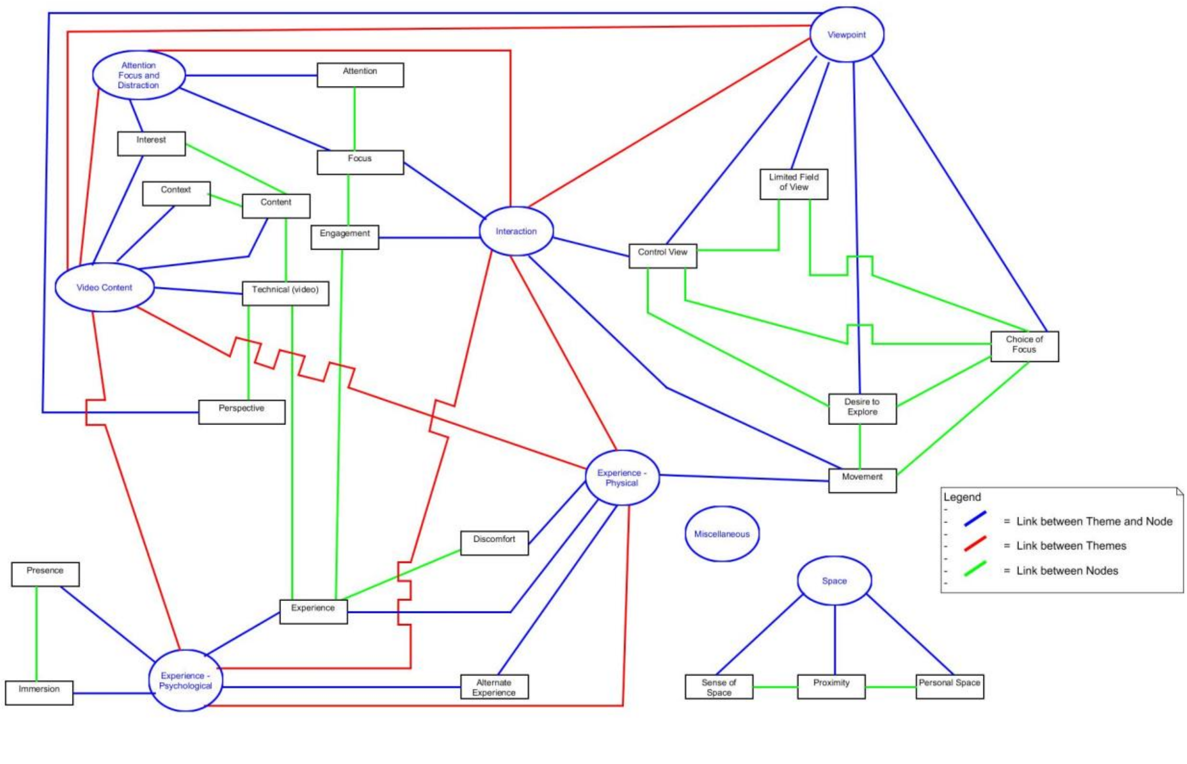


Figure 3.7: An initial thematic map based on the initial general themes.

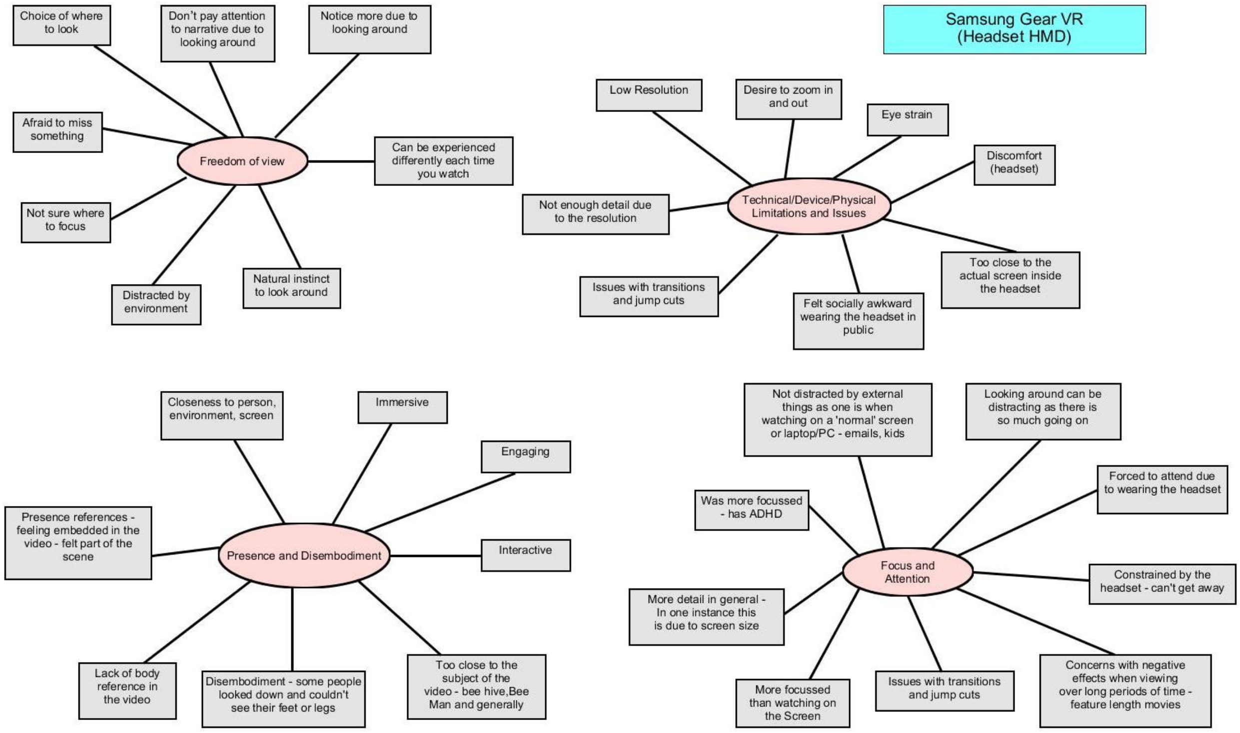


Figure 3.8: The final thematic map for the Headset condition.

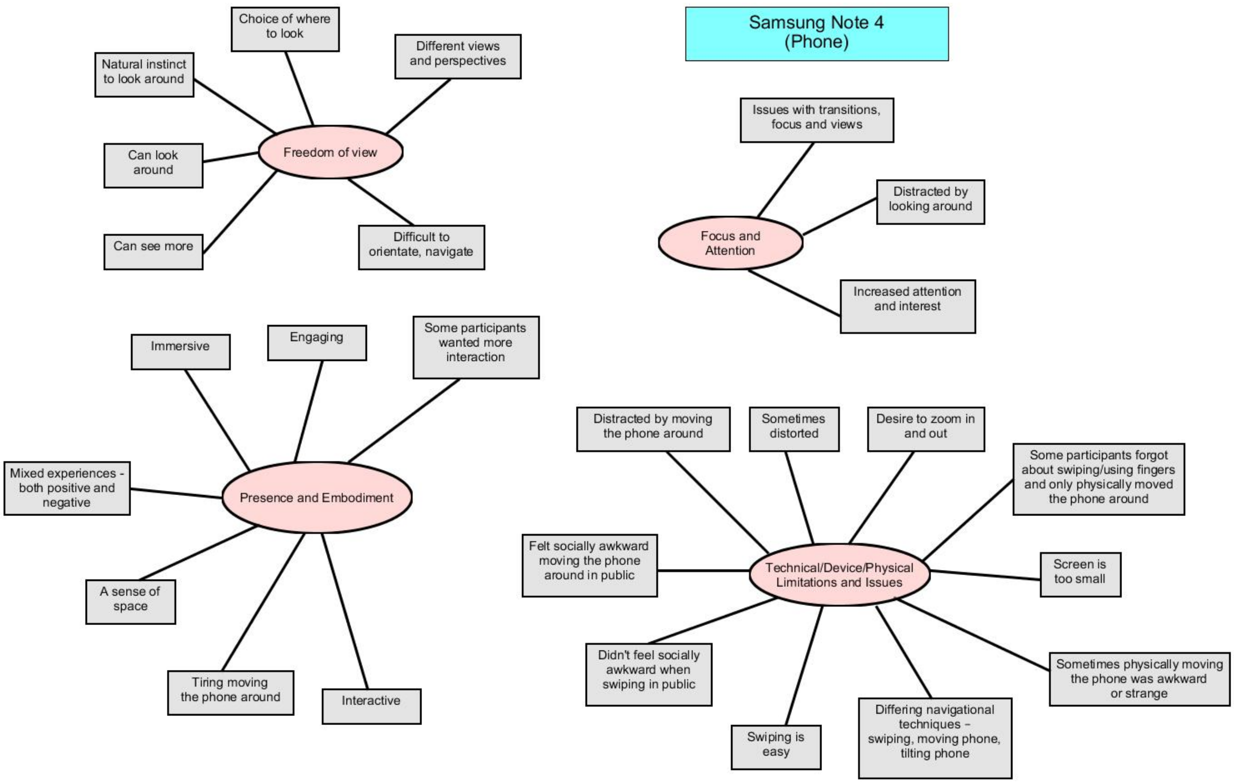


Figure 3.9: The final thematic map for the Phone condition.

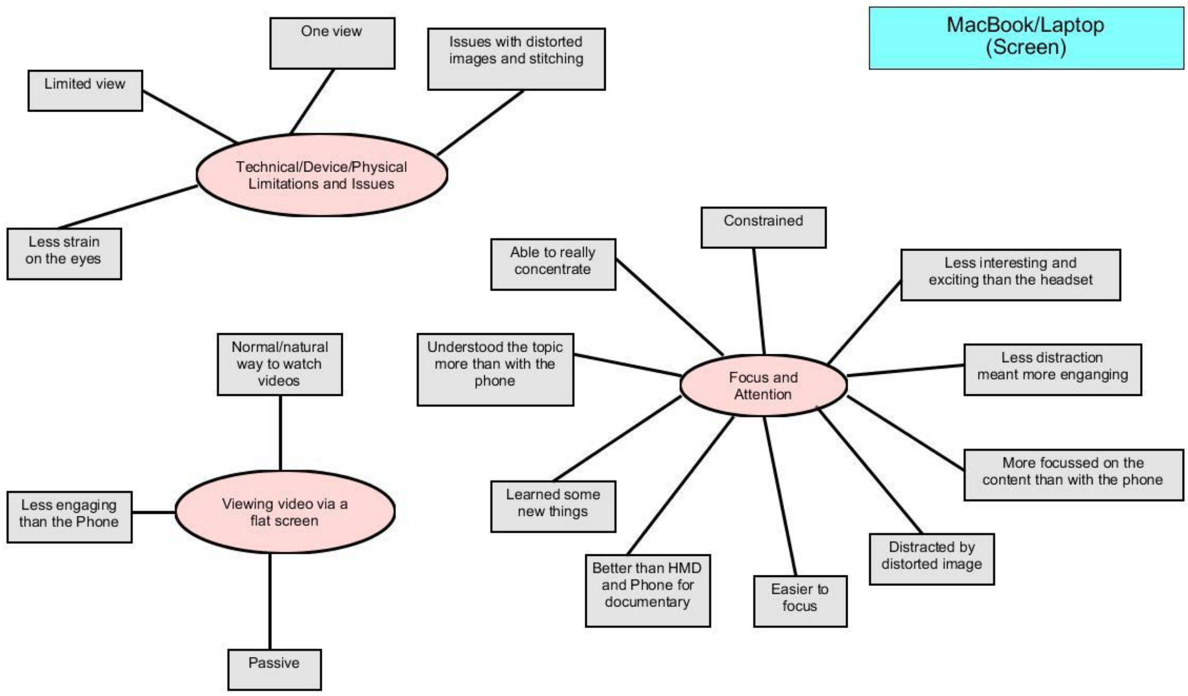


Figure 3.10: The final thematic map for the Screen condition.

The final stage of the thematic analysis consisted of an iterative process by which the mind maps and thematic maps were distilled into a list of themes. The frequency of references to specific themes via NVIVO also contributed to the final list, which was narrowed down, via amalgamation and elimination, to seven themes.

3.5.2 Thematic analysis results

The final seven themes which emerged from the thematic analysis were:

- Presence
- Attention
- Engagement

- Concentration on story
- Certainty (about what should be attended to)
- Comfort
- Social ease

An example of one theme from an early iteration of node to theme allocation (including number of references) can be seen in Figure 3.11 which features the theme, nodes, and number of references of each node.

Theme/node	**No. of References**
Interaction	
Engagement	23
Movement	17
Control View	16
Navigation	14
Immersion	16
Technical (device)	12
Interaction	11
Device Movement	11
Head Movement	5

Figure 3.11: An early example of node allocation to theme with number of references from the thematic analysis.

Following the thematic analysis, the transcripts from the interviews were reviewed again, taking into account the final seven themes. The frequency of typical responses from the participants relating to the themes were recorded for each viewing condition. A value of low, medium, or high was assigned for each condition for each theme and were plotted on the radar diagram in Figure 3.12, creating the Viewer Response Profile.

The participants mentioned attention a lot for each of the devices and they reported that they were unable to concentrate well at times, especially when using the VR headset and phone. They also mentioned that they may be distracted by their environment and were unsure where to be looking or what to attend to. The VRP shows a high frequency of responses related to presence for the VR headset condition, but it is low for the screen condition and middling for the phone condition. Engagement responses from participants were higher for the VR headset compared to the screen and phone conditions. However, although VR headset users may have been more engaged, they reported concentrating less on the story and were much more uncertain in regard to what they should attend to compared to screen users. The differences in terms of concentration on story and uncertainty are possible issues that storytelling needs to resolve in order to be effective in panoramic video.

With respect to physical issues, VR headset users reported issues with the comfort of the actual headset and were much more likely to be socially uneasy, with respect to being in the actual world while viewing, compared to screen users. Phone users fell somewhere between these two profiles.

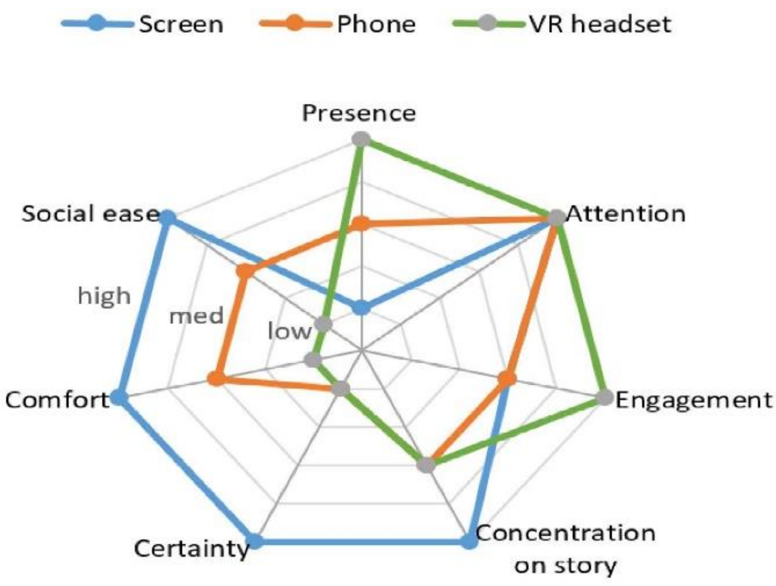


Figure 3.12: The Viewer Response Profile (Passmore et al., 2016).

3.5.3 Questionnaire results

The questionnaire comprised six questions which used a five-point Likert scale ranging from agree 'not at all' to agree 'very much'. The questions were adapted from various other questionnaires to suit the study (e.g., IPQ, GUESS and GEQ mentioned in Chapter 2, section 2.14). The responses to these questions are shown in Figure 3.13 through to Figure 3.18. The results per viewing platform were pooled to yield one graph per viewing platform per figure. At this stage, it was not necessary to carry out a statistical analysis of the results of the questionnaires as the study was an exploratory study which did not have any hypotheses. The questionnaires were of an exploratory nature and were performed with a view of providing information to accompany what had been said by the participants.

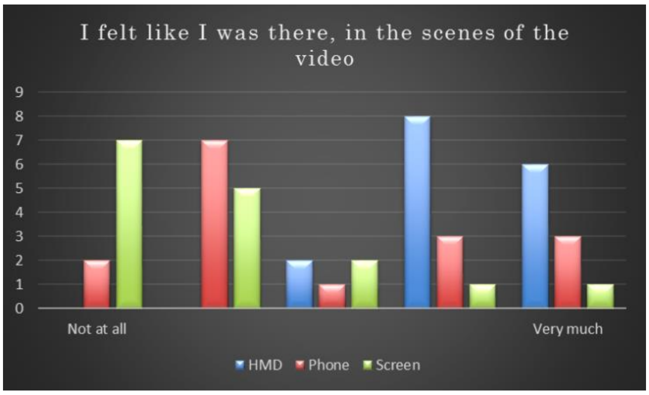


Figure 3.13: Question one response results.

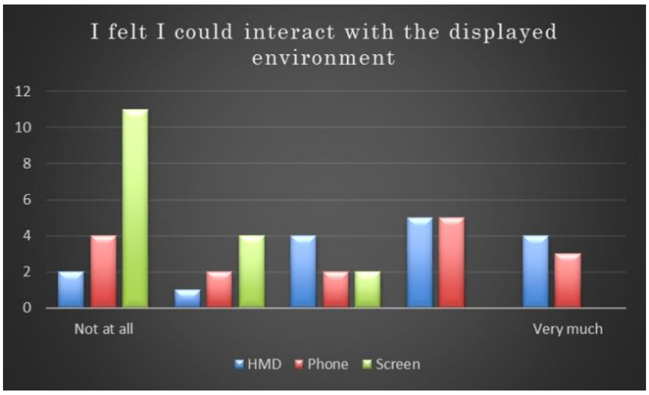


Figure 3.14: Question two response results.

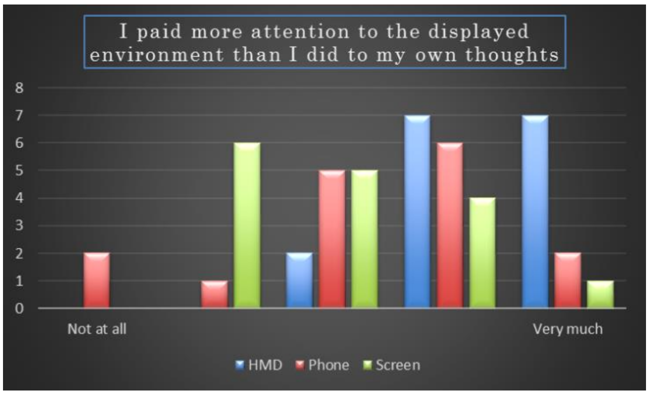


Figure 3.15: Question three response results.

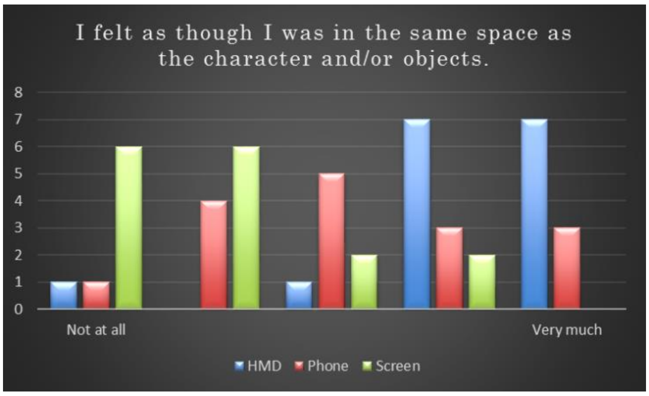


Figure 3.16: Question four response results.

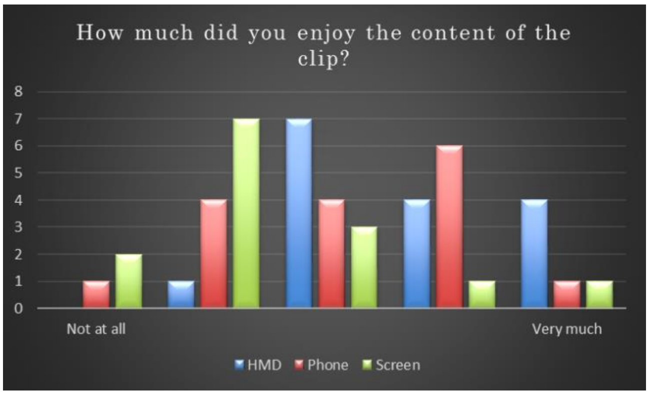


Figure 3.17: Question five response results.

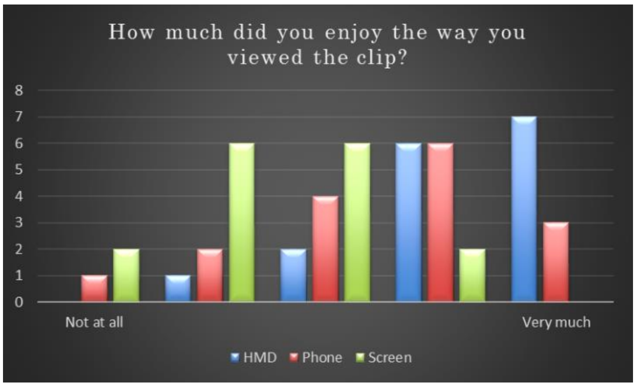


Figure 3.18: Question six response results.

3.6 Discussion

There were several prominent themes which emerged from the interviews and questionnaire results throughout the iterative refinement of the analysis. Some of which evolved into the final list of seven themes. However, there were also some which were amalgamated into one of the seven themes. The most prominent themes are now discussed with some observations, remarks, and reflections, supported by some quotes from the interview transcripts. The quotes are identified with a participant number, condition and condition order e.g. [P1 VR 1st] or [P7 Screen 2nd] or [P11 Phone 1st].

3.6.1 Presence and disembodiment

8 from 16 participants who completed the headset condition alluded to the concept of presence by talking about feeling embedded in the video or being with the Bee man etc. This was quite a strong result that was backed up by the responses to the questionnaire questions related to presence. The interview questions did not specifically mention presence and the questionnaire question related to presence was only asked at the end of both viewing sessions, so as not to lead the participants or mention pre-existing concepts. One viewer said, “I felt I was there with that person...” [P3 VR 1st], and “... gives you ... sense of being a part of it

rather than just watching ...” [P16 VR 2nd]. For the phone condition this was much weaker, only two subjects’ comments were coded under presence. One was very positive: “You feel like you are there.” [P9 Phone 2nd], while the other commented on the lack of presence in comparison to viewing with the headset: “I don’t feel so much in that environment.” [P3 Phone 2nd].

A number of participants specifically talked about the headset experience as either being immersive or more immersive than either the phone or screen conditions, and the phone condition being more immersive than the screen condition. For example, concerning the headset condition: “It was interesting to feel like you were that person changing the music around or actually doing that action ...” [P11 VR 1st] or for the phone condition: “I think it’s a lot more immersive [than the normal way of watching video].” [P10 Phone 1st].

For the headset condition, some participants positively reported feeling close to the Bee man and located in the same environment or scene: “One shot was close to him and it was good to be able to look down to see what he did.” [P15 VR 1st]. The shot being referred to here was of particular interest in this study. In the Bee man’s studio there was a point where the Bee man is sitting at a table and producing music by adjusting potentiometers and the like on electronic circuits that had components and wires exposed. The shot was taken with the camera placed between the Bee man’s face and his hands. This shot was within the zone of intimate or personal space as described by Hall, (1969), which is not normally perceived neutrally and may be threatening (Hall, 1969). However, some viewers particularly liked this view with one viewer saying that she felt like she was actually making the music [P11 VR 1st]. Others reported this closeness as being a negative experience. “The Bee man was kind of odd” [P15 VR 1st], and “I turned around and then suddenly the Bee man just appeared in strange clothing. It felt sinister.” [P15 VR 1st].

Closeness to the screen was uncomfortable for some participants "being up close to a screen, you don't blink as much your eyes don't feel as comfortable afterwards" [P17 VR 2nd], and "it's like something you could get addicted to.. which probably isn't too good for you as your so close to the screen." [P11 VR 1st]. The nearest theme to closeness for the phone condition was discussion of a Sense of Space: "because it's a voice over I think it's much more successful because it gives you that space to kind of explore." [P21 Phone 2nd].

Many participants described the experience as engaging e.g., for the headset condition: "it's around you so you have to focus on it, it's around you so in that sense it's much more engaging" [P17 VR 2nd], and "it just engages you with what you are watching more" [P11 VR 1st], and "I'm more engaged emotionally, so to speak." [P9 VR 2nd]. Similarly for the phone condition: "I think it's a lot more immersive, or interactive, in a sense that it's more engaging." [P10 Phone 1st].

Although the user's agency was limited to being able to choose where to look, some participants commented particularly on the interactive nature of the viewing experience which does indeed distinguish it from a normal screen viewing experience. For the headset condition it was being able to look around by turning the head and for the phone, it was the ability to look around by moving the phone or swiping on the screen. However, regarding the phone condition, previous interaction with phones led to some unfulfilled expectations: "I would like the option to zoom..." [P14 Phone 2nd], and "if I can swipe, can I do this as well? [zoom reverse pinch gesture]." [P12 Phone 1st].

For the headset condition, some participants were upset by the lack of any reference to their own bodies in the video, and some talked specifically about not being able to see their legs when they looked down: "It feels like an out of body experience" [P7 VR 2nd], and "It's weird looking down and you can't see your legs." [P15 VR 1st].

For the phone condition it was also a mixed experience. While there were many positives; some participants found it more immersive than normal, more fun, could see more of what is happening around and: "Thought it really added to the film." [P21 Phone 2nd]. There were also many negatives: the screen was too small, it was tiring moving the phone around, participants could not zoom, and one user reported: "... a weird separation away from the content ..." [P24 Phone 2nd].

3.6.2 Focus and attention

For the headset condition, some participants reported a positive effect as not being distracted by external stimuli as one might normally otherwise be: "the headset really concentrates your mind so you're not distracted by anything else" [P17 VR 2nd], and "if I was at home I'd get distracted by kids etc. but when you're shut away you've got no option it's around you so you have to focus on it." [P17 VR 2nd]. However, others reported that looking around was distracting because there was so much to see: "It can be distracting having 360" [P16 VR 2nd], and "looking around made me take in the information less" [P20 VR 1st], and "Sometimes I felt I had to look around, or you worry that you will miss something if you don't look." [P24 VR 1st].

Some headset viewers complained of being forced to attend with the headset on, that they were constrained by the headset, and they could not get away from the presentation: "so you can't wander off. In that way, you are physically made to pay attention" [P19 VR 1st], and "I tried to get away and then realised I can't because it's still there" [P11 VR 1st], and "you can't get away from it unless you close your eyes." [P23 VR 2nd].

One participant, a sufferer of Attention Deficit Hyperactivity Disorder (ADHD), reported positively that it helped him to concentrate: "Usually people with ADHD, they basically are, they need to work hard to focus on something, but I was basically in the video so there was ... nothing else distracting me around me." [P2 VR 1st].

Others also reported to be more focussed than, for example, the screen condition: "I felt much more focused, all your senses need to be engaged, wearing a headset your work is done it's there" [P17 VR 2nd], and "I think maybe I took more in from what was being said in the headset." [P23 VR 2nd].

Some viewers, although enjoying the experience, were still relieved to take the headset off: "...it's a relief to take it off and look at real things." [P17 VR 2nd]. Another expressed a concern that it may not be good for you to watch over a long time, for example feature length movies. In fact, most current panoramic videos tend to be short, around the ten-minute mark.

These comments about using the headset can be contrasted with those using the phone. Many phone viewers also reported increased attention and interest: "I focused more on how I had the chance to check around the video and move and yeah, so that's what really got my attention" [P4 Phone 1st], and "I think it's much more successful because it gives you that space to kind of explore. I think it really works with the focus; I was definitely focused more on this." [P21 Phone 2nd].

They also quite commonly reported being distracted by being able to look around in the video and distracted also by moving the phone around: "I was more focused on what I was seeing but less focused on what he was saying" [P4 Phone 1st], and "I can, in some ways lose focus because I'm just looking at something completely different." [P6 Phone 2nd].

Both headset and phone viewers sometimes complained about transitions and jump cuts used in the video. For example, as with regular video, a jump cut that occurs where the user is focussed on a subject but there is continuity with the position and pose of the subject in the new scene, can be acceptable without discomfort. However, when this is done in 360° video and the viewer is not looking at the subject, this can be jarring; if the user feels they are immersed in the scene, it can be the equivalent of instantly teleporting them to a new place without warning. Phone users complained, for example: "it was quite jarring to land in another shot" [P23 Phone 1st], and "it is very disorientating when the camera changes angle or even changes the scene." [P12 Phone 1st].

Headset viewers sometimes reported seeing more detail than, for example, the phone condition where some complained of the screen being too small. In the screen condition, by contrast, there were no issues reported with attention and focus. Instead, participants report being able to really concentrate, finding it easier to focus, and being more focussed than, for example when using the phone: "I felt more focused on the actual content this time" [P13 Screen 2nd], and "I was able to focus more on what he was saying and the topic in general" [P4 Screen 2nd], and "I was able to concentrate more." [P20 Screen 2nd].

Screen users reported learning new things, that they understood the topic more than for example, using the phone, and that the format was better than the headset or phone for documentaries; also that not having the distraction of being able to look around they became more engaged: "I thought this way was better if I was supposed to be focussing" [P4 Screen 2nd], and "It's still engaging and for specific types of videos, it's my preferred way of viewing them" [P12 Screen 2nd], and "if I'm just watching this kind of format (screen) just um for, I don't know, a TV drama or something like that, or an informative piece, then this is probably the format I would want to select." [P7 Screen 1st].

On the downside, screen users found the condition less interesting and exciting than the headset and they found that the view was constrained (which in fact it was compared to the other two conditions): "I prefer the other version (headset). It's definitely a less exciting experience" [P19 Screen 2nd], and "I felt less stimulated by the screen version" [P20 Screen 2nd], and "I didn't feel as engaged in the video as much as I did with the 3D [360] viewing." [P12 Screen 2nd].

Screen users also complained about distortion in the image, which was a fair complaint as what they were seeing was a portion of the equirectangular view. This view (being the central twenty five percent of the image) was chosen specifically as being the area showing least distortion, although distortion was still present. However, as can be seen above this did not stop viewers being able to concentrate on and follow the video.

3.6.3 Freedom of view

For both the phone and headset conditions, participants commented positively that they allowed the natural instinct to be able to look around. For the headset view particularly, the freedom to look around was both liberating and unsettling. Participants reported being distracted by the environment: "if you spend the time looking at the guy over there, you're missing out what's happening at the back" [P10 VR 2nd], and "At times my concentration was directly with it but then I'd find myself just looking around at other things too." [P11 VR 1st].

Participants also reported they were afraid they might miss something by looking in the wrong place, and that they were not sure where to focus: "I was like, should I look at his face or should I look at what he is doing with his hands?" [P2 VR 1st], and "so I was confused; shall I look at that guy or shall I look at the other person." [P2 VR 1st].

In fact, one editorial device that works fine in regular video, but does not necessarily work with 360° video, is that of the voice over. When watching a normal video, if a voice over follows a piece with a character or presenter talking, it is immediately obvious to the viewer that it is a voice over because they cannot see a presenter. However, in panoramic video, this does not work as well because the viewer needs to look around to see if there is a presenter or not and is generally uncertain whether one is present: “it was quite hard to tell who was actually talking so whether he was actually talking on camera or whether it was a voice over.” [P23 Phone 1st]. Headset viewers specifically reported not paying attention to the narrative because of looking around: “I’d find myself just looking around at other things” [P11 VR 1st], and “So keen to explore so you don’t pay attention to what he said.” [P16 VR 2nd].

On the positive side, headset viewers reported being able to notice more looking around, and that videos have more repeat value in that they can be experienced differently each time, depending on where you look: “So, the next time you look at it, if you change your point of view or you change your focus, you’d also experience it in a different way as well” [P10 VR 2nd], and “you just notice, there’s more things that you notice on the rift [Gear VR] than you do on the flat screen” [P7 VR 2nd], and “What I really like about is that you can always experience that same video in a different way.” [P10 VR 2nd].

For the phone condition, participants commented favourably on being able to get different views and perspectives, that they had the choice of where to look, and consequently, they could see more: “it gives you freedom to choose where to look” [P4 Phone 1st], and “I get a sense of the environment.” [P3 Phone 2nd]. However, phone viewers found it both difficult to orientate the phone at times and expressed difficulty in navigation. There were times when some participants appeared to get lost and lose orientation when navigating by swiping on the phone: “it was hard because you had no orientation in space 'cause you had no idea where you are in the space." [P23 Phone 1st].

For screen viewers, there was no freedom of view as they were given only one view. This was seen as positive in the sense that it was the normal way to watch video, however, screen viewers reported it to be less engaging than, for example, the headset: "it's just normal, the way we watch it" [P5 Screen 1st], and "A bit bored" [P17 Screen 1st], and "You were more engaged when you had the headset on" [P1 Screen 2nd], and "I wasn't looking at the video and listening to the narrator as engaged as I was before." [P12 Screen 2nd].

3.6.4. Limitations and issues

In general, participants were quite positive about viewing with a headset, but when asked, could point out many technical issues with both the headset and phone. Participants reported the headset to be, at times, low resolution and not showing enough detail: "The resolution was a bit low, it was quite annoying for me" [P2 VR 1st], and "I missed some of the fine detail you get on a high def-TV picture." [P20 VR 1st].

Some participants found that the screen in the headset was too close. Others reported eye strain from using the device. Some found actually wearing the headset to be uncomfortable: "being up close to a screen and you have that feeling you don't blink as much; your eyes don't feel as comfortable afterwards" [P17 VR 2nd], and "it's not particularly comfortable to wear." [P17 VR 2nd].

Some participants wanted to be able to interact more. In particular, given the low resolution compared to normal video, participants wanted the ability to zoom in and out. A further issue was that some participants felt socially awkward wearing a headset in the presence of other people: “I would like to be able to zoom in” [P18 VR 2^{nd}], and “I would find it quite weird to sit with a group of people with a headset strapped to my face.” [P10 VR 2^{nd}].

In contrast, phone viewers did not feel socially awkward when viewing videos and navigating by swiping, however, they did feel socially awkward when navigating the video by moving the phone around. Having different navigation techniques, rotating the phone around the viewer, tilting the phone to change view and navigation by swiping, were viewed positively. Some participants said navigation by swiping was easy, but others were confused by the navigation and forgot about swiping and only navigated by moving the phone around. Sometimes, physically moving the phone was awkward to do: “I would feel self-conscious doing that if I was in a public space [moving phone], you can do that anywhere without being self-conscious [swiping]” [P21 Phone 2^{nd}], and “It feels strange to move around. I wouldn’t do it on a train.” [P18 Phone 1^{st}], and “From the start I tried to move it about, but I found it easier after a while, just swiping through.” [P13 Phone 1^{st}].

Otherwise, phone users complained that the view sometimes appeared distorted, and that the screen size was too small: “There’s still a bit of weird distortion going on when things come close to the camera” [P21 Phone 2^{nd}], and “if you slightly shift it to the right or left or you tilt it you can get perspective of that person, it can distort the perspective as well” [P10 Phone 1^{st}], and “it’s a small screen so you have to, you can focus on only a small part of that spectrum.” [P8 Phone 2^{nd}].

Screen viewers had much less to say about limitations, presumably because they are used to using them in normal viewing. They found the view more limited than the headset and phone conditions; in fact, it was reduced to the central twenty five percent of the equirectangular view. They also commented on issues with the distorted view and stitching. Indeed, there was some distortion introduced by the view, but as only the centre of the equirectangular view was used, this was minimised. The creation of the 360° video involved shooting with six cameras and using software to stitch the videos together into one panorama and to correct errors arising from parallax. Some errors remained in the video, which were quite hard to spot for the headset and phone conditions but were painfully obvious for the screen condition. So, this was fair comment: "This [screen] seems very constrained in what you can do." [P20 Screen 2nd], and "you could see distortion in a few parts of the video" [P7 Screen 1st], and "when he moves from the side view to the central part of the screen, it distorts the objects" [P8 Screen 1st], and "The stitching of the video was a lot more visible this way." [P12 Screen 2nd].

3.7 Conclusion

From this first study, a huge amount of data was generated from the various analysis methods and the results were collected to form the basis of the analysis. The protocol for the study was found to be an effective way to expose the participant to 360° video using various devices. The methods used to analyse the data proved to be effective and yielded very interesting results which provided good information with which to form the foundations of the user study research. The thematic analysis was an in-depth process which provided the opportunity to become very well acquainted with the data and prominent concepts and themes associated with the domain. The seven main concepts and themes which emerged from the thematic analysis formed a good base of information and knowledge which would be put to good use in the next user study.

In terms of the main objective of the research and the thesis, the themes and data gathered from the interviews was a good foundation to build an understanding of the user experience of 360° video upon. The participant's experiences were compiled and presented in the VRP which is a quick, easy to view way to get a feel for the main themes of UX of 360° video. Through the thematic analysis, the participant's interview transcripts provided lots of valuable insight into the UX of 360° video, which would be central to the development of the conceptual framework.

Chapter 4 User study two – The effect of viewing platform on the user experience: CAVE vs HMD

4.1 Research question

The second in the series of user studies, this user study addressed research question two: How does platform affect the user experience of 360° video when viewing a 360° video on a VR headset or in a CAVE?

The study was, again, carried out as a collaborative study with members of the BBC Research and Development (R&D) team. Ethical approval was applied for, and granted, at the BBC organisation by the BBC R&D team as well as from the Middlesex University Computer Science Research Ethics Committee.

4.1.1 Author's contribution

As with Study one (Chapter 3), the author contributed to this study as part of the team. However, this time a leading role was undertaken which placed more responsibility on the author in terms of direction of the research team, task allocation, time management and the write up. The following were contributed to:

- Study protocol design – the order of events was proposed, the interview questions and questionnaire from the first study were used. The protocol was very similar to the first study with allowances made for the change of devices.

- Application for ethical approval and preparation of all study documentation – this process was required by the university before the research could commence. All documentation was prepared and collated by the author before being submitted by the author.
- Recruitment of participants – this was carried out by the author via email and word of mouth on site at Middlesex University.
- Design of the analysis methodology – the analysis methods which were used in the first study were also applied to this study.
- Execution of the analysis – the analysis was carried out in the main by the author, along with some input from and consultation with the other members of the research team.
- Production of results – the results of the analysis were presented in the main by the author, along with some assistance from and consultation with the other members of the research team.
- Write up of the published paper – the write up of the study was a joint effort of the research team. The first two authors of the paper (Philpot and Passmore) wrote the majority of the paper and the research team reviewed what was written and provided some feedback.

4.2 Aim

To acquire and compare information pertaining to user experience of viewing 360° video using two different viewing platforms i.e., devices: a HMD (VR), and a CAVE.

4.3 Protocol

Similar to user study one (Chapter 3), this study used a within group design but was executed at University College London, as the CAVE was located there. The potential participant read the PIS (see Appendix C, C.3), filled in the screening questionnaire and signed the consent forms (see Appendix C, C.1 and C.2). The participant was then assigned a viewing condition combination of HMD first, CAVE second or CAVE first, HMD second. The viewing conditions were arranged in an attempt to avoid ordering effects. A Samsung Galaxy Note 4 was inserted into a Samsung Gear VR for the VR condition. The Note 4 was used in order to avoid differences in responses due to using a potentially improved technology resulting in better screen resolution etc. The CAVE system used was the ReaCToR system at University College London. A swivel chair was used for the HMD condition in order for the participant to easily look around 360 degrees without causing any discomfort. An inflatable white sofa, aligned with the (missing) back wall of the space, see Figure 4.1, was used for the CAVE condition.

Figure 4.1: The inflatable sofa used in the CAVE – inside the bee hive scene.

The video viewed was the same video which was used in user study one (see Chapter 3, section 3.3 for details of the video). For any participant that was unfamiliar with VR and had not used a VR HMD before, a demonstration video about London's Chinatown was shown to participants in order to familiarise them with HMD and 360° video navigation mechanisms such as moving the head to look in different directions etc. This was shown before the feature video, 'The Resistance of Honey', using the HMD. The same demonstration video was shown in the CAVE before the feature video to orient the participants and help them to familiarise with the viewing environment. A pair of on ear headphones were worn by the participants in both viewing conditions, which provided the audio to the video.

Each participant proceeded to watch the feature video using the first viewing condition. Once the video had finished, the participant took part in a semi-structured interview comprising several questions which can be found in Appendix C, C.4. The participant then watched the feature video using the second viewing condition and once completed, the interview was administered and a questionnaire for each of the conditions was administered i.e., two questionnaires. The questionnaire had six questions in the form of a 5-point Likert scale for each condition undertaken. The questions referred to the participant's experience in relation to the device used (see Appendix C, C.5). While partaking in the interviews, each participant was video recorded via a video camera to allow future transcription of the audio. Finally, a debriefing was provided to the participant (see Appendix C, C.6).

There was a total of 16 participants for the study: 12 male and 4 Female. The youngest participant was 19 years old, and the oldest participant was 52 years old. Seven participants viewed the CAVE condition first and nine viewed the HMD condition first. All subjects had tried VR before, but none had previously experienced a CAVE system. The participants were volunteers that were recruited via email to employees of the BBC who were from various backgrounds and disciplines within the company. The participants from Middlesex University consisted of students from the computing area and two members from a university based HCI interest group.

4.4 Results and analysis

This section presents the results and analysis of the user study.

4.4.1 Thematic analysis results

Following the same procedure employed in user study one (Chapter 3, section 3.3), the interviews were transcribed from the audio and a thematic analysis was performed using the Braun and Clarke method (Braun and Clarke, 2006). The transcripts were coded using an open coding procedure, during which the coding scheme was inductively defined and refined as the coding proceeded, very much in the spirit of Grounded Theory's constant comparative method (Glaser, 1965; Holton, 2007).

A starting point for the thematic analysis was the seven codes from study one. These codes are referred to as the Established Themes from this point forward. Items of the interview data were considered in turn, and compared to the emerging coding scheme, to find existing codes that apply, to refine the definition of previously generated codes, or to produce new codes as appropriate. Thus, while reading the transcriptions, nodes or themes were created as necessary and sentences were assigned to them. The nodes were created according to the judgement of the author and refined and modified during the coding process. Subsequent words or sentences were allocated to the newly formed nodes, with new nodes created as and when the author felt they were needed. Five of the sixteen transcripts were also coded by a second author, and discrepancies between the two sets of nodes were resolved through discussion. The analysis resulted in the addition of a further seven new codes under the title 'Discriminating Themes'.

Established Themes: Presence, Certainty (about what should be attended to), Comfort, Attention, Concentration on story, Engagement, and Social ease.

Discriminating Themes: The size of images, Embodiment, Peripheral Vision, Projection of image on self, Physical surfaces particularly the floor, Cube effects, and Confined or Trapped.

4.4.2 Questionnaire results

The questionnaire used was the same as was used in study one (see Appendix C, C.5). The analysis went a step further than user study one and a statistical test was used, namely the Related Samples Wilcoxon Signed Rank Test. The Wilcoxon Signed Rank Test is the non-parametric version of the paired samples t-test and was chosen to analyse the results of the responses from 16 participants to the six statements. It is used to test whether there is a significant difference between two population means when the distribution of the differences between the two samples cannot be assumed to be normal. A parametric test was not used as there were no assumptions or hypotheses made beforehand and there were no assumptions of normality or equal variance in the distributions. Following the tests, a histogram was produced on the data for each viewing condition and each statement to test for normal distribution; 5 of the 12 had normal distribution. The results of the tests are summarised in Table 4.1.

A Wilcoxon Signed Rank Test was performed to determine if there was a statistically significant difference in the means of the responses from participants when viewing The Resistance of Honey using a HMD and in a CAVE. The test revealed that there was a statistically significant difference in means between the two groups for statement S1 ($z = -2.001$, $p = 0.044$). These results indicate that the viewing condition used had a significant effect on the extent to which the participant felt like they were there, in the scenes of the video. This was the only significant difference in means between the two viewing conditions - S1 in Table 4.1.

HMD viewers rated higher agreement with this statement than CAVE viewers, which suggested that the sense of presence was higher for the HMD condition. This may be due to the fact that in the CAVE condition the video was not completely 360 degrees around the viewer and the anomalies affecting the illusion may have played a key role (shown in Figure 4.1).

	CAVE	HMD	CAVE	HMD		
Statement	Median	Median	Mean	Mean	P-value	Z-value
S1 I felt like I was there, in the scenes of the video	3	4	3.25	3.94	0.044	-2.001
S2 I felt I could interact with the displayed environment	2	2.5	2.31	2.56	0.43	-0.788
S3 I paid more attention to the displayed environment than I did to my own thoughts (e.g., personal preoccupations, daydreams etc.)	3	4	3.31	3.88	0.169	-1.375
S4 I felt as though I was in the same space as the character and/or objects	3	4	3.25	3.81	0.147	-1.452
S5 How much did you enjoy the content of the clip?	4	4	3.69	3.63	0.705	-0.378
S6 How much did you enjoy the way you viewed the clip?	4	4	4.06	3.88	0.417	-0.812

Table 4.1: The results of the questionnaire responses.

The test revealed that there was not a statistically significant difference in means between the two groups for statement S2 ($z = -0.788$, $p = 0.43$). These results indicate that the viewing condition used did not have a significant effect on the extent to which the participant felt that they could interact with the displayed environment. Interaction was limited to changing viewpoint; therefore, it is not surprising that both conditions scored low here.

The test revealed that there was not a statistically significant difference in means between the two groups for statement S3 ($z = -1.375$, $p = 0.169$). These results indicate that the viewing condition used did not have a significant effect on the extent to which the participant paid attention to the displayed environment more than they did to their own thoughts. S3 queried how much viewers paid attention to the display. This was a little higher for the HMD than for the CAVE condition but not a significant difference.

The test revealed that there was not a statistically significant difference in means between the two groups for statement S4 ($z = -1.452$, $p = 0.147$). These results indicate that the viewing condition used did not have a significant effect on the extent to which the participant felt as though they were in the same space as the character and/or objects. S4 was also related to presence, and while the P value was lower than for the other statements apart from S1, it was not significant.

The test revealed that there was not a statistically significant difference in means between the two groups for statement S4 ($z = -0.378$, $p = 0.705$). These results indicate that the viewing condition used did not have a significant effect on the extent to which the participant enjoyed the video. S5 asked how much viewers enjoyed the video, and it was generally rated positively in both conditions with means and medians above three and very similar.

The test revealed that there was not a statistically significant difference in means between the two groups for statement S6 ($z = -0.812$, $p = 0.417$). These results indicate that the viewing condition used did not have a significant effect on the extent to which the participant enjoyed the way in which they viewed the video. In order to look at the format of the presentation, S6 asked whether viewers enjoyed the way they had viewed the content, and again, they gave generally positive responses with mean and median values above three for both CAVE and HMD conditions.

4.5 Discussion

To begin with, during the thematic analysis, the Established Themes were used to begin the coding process. In the Established Themes section, themes for which user experience was similar for both viewing conditions, with subtle differences are discussed. In the Discriminating Themes section, the themes that discriminate between the user experience of the two viewing conditions are discussed. The text contains quotes from users and are labelled thus [User ID, the condition they are talking about, H or C - short for HMD or CAVE] e.g., [P99, H].

4.5.1 Established themes

Presence

Both CAVE and HMD viewers referenced presence in various ways. Some were more explicit than others, with some participants suggesting presence through their use of words by describing parts of the video as when they were ‘in’ the beehive, studio, or park.

A number of participants referred to the environment and/or video as being immersive or feeling immersed in the video or environment. It was quite similar for both conditions with neither appearing to be more immersive than the other. Attributes which contributed to the participant's immersion included feeling as though they were a part of the environment: "You are in a more real environment and that made you feel you are actually in there; in the display." [P12, H], and "Definitely, the actual sense of being sat down watching something happening and being sat in that moment." [P11, C]. Many participants' comments referred to being 'in' particular scenes of the video which contributed to their increased sense of immersion and presence.

Some participants felt that the HMD was more immersive than the CAVE: "It's probably more immersive because you're actually sitting within and obviously there's the 360 element." [P6, H], and "Here [CAVE] I had a good overview, but it just wasn't as immersive." [P15, C].

Some participants mentioned the height of the camera in specific scenes of the video. When the camera position was high up, some participants mentioned feeling tall while another felt a sense of vertigo, and when the camera position was lower some participants felt small: "You're in the beekeepers hut and you're very tall, and then you're outside and you're at the vent where bees are coming out, and you're really small again." [P8, H].

One particular scene, where the camera is positioned between the Bee Man and a table, and the Bee Man is working with some electronics, provoked many comments, mainly from HMD viewers, both positive and negative: "Then I was thinking, it feels like I'm in his lap or something, that feels weird." [P7, H], and "One really good bit was, it was kind of a first-person perspective where he was fiddling with the controls so I could see his hands and see all the different electronic bits." [P15, H].

Some participants referred to feeling like a 'fly on the wall': "I was just looking, and it felt like I was a fly on the wall up in the ceiling." [P7, H]. Some participants remarked on the size that they felt within the scene also relating that their reduced size made them feel more a part of the scene, for example, feeling small in the scene when viewing in the CAVE: "There's a marked difference in this environment, because you feel like you're shrunk down and you're much more in the scene." [P14, C].

Certainty (about what should be attended to)

Participants in both conditions expressed concerns about whether they were looking in the correct direction or where the focus of the action was and whether they were missing anything by looking somewhere else. CAVE viewers did not express a fear of missing out directly but hinted at the fact that there may be other things to look at while watching one area of the video: "It wasn't like I was focused on one point, I could kind of just glance left and right and still see a bit of what was going on." [P8, C]. Whereas HMD viewers were slightly more specific with mentioning that they could miss information somewhere else; while looking in a particular direction, or when looking around the environment: "I was wondering if anything else is going on at the time, whether I was looking at the right thing." [P11, H].

Many participants sited a scene change as a good time to look around. This was to familiarise themselves with their surroundings and to explore the environment: "I think when the scene changed, I'd look around to get to understand where I am, so to speak." [P13, C]. Once the scene remained the same for a period of time, some participants said that they felt that it was a good time to look around, also when they found themselves not so interested by a particular part of the video: "I think essentially, whenever a shot was kind of in the same place, not moving for 10 or 15 seconds, that's when I start looking around." [P16, C].

Some participants said that while the Bee man was talking, they felt that they could listen and look around at the same time without fear of missing anything: "I was listening to what he was saying, and looking at what he was doing, just looking around the environment as he was talking." [P9, C]. Additionally, the fixed voice to camera affords users to look around confidently.

Comfort

Some CAVE viewers remarked about how relaxing and comfortable it was to view the video in the CAVE. This could be attributed to the fact that they were sitting on a soft sofa (as opposed to a swivel chair in the HMD condition) and they can relate to the situation as the way that they usually watch videos: "[I preferred] The CAVE, because I generally felt more relaxed. I felt more comfortable, it was nice to be surrounded and it was atmospheric. This one [HMD] just felt not as comfortable." [P1, H]. Some participants directly compared the relaxation of the CAVE to the HMD: "Sitting on a sofa without a head thing on is a bit more comfortable." [P13, H], and "Compared to the headset, it was more relaxed because it's not so... There's nothing pressed up against your face." [P14, C].

None of the participants exhibited any signs of cyber sickness, though two participants mentioned that they felt slightly disoriented when removing the HMD. However, they soon adjusted to the actual world, with no lasting implications: "Once I'd taken the headset off, I feel a bit sort of um, my mind feels a little bit kind of lost for a moment, just trying to re-orientate myself as you come out of it." [P8, H].

Some participants found the HMD quite uncomfortable due to its weight pressing on the face, some eye strain due to the closeness of the screen to the eye and feeling slightly claustrophobic: "Comfortable, though the weight of the actual headgear at times felt a bit uncomfortable." [P13, H], and "My eyes were beginning to strain a bit. There was slight discomfort." [P3, H].

Attention

Both CAVE and HMD viewers appeared to be aware that most of the 'action' in the video took place in the forward viewing direction of the camera (in front), as in traditional documentary. This provided a reference point of where to return one's view following looking around or exploring the environment: "Especially in a piece like this where most of the action takes place in front of you, so you know to go back to looking forward." [P14, H], and "The bulk of the activity still happened in front of you." [P13, C]. In the CAVE condition, the use of a fixed seat (as opposed to a swivel chair in the HMD condition) encouraged this, and also discouraged viewers from turning and looking behind them; it was not essential to view behind, considering that the majority of the action was taking place in front of the camera: "When I was in the CAVE, probably because my chair was fixed, I was looking in front of me." [P9, H].

Some participants noticed the absence of the ceiling and the back wall when viewing in the CAVE and others liked the fact that they could look all the way round and up when viewing using the HMD: "Well you missed the ceiling and the back, but they don't matter at all." [P10, C], "I preferred the headset, because I could look all the way around." [P5, H] and "In the CAVE, I knew there wasn't a back wall, so I didn't look right around." [P1, H].

Concentration on Story

Some participants were able to recall specific information about the video at will when speaking about their experience. This occurred both following the first and second viewings regardless of condition: "No I can't remember, but I remember a whole load of stuff about him being allergic to animals and stuff like that." [P15, H], and “The fact the guy made music from bees, and then there were all these alternative ways that he was finding to make the music from the bees, yeah, I found that quite interesting.” [P8, C].

Two participants mentioned that they were sometimes following the visuals as opposed to what the Bee Man was saying: “When I had the headset on, I wasn’t listening as much to what he said because it’s visually more immersive, so you don’t listen, you’re too busy looking round.” [P6, C]. Whereas others were able to concentrate on the narrative as well as look around: “I was listening to what he was saying and looking at what he was doing, just looking around the environment as he was talking.” [P9, C].

Engagement

Twelve of the sixteen participants mentioned that they either had some interest in the video or found elements of the video interesting; if a user has no interest in the subject however, they did not engage with the content of the video: “Nice to be surrounded by things and the story is interesting.” [P1, C], and “You’d never put bees with music making, so that alone is interesting.” [P3, H]. Conversely, some participants were not interested in the video. The video was described in many ways, ranging from unique, quirky and interesting to dark, sinister and weird. This eclectic collection of descriptors contributed to the interest and range of user responses exhibited towards the content of the video: “I thought it was very silence of the lambs stroke Aphex Twin a little bit sinister.” [P6, C], and “I felt that it was a little bit quirky. Towards creepy because they never got their hats off.” [P7, H].

Some participants commented that sound was good to help create atmosphere and also blocked out the surrounding noise allowing enhanced engagement and focus: “And especially with the sound it goes a long way because it tends to block out what you are hearing in the room, you’re in or where you are.” [P14, H]. The video production included a lot of work on the sound to attempt to achieve an enhanced viewer experience.

Social Ease

There was not much said by participants; however, it appears that users would not watch videos with other people while wearing HMDs as they found it quite a solitary, isolated experience: "But all wearing your headsets in the living room in isolation, so it's an immersive experience, but you're quite isolated." [P3, H]. The CAVE was also described as "less for social watching." [P1, C], but two participants believed that one could watch a video in a CAVE with others and have an immersive experience: "And being able to sit with someone else and watch a movie and still have the immersive experience, that would be really cool." [P11, C]. It is not unthinkable that a sofa can be shared and, ultimately, the viewing experience in a CAVE. Participants were specifically asked if they could imagine viewing with other people in the CAVE, surprisingly not many considered that they would.

4.5.2 Discriminating themes

The Size of Images

Some participants liked the apparently larger scale of image in the CAVE (though the image size on the retina should have been the same for both conditions): "I enjoyed the size of it, the ability to be able to look at really small details whilst still, because the main image is so big you can't miss it." [P16, C].

Embodiment

Some participants mentioned that they felt disembodied, more so when using the HMD. The fact that when they looked down and did not see their legs or any kind of body representation was quite strange for some participants: "It's a disembodied experience; I wasn't a person sitting in space, I was an undefined body voyeur." [P4, H], and "When I looked down, I realised I wasn't standing there." [P5, H]. One participant quite liked the experience: "That's what was interesting, I felt disembodied a load of the time. I really liked instances, where, again going back to disembodied, so put in places that weren't to scale with my body." [P4, H].

One participant reported feeling disoriented due to feeling like they were 'Hovering in mid-air': "Initially it was disorientation, when you look down it's like you are hovering in mid-air." [P5, H].

Peripheral Vision

Some CAVE viewers liked the wider field of view and that the image was 'everywhere': "The wider view, so you could see more at the same time from a better perspective." [P12, C], and "What I like, more in theory than in actual, is the idea that nothing ends in my field of vision, which is great." [P4, C].

Some participants really liked seeing things in their peripheral vision: "I like the use of my peripheral vision. The use of my ability to use my peripheral vision." [P9, C], and "You can see, I suppose, the interesting difference in the headset; you seem to be restricted to your line of vision you have to look around to see it, but here you can catch it more easily out of your peripheral vision." [P14, C]. HMD viewers did not mention peripheral vision.

In the CAVE some participants were distracted by things happening in the background, such as a car moving past or other people walking by: "Times he might be talking about stuff that's interesting, but I'd be distracted by a car." [P3, C]. This is related to having a wide field of view as in real life. One does not have to contend with this in usual TV viewing. One participant pointed out that it was more visually stimulating and therefore found that they gave more attention to looking than listening: “When I had the headset on, I wasn’t listening as much to what he said because it’s visually more immersive, so you don’t listen, you’re too busy looking round.” [P6, C]. HMD viewers were distracted by the ability to look around the environment, and while doing so, to not pay attention to what was happening in the video: “Sometimes you were so consumed by the fact you were in this world, and you could look around, that it’s easy to be distracted.” [P3, H]. Some participants mentioned that they were not distracted by external influences due to wearing the HMD: “It’s not like you can be distracted by anything else going on outside of the screen, the screen is all you can see.” [P14, H].

Projection of Image on Self

The projection of the image onto the participant in the CAVE provoked various comments. Some participants found it quite pleasant and interesting; one participant did not like it. Some participants found that it increased the immersion, made them feel physically involved and added to the experience: “What really did it was the projection on the floor and on you as well, it was noticeable and interesting.” [P3, C].

The projection of the image upon the participant raised some interest with one or two participants commenting to this effect. It did not increase engagement, but did add ‘something’ to the experience, one participant commenting that: “You notice it’s on your legs therefore you sort of, there’s an element of feeling physically involved.” [P6, C]. One participant particularly did not like being projected upon stating: “And I didn’t feel like I liked it projected upon me, like the flowers or the beehive upon me, it was like, ‘eh?’.” [P7, C].

Physical Surfaces Particularly the Floor

Some participants noticed that the image on the floor made a difference to their viewing experience and liked it; in one part of the video the electronics were projected onto the floor, and they looked down to see that: "Oh yeah yeah the floor especially that bit with the table when he was doing the, building some electronics stuff. So yeah, that was based on the bottom, so definitely, I looked at the bottom part." [P12, C]. However, one participant found it strange that they had to look down to the floor to see what was happening and one participant did not like the image projected onto the floor: "No, I think it was a little strange, for instance, looking down to the floor to see, to focus on the activity when he was pulling out the honeycomb." [P13, C]. The user observations could be attributed to the novelty of the CAVE, as it is something different to the 'normal' way of viewing, on a TV, phone etc.

Cube Effects

Something that CAVE viewers remarked upon was the visibility of the angles in the room where each wall met each other and the floor, at 90-degree angles: "Things that let it down were you could see the joins between the wall and the floor, and that made it slightly less than the headset." [P5, C], and "With the CAVE, you've got these clear lines between it, which kind of throw you off a little bit with it." [P8, C].

The video had scenes inside a shed, and other rooms, and some participants felt that the fact that these scenes did not map to the walls and floor in the room via the projection was problematic: "So the nature of the environment means for example the walls of the beehive didn't look straight because of where it was dissected by the lines of the room." [P13, C], and "Sometimes the wall was on the floor." [P9, C]. Some participants suggested a solution could be to project onto a dome or curved walls: "I guess if it was a dome, it would be fantastic." [P7, C].

Confined or Trapped

One participant found that being cut off from the actual world when viewing the video using the HMD was a good thing: "Specifically 360 video, you are so much more part of the experience because you, there's no getting away from it the same way." [P14, H]. Whereas others found it unpleasant and in one instance claustrophobic: "It's a bit claustrophobic at times compared to a normal usual screen." [P16, H], and "And the beehive, it was so close that I wanted to get some distance." [P7, H]. One participant liked the fact that the HMD does not have any 'sides' like a TV screen: "Just the fact that you can explore the environment more instead of being confined to the sides of a screen." [P10, H].

4.5.3 Viewing condition preference

Participants were asked which condition (CAVE (C) or HMD (H)) they preferred and why, at the end of their second viewing. Seven participants preferred the HMD and seven participants preferred the CAVE; two participants could not decide and have been assigned the preference of 'BOTH'. In the following section participants are denoted by their participant number with their preference following in parentheses.

Although participants P5(H), P6(H) and P13(H) preferred viewing the video using the HMD, they all remarked that the CAVE was more comfortable. They found the HMD uncomfortable, simply due to the fact that they were wearing it, and in the CAVE they were not: "The CAVE experience was more comfortable, because I didn't have this thing on my head." [P5], "But the headset's quite uncomfortable, so this [CAVE] is comfier." [P6], and "sitting on a sofa without a head thing on is a bit more comfortable." [P13].

Participants P1(C), P3(C) and P6(H) specifically mentioned the discomfort of the HMD: “This one (H) just felt not as comfortable.” [P1], “It’s more immersive, you felt you were there. But with that comes discomfort.” [P3], and “But the headset’s quite uncomfortable.” [P6]. Also, pertaining to discomfort when using the HMD, two participants, P3(C) and P16(C), both mentioned the feeling of claustrophobia when viewing using the HMD: “It’s less claustrophobic in the CAVE.” [P3], and “The full immersion of the headset I found actually quite overbearing and claustrophobic.” [P16].

As well as the comfort and discomfort of the two conditions, three participants, P1(C), P8(C) and P16(C) felt relaxed in the CAVE setting. This was not attributed to anything in particular; however, the inflatable sofa could have been an influential factor: “The CAVE because I generally felt more relaxed.” [P1], “I was more relaxed in it. I felt I could just chill out and I didn’t have this thing stuck to my face and that was more relaxing.” [P8].

Presence and Immersion was quite prominent in the reasons for some participants’ preference. Participants P2(C), P3(C), P5(H), P6(H), P10(C), P12(H), P14(BOTH) and P15(H) all either specifically mentioned, or alluded to, presence and/or immersion as a key factor in their preference of condition: “Gives a greater sense that you are there.” [P2], “The headset felt far more as if you were ‘in’, it’s more immersive, you felt you were there.” [P3], “The headset, just because it’s more immersive, more interesting.” [P6], “Again it feels a lot more immersive.” [P10], “You are in a more real environment and that made you feel you are actually in there; in the display.” [P12], “I certainly felt more immersed in the headset.” [P14], and “It’s an immersive experience.” [P15]. Clearly, both conditions provide presence and immersion to the user which ultimately contribute to a pleasurable experience.

There were two participants P11(BOTH) and P14(BOTH), who could not decide which they preferred, citing the dependency on what type of content they viewed in each condition as the crux of their indecision: "For this particular bit of content the headset. But I would say, with different content, like a movie, probably this [CAVE]." [P11], and "Depends on content." [P14].

Overall, the fact that the participants were split equally in their preference of condition, in this instance, did not highlight whether one is preferred over the other. Although just two participants mentioned content when speaking about their preference, it is likely to be quite influential in a viewer's experience when watching panoramic video using various conditions. The comfort and relaxation associated with the CAVE contributed to participants' preference but was not a distinguishing factor. The outstanding attribute relating to preference of condition in this study appears to have been whether the viewer experiences presence and immersion when watching panoramic video in a CAVE or when using a HMD.

4.5.4 Drawing comparisons

Clearly, a comparison of CAVE and HMD is only relevant for content that may be shown in a CAVE missing the ceiling and back wall. However, casual sampling of 360° content shows that many videos do not fully use 360 degrees most of the time. Furthermore, it is a consideration that making people look around a lot could be tiring. Given the position of the sofa, and the fact that the CAVE system had no projection on the ceiling or back wall, viewers could view the remaining walls and floor by looking around, without the need to rotate the seating. However, the restriction in the freedom to move around and to sit comfortably possibly caused biases which are not part of the systems compared.

That presence is an overriding feature of panoramic video is evident in participant discussion around that concept, and it is also largely supported by responses to the questionnaire. It is interesting that subjects tended to cite presence and immersive factors as reasons for their preference of viewing condition, regardless of which it was.

There are some obvious differences between the two viewing conditions, such as in peripheral vision and sense of embodiment. Thus, it was not surprising when these terms came up during the interviews, and that they eventually emerged as themes. However, even though obvious differences came up, it was still difficult to predict which of the two viewing conditions the participants would prefer.

The Discriminating Themes found in this study have identified issues which could be addressed to improve the user experience of watching monoscopic panoramic video within a CAVE-like environment. Careful consideration should be paid to the video environment mapping to the physical space i.e., the walls of the CAVE, and care in technical post-production i.e., stitching.

There were some references to both embodiment and disembodiment when viewing the video in both conditions. The fact that the viewer has no reference to themselves within the video environment, when watching using the HMD, was pleasant to some participants and off-putting to others. In respect to viewing panoramic videos using the HMD, there may be advantages to representing the viewer as part of the video in order to ease the negative sense of disembodiment. A range of differences between viewing conditions are thus evident in the reports of participants. The following section presents a framework that aims to make sense of the differences, organising themes into clusters, based on how they appear to influence the users' experience of panoramic video.

4.5.5 Towards a framework

The thematic analysis research method adopted here, through the careful examination and coding of interview data, sought to arrive at an understanding of the key concepts at work when people draw comparisons between the two viewing platforms. In common with methods like Grounded Theory, the current research aims to make connections between themes produced, looking for common patterns, aiming to identify which, of all the issues raised, are the key ones – analogous to the Grounded Theory notion of a core category or core variable that can help to explain the majority of the variability observed in the data.

Looking at the discussions of themes, the concepts that appear most central are those to do with presence and immersion – the words and the theme crop up in much of what people say (both in the analysis of themes and in the participants explanations of their preference for one system over another). Many of the other themes described above are not explicitly about presence but are still connected in some way (for example, the comments relating to projection of image on self refer to the significance of such projections in helping to create or diminish people's sense of being there, being involved, and so on). Identification of presence as a central theme is supported by the qualitative analysis, in which the Likert item S1, relating to peoples' sense of 'being there' – closely connected to presence, produced a significant difference between viewing platforms.

Having identified the central theme of presence, the relationships between the remaining themes and presence can be considered, producing clusters of themes that stand in a similar relation to the central theme of presence. The emergent framework, illustrated in Figure 4.2, identifies clusters of themes that capture the ways that presence can be influenced, positively or negatively. Three clusters have been identified:

- Anomalies affecting the illusion.
- Affect and feeling.
- Cognitive and perceptual effects.

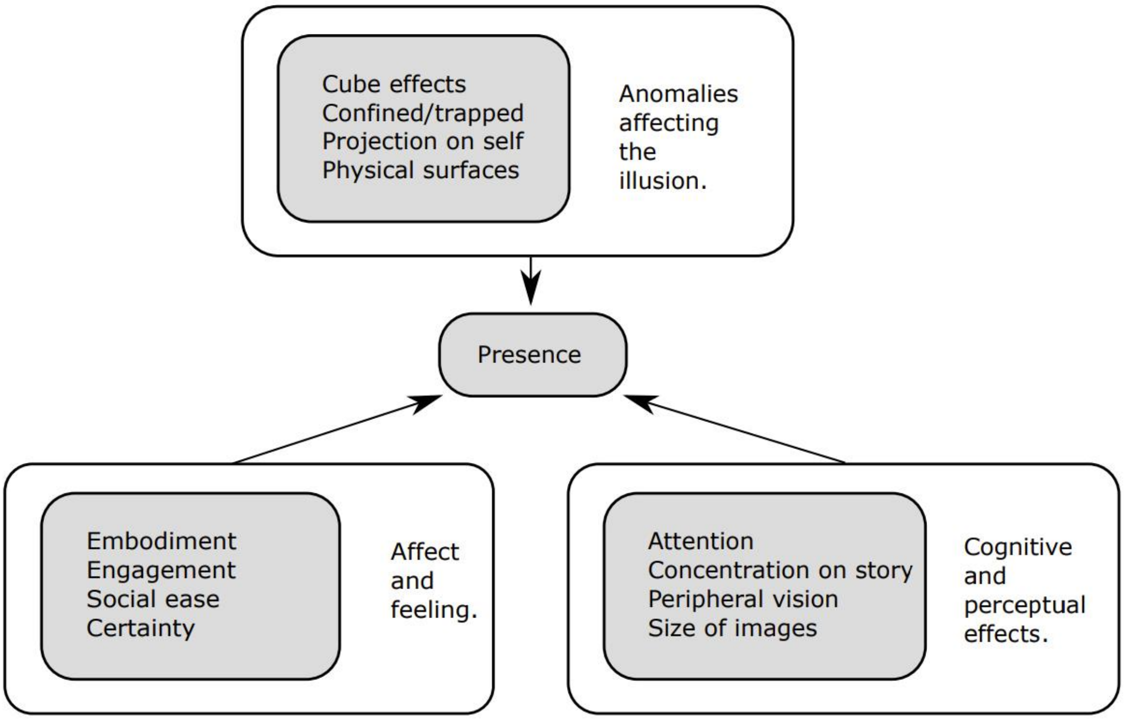


Figure 4.2: A framework for understanding user experience of panoramic video in a HMD and CAVE.

4.6 Conclusion

This study has added to the body of knowledge concerning the user experience of panoramic video by considering the differences between viewing in a HMD and viewing in a CAVE-like environment. A set of themes that were previously applied to comparing HMD and phone and screen viewing were used to compare viewing in the HMD and CAVE conditions. However, consideration of these themes did not discriminate between viewing experiences for these two viewing conditions, and the user responses in relation to these themes was very similar. Consequently, a set of themes which do discriminate between the two was identified and elucidated. Participants were also asked which viewing condition they preferred, and their opinion was split equally between the two options.

Presence is a major feature of 360° video, compared to traditional film, and it appears that the users reported sense of presence was the deciding factor in choosing a preference. The emergent themes that summarise what participants reported when asked to describe various aspects of their experience of panoramic video on the two platforms, have been organised into a framework that puts Presence centre-stage, and aims to identify the clusters of sub-themes that influence the experience of being present in the panoramic video scene.

This study has informed the initial development of a theoretical framework and has provided additional insight into how cinematic conventions are used in the production of panoramic video, and how viewers understand and orient towards directorial elements. The exploration of such elements has provided some understanding of an emerging filmic literacy for this novel medium. The results and findings have also helped to inform 'design advice' or considerations for 360° video content creators and researchers alike.

Chapter 5 360 Cinematic literacy: A case study

5.1 Research question

This case study addressed research question three: What can be inferred about 360° cinematic literacy following user studies one (Chapter 3) and two (Chapter 4)?

The case study was carried out in collaboration with Maxine Glancy, a research scientist for BBC Research and Development.

5.1.1 Author's contribution

The author contributed to this case study as part of the team and was involved from the beginning to end of the case study in the following:

- Analysis of the results of user study one and two (Chapter 3 and Chapter 4) in relation to cinematic literacy – the thematic analysis results, interview transcripts and questionnaire results were all reviewed and analysed by the author.
- Discussion and collation of results – the observations and results of the review were discussed with the members of the research team.

- Content of the published paper – the proposed content of the paper was discussed with the research team.
- Write up of the published paper – reviewed the paper and made suggestions and modifications.

5.2 Aim

This case study aimed to investigate the necessity of a new language for storytelling in 360 degree film making. The issue was investigated from the point of view of the user/viewer and attempted to infer 360 degree literacy from what users/viewers had said about their viewing experiences from the two previously executed user studies; user study one and user study two (Chapter 3 and Chapter 4 respectively).

5.3 Discussion

Making sense of the story while watching a video, film or programme was mentioned earlier in Chapter 2, section 2.13. As this research progressed, it became apparent that film sense making, making sense of the story, was very important when considering watching 360° videos; especially when viewing using a HMD.

People 'make sense' of the situation they are in as a part of the routine activities that they are involved in. Theories of sensemaking can be usefully applied to analysing the understanding of films, as they emphasise the cognitive tasks that the user actively engages in, in order to create meaning (Klein et al., 2007). With traditional viewing (flat screen e.g., TV, cinema etc.) the user is fairly limited in what they can do to actively seek information in order to aid sensemaking e.g., generating and testing hypotheses, and guiding their attention to look for cues in the frame. However, in 360° video, this capacity is altered and enhanced by the ability to look around freely in 360 degrees. This can aid sense making, but can also hinder it and potentially cause the viewer some confusion, a fear of missing out (FOMO) on something important in the video, and a lack of certainty of what they should be attending to i.e., which direction they should be looking in or which part of the scene they should be paying attention to (Passmore et al., 2017).

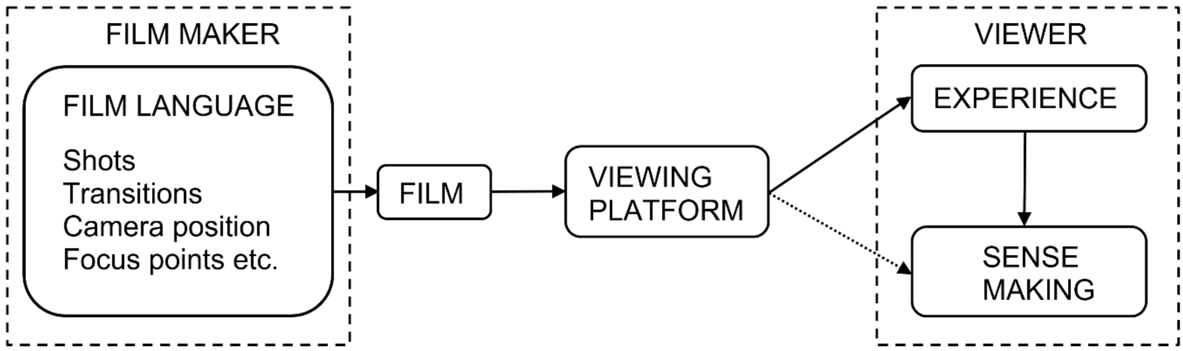


Figure 5.1: A model of film sensemaking (Passmore et al., 2017).

Figure 5.1 shows a simple language-based model of film sensemaking. In order to tell a story and embody that story in a film, the film maker uses the language of film making, which is composed of shots, transitions and sequences etc. The user then views this via a viewing platform, e.g., a TV or VR HMD, and this leads to an experience that needs to be made sense of in order to understand the story. For experienced literate viewers, it may be considered that experiential factors require minimal attention and that viewers more or less directly make sense of the film (hence the dotted line from viewing platform to sensemaking) (Passmore et al., 2017).

Film making and TV production is dominated by continuity (often referred to as 'invisible') editing, which has a set of rules about how shots are composed and edited, the aim of which is to convey narrative by producing an easy to watch, seamless viewing experience. Viewers of such film could give a good account of the story they viewed, without necessarily being able to recount much detail of how shots were composed and edited. Continuity editing aims, by careful composition and editing of a sequence of shots, to direct viewer attention to consistency of story across time and space. Some rules of continuity editing apply to 360° video, such as continuity of sound over shots. However, many others, such as 'shot/reverse shot', do not.

Throughout the video used in the user studies, The Resistance of Honey (details can be found in Chapter 3, section 3.3), several different shots were used via camera placement alone, as opposed to the usual combination of camera placement, zoom and focus. This was due to no available zoom or focus in 360° film making (at the time of shooting the video). This left camera placement as the main method to attempt to get the viewer to attend to the content intended by the director. It was discovered that camera placement played a significant role in determining how a viewer felt in a scene; both the height of the camera and the distance of the camera to the subject (Philpot, 2017). The following details the shots which were used in the video, what was in the shot, and some remarks regarding some effects on the viewer:

- Establishing shot – An establishing wide shot of a location followed by a closer shot of the same location, possibly inside the location, is a standard continuity editing technique at the beginning of a sequence. The video started with an opening wide shot of the Bee man walking to his shed and entering it. This was followed by a closer shot of the Bee man in the shed. This worked well, and viewers appeared to have no issues following it.

- At head height – The general advice was that the camera should be at head height. Viewers either commented positively when this was the case in the video, or they did not comment at all. This suggests that it did not cause them any issues which agreed with advice from guidelines.

- Above head height – These shots were inside the Bee man's shed. The camera was placed above the Bee man's head, approximately a metre away from him. Some viewers complained that the shot was too high, as was predicted by the guidelines, or that they experienced vertigo. This also accentuated the fact that the viewer had no body in the scene. This was due to the viewer looking down to see the action and not seeing a [their] body, which can be disorientating for the viewer. One or two shots were taken in the Bee man's studio from above head height, near to a wall, which showed the Bee man sitting in his studio. Some viewers commented that they felt like 'a fly on the wall'.

- Below head height – One shot of the mouth of the hive outside the shed had the camera situated at approximately 60cm high. Some viewers said that this made them feel small, again as predicted by the guidelines.

- Close-up shots – The Jaunt guidelines recommend not to use close-ups in general in 360° filming, citing the Oculus guidelines that objects should not be closer than 0.75 m (Facebook Technologies, LLC, 2020; Jaunt, 2018). Such advice is likely meant for situations where stereo 360° video is viewed, but it is quite possible to get closer in monoscopic 360° without apparent eye strain.

Several shots were taken in close-up, which was contrary to the guidelines, and were usually 10cm or less from objects in the scene. These shots lead to the greatest number of comments during the interviews. One short sequence simulated the inside of a beehive, with a viewpoint about 10cm away from bees crawling on honeycomb in the full 360° view. Users described this scene in various ways including that it was interesting to get a view from inside a hive and that the view was too close. Some users said it made them feel free to look around because there was no obvious focal point.

The low shot at the hive mouth, (viewing distance about 10cms), some users found interesting because they could get a novel view and be close to bees without being stung.

In one shot, the Bee man was seated at a table in his studio manipulating electronic boards with wires, components, potentiometers etc. attached, and was making music. The camera was placed between his face and hands at about 10cms distance from each. This shot received the most comments from viewers during the interviews. They generally found it interesting to see what the Bee man was doing with his hands. Some viewers described their feelings, some felt small (e.g., two inches high), some felt awkward (as though they were sitting on the table), some felt as though they were in an odd pose ("I'd be sitting in his lap or something"). One viewer said she felt as though she actually was the Bee man manipulating his electronics. There were some similarly close-up shots that were less than 10cms distance of bees on flowers and a couple of viewers mentioned feeling 'bee sized'. It appeared that the sense of presence, and lack of embodiment, made some viewers try to rationalise about their size in the close-up views. This led to a range of different perceptions. The effect was not apparent when viewers watched the video on a flat screen.

- Unexplained shots – In two shots in the video, the Bee man appears briefly with other 'bee men' dressed in beekeeper suits, this was completely unexplained in the story. Some viewers were confused by this and commented on it, saying that it was spooky. Such comments are not limited to 360° video viewing, however.

- Unexplained shot not commented on – One shot showed a sped-up stop frame like animation of five beekeepers moving around in a park. No viewers commented on this incongruous shot at all, perhaps just interpreting it by the music and visuals as a music videoesque transition.

- Transitions – There were three types of transitions used in the video. These were considered when analysing the transcripts in each user study. As predicted by guidelines, fade to black transitions appeared to work well - viewers did not comment on them. Jump cuts were used and they provoked some negative comments from some viewers e.g., they were too jarring. However, many viewers did not comment on the jump cuts, perhaps suggesting that they can be tolerated. One viewer commented that he was confused by a jump cut between two shots that were at different positions outside; at first, he did not realise that the camera position had changed. This suggested that a fade to black transition may be better suited in this situation. One transition between two scenes was based on matching on action. The Bee man was holding up a bee comb with some microphones attached, scanning from right to left, first in a polytunnel, then outside in the garden. This transition worked well only if viewers were focused on the Bee man at the time of the transition.

5.4 Findings

The thematic analysis methodology of Braun and Clarke was again used for the analysis of the transcripts of interviews collected during the first two studies

(Braun and Clarke, 2006). Although the interview questions were not specifically designed to investigate literacy, much could still be concluded from the interview transcripts. In this case study, the interviews were re-analysed with a view to understand how directorial devices affect a user's experience in making sense of and understanding 360° video.

It became apparent that the viewers had applied their existent filmic literacy to understand the video. Their comments indicated that they understood, without question, both temporal and spatial aspects of the film. For example, it was understood that the piece was about one individual, who was the same individual appearing from shot to shot, and that he was the source of the narration. Also, it was implicit in viewers' discussion, and was never questioned, that the shots depicted a sequence over time. Their understanding of the general geography of the scenes was also good. For example, viewers managed to work out that the Bee man was in the same shed that he had been standing outside of earlier in the video. Points where the viewers were confused about what was going on, were the same points at which one would expect them to be confused, if the film were viewed traditionally (e.g., on a flat screen).

The analysis of interviews identified quotes which inferred literacy and resulted in a collection of quotes from each study under the following headings: Shots, Transitions, Narrative and Camera Position. These were scrutinised and attributed codes using pre-existing themes from the first two studies with new sub-themes created if, and when, required. The focus of this case study was language and literacy, therefore the emerging themes largely focussed on the structure of the video. The themes that emerged were in relation to scenes, camera position, cuts, and transitions. Viewer reaction was inferred by the frequency and range of comments they made about individual items and also from their lack of comments on others.

The emerging themes were quite different to what had been discovered from the first two studies. This was largely due to the shift in motivation of the analysis. However, the emergent themes could be linked to the previous prominent themes; in particular presence. The following emergent themes in relation to viewer literacy and viewer experience were identified. Items 1 – 4 relate to the theme ‘Presence’ and items 5 and 6 relate to ‘Looking Around’.

1. Being in unusual places – Many viewers commented positively about being in, rather than seeing, unusual places.
2. Changes in Distance or Scale – Some viewers commented on a change in perceived size within the scene due to camera placement.
3. Differences between third and first person view of the character in-world – Viewers commented on a number of perspectives: like being a guest in the Bee man’s studio; feeling they were seeing the Bee man’s perspective; feeling small, or like a ‘fly on the wall’.
4. Close-ups and Interest – Close-up shots seemed to lead to an increase in viewer interest, but also sometimes changes in perceived size.
5. Following the action, knowing where to look – There were some instances where the viewer was not sure of where they should be looking.
6. Multiple and Single focus points – In some scenes, viewers found that multiple points of focus, or identifying a single one, (e.g., the Bee man) gave them confidence to look around.

Presence, and the ability to look around, both mediated and interfered with viewers’ ability to make sense of the video. For ordinary TV viewing, there is not the same sense of presence because of the way the film is viewed, i.e., a flat screen, and the inability to look all around in the film world. An important consequence of presence is that viewers find it harder to make sense in 360 degrees because of a lack of certainty in what should be attended to and FOMO.

If there is lots to look at, concentration can be divided such that viewing is not just about receiving the narrative but is also about guessing where one's attention should be directed. Viewers may also look around out of curiosity and the need to establish where they are, or could be affected by the context, rather than just focussing on story. The context can help to provide focus, for example in football, the focus is generally just tracking the ball, but in other contexts it is less clear. This can force the viewer to try and decide what should be attended to before they can deal with making sense of the story. Knowing what to attend to thus emerges as a key component of 360° literacy because whereas previously narrative components could be served to order, through framing and zooming etc., now the viewer may have to play the role of the director to some extent, to frame the appropriate shots at the right time for themselves, to get the correct message. As a result, there are two main aspects to viewing in 360 degrees, namely, dealing with the experience and making sense of the story.

Having identified the emergent themes and the main aspects of viewing video in 360 degrees, a model was produced which attempts to detail how experience and Sensemaking play out for 360° video. Figure 5.2 depicts the user experience of watching the 360° video on the left and sensemaking of 360° film literacy on the right. The experience component is largely dominated by presence, while the sensemaking component contains a restricted version of classic literacy (for example some elements such as framing, are not available in 360 degrees), augmented by the new literacy elements, largely relating to looking around. Individual 360° films have experimented with custom cues to sensemaking, and it is expected that some of these may become new literacy conventions over time.

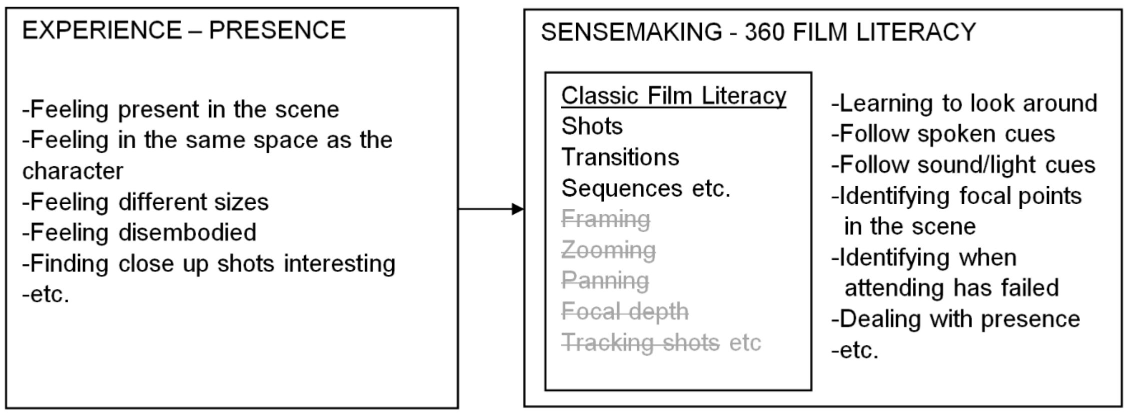


Figure 5.2: A model of user experience in the sensemaking of 360° video via HMD viewing (Passmore et al., 2017).

5.5 Conclusion

In general, the results of this case study agree with the consensus guidelines from Jaunt and Oculus regarding basic film language elements such as camera placement and use of transitions. A notable exception found in the user studies is the level of interest shown in close-up shots, along with possible accompanying feelings around perception of placement or size of self in the scene. This was evident from the high frequency of relative comments from the user study interviews.

Viewers clearly seem to understand elements of the video from a continuity editing point of view, which is not surprising, given the general level of viewer filmic literacy among the user study participants. Two elements were notably different from traditional viewing, namely the sense of presence and the ability to look around freely. The sense of presence was found to both mediate and interfere with understanding the story and made many viewers feel as though they were actually in the scene of the video, which provided a visceral experiential component to the activity of watching the video; something which is not encountered when viewing traditionally. The ability to look around left viewers uncertain about how to read the 360° scene in terms of where they were expected to focus their attention and whether they were missing anything important. However, they soon developed strategies such as scanning for focal points of interest and making judgements about when it was OK to look around without missing anything crucial to the story, as shown in Figure 5.2 (on the right side – 'Sensemaking – 360° Film Literacy').

The simple sensemaking model of filmic literacy (Figure 5.1) is general and applies to traditional and 360° filmic literacy. When considering 360° literacy, a key aspect is that the experiential components are much stronger than for traditional viewing. It is possible that a language-based model for creating 360° experience is inadequate, as it does not cover the experiential components of 360° viewing. 360° video viewing is taking traditional viewing towards interaction, and as film, VR, and gaming continue to converge, the importance of designing the experiential aspect will only increase as experiences become more interactive.

This investigation provided some very relevant information regarding filming techniques, filming literacy and their importance in the user experience of 360° video, especially using a HMD. It became very clear that film language, shots, transitions etc., were going to play an important part in the conceptual framework as they have a direct impact on the user experience of the video. The choices that the content producer makes at the production stage of the video will greatly determine the outcome and greatly influence specific elements of and the overall user experience of the video. The conceptual framework will endeavour to highlight this importance.

Chapter 6 User study three – The effect of viewing platform on the user experience: Phone vs HMD

6.1 Research question

This user study addressed research question four: Does quantitative measurement of presence support the results returned from the methods used in the qualitative studies – study one (Chapter 3) and study two (Chapter 4)?

The study largely replicated the protocol of the first two studies (user study one Chapter 3 and user study two Chapter 4), this time using a HMD and a smart phone. The difference with this study was the use of methodological triangulation via the introduction of a quantitative research method i.e., a questionnaire. The IPQ was chosen as it specifically focusses on presence – the central theme which had emerged from the previous two user studies and case study. The reason for using triangulation was to discover whether the more efficient method of administering a questionnaire would return similar results to the lengthier qualitative methods used in the previous user studies.

6.1.1 Author's contribution

The study was designed, executed, and analysed solely by the author.

6.2 Aim

- To investigate whether the use of quantitative techniques provide similar results to the results of the qualitative techniques used in the earlier studies.

In the first two user studies (user study one Chapter 3 and user study two Chapter 4), predominantly qualitative methods were implemented in order to establish an initial collection of data. The questionnaire used in those studies was a short questionnaire which aimed to gather some further data which could be considered while analysing the interview responses. Following the completion and publication of the first two user studies (user study one Chapter 3 and user study two Chapter 4), a corpus of data had been amassed. The qualitative methods which were used proved to be lengthy processes, and more efficient methods were considered. It was decided to further explore some quantitative methods of collecting data in more detail with a view to employ established quantitative methods of gathering data. Not only could this be more efficient in terms of time spent, but it could also provide some insight into whether what the participants had said in the qualitative data could be quantified in a meaningful way and determine whether the results aligned somewhat when compared to the quantitative results. For example, if a result is proven to be significant, an immediate interpretation can be achieved. This use of methodological triangulation was intended to not only develop a more comprehensive understanding of the phenomena present in this study, and the previous two studies, but to also provide confidence in the qualitative results (the themes) from all of the user studies in preparation for the development of the UX360 conceptual framework (Carter et al., 2014).

There are numerous questionnaires associated with UX available to use in the HCI realm (see Chapter 2, section 2.1.4). However, the questionnaires either cover a range of factors and are quite general or focus on a single element or concept.

After investigating several established questionnaires, the IPQ was chosen and used in this study (user study three) as it concentrates on the concept of presence (details of the IPQ can be found in Chapter 2, section 2.14.4). It was decided to centre this study around presence as it had emerged as the central theme of the UX of 360° video from the previous studies (user study one Chapter 3, user study two Chapter 4, and the case study Chapter 5) and it had proven difficult to find questionnaires that covered all of the themes which had emerged from the previous user studies e.g., a quantitative measure of social ease (one of the seven main themes). Additionally, the IPQ contains categories, and this structure has a good fit with the thematic analysis and theme nature of the overall user study results analyses which had been carried out previously. The IPQ categories allow the questionnaire results to be presented specifically in relation to those elements of the user experience. The questionnaire results could then be analysed alongside the interview transcripts in order to identify similarities and differences in the participants responses.

6.2.1 Criticism of questionnaires used to measure presence

An important note here is that this is not criticism of questionnaires in general but is a specific criticism of questionnaires being used to measure the concept of presence. Mel Slater is a prominent figure in VR research and has contributed a lot to the field. His criticism of questionnaires used to measure presence and of the Likert scale were presented in the following papers respectively and are briefly discussed 'How Colorful Was Your Day? Why Questionnaires Cannot Assess Presence in Virtual Environments' by Slater, (2004) and 'The Use of Questionnaire Data in Presence Studies: Do Not Seriously Likert' by Slater and Garau, (2007).

In the paper entitled 'How Colorful Was Your Day? Why Questionnaires Cannot Assess Presence in Virtual Environments', Slater, (2004), argued that a scientific basis for "presence" could not be established on the basis of post-experience presence questionnaires (such as Witmer and Singer's PQ) alone. A reason for this was that the concept of presence is often unknown to many participants of VR user studies due to a lack of exposure to both VR and the concepts and phenomena associated with VR and experiencing a VE. The fact that a presence researcher may "bring into being the idea of presence in the minds of VE participants" means that a participant may have a misconception of and not fully know or understand what presence actually is. Hence, the participant's responses in the presence questionnaire may be somewhat worthless (Slater, 2004, p. 484).

To illustrate the point, Slater conjured up an arbitrary mental attribute called "colorfulness of the experience" and administered a set of questions to 74 respondents using an online questionnaire. According to Slater, (2004), the results suggested that "colorfulness of yesterday's experiences was associated with the extent to which a person accomplished their tasks, and also associated with yesterday being a "good," "pleasant," but not frustrating day." The "colorfulness of the experience" can be compared to presence in the way that a participant was not fully sure of what the term meant, as there was no description or definition provided; the participant made their own interpretations (Slater, 2004, p. 484).

When considering these findings, it was decided that it was not desirable to influence the participant's experiences by introducing, in writing or verbally, concepts such as presence, immersion etc. via questions or statements in instructions, surveys or questionnaires. Rather, an organic approach was to be implemented by allowing the participants to freely speak about their experiences with some prompts such as 'how do you feel following the VR experience?' and 'what can you tell me about X?'. Although this would likely be more work to analyse the results, the expected benefits appeared to be worthwhile due to how relatively new and widely available 360° video was as a form of media at the time of the early user studies.

Additionally, Slater and Garau, (2007), argued that questionnaire data is treated far too seriously, and that a different paradigm was needed in presence research. They believed that a paradigm "where multivariate physiological and behavioral data is used alongside subjective and questionnaire data, with the latter not having any specially privileged role" was required. This would ultimately take the emphasis away from just the questionnaire results and take more into account when considering the presence felt by a participant of a user study (Slater and Garau, 2007, p. 447).

The content of the two previously mentioned papers influenced the decision of the author to not rely upon the already established and validated questionnaires as the only means of gathering data regarding the user experience when carrying out the series of user studies. Instead, a mixed methods approach was adopted and executed throughout this research. The research methodology included semi-structured interviews and questionnaires with no emphasis placed upon either method.

6.4 Protocol

Similar to user studies one and two, this study used a within group design and was executed at Middlesex University where the participants were also recruited. The potential participant read the PIS (see Appendix D, D.3), filled in the screening questionnaire (see Appendix D, D1) and signed the consent forms (see Appendix D, D.2). The viewing conditions were alternately assigned to participants and was either VR first Phone second or Phone first and VR second. The viewing conditions were arranged in an attempt to avoid ordering effects and were executed in the stated order. The potential impact of ordering effects was not investigated further as it was not required for the purposes of answering this user study's research question – Does quantitative measurement of presence support the results returned from the methods used in the qualitative studies – study one (Chapter 3) and study two (Chapter 4)?

The phone condition comprised a Samsung Galaxy Note 4 and the same phone was used with a Samsung Gear VR for the VR condition; the Note 4 was inserted into the Gear VR. The Note 4 display resolution was 2560 x 1440 (Quad HD) using Super AMOLED technology with a colour depth of 16 million. The Note 4 was used in order to avoid differences in responses due to using a potentially improved technology resulting in better screen resolution etc. A swivel chair was used for the participant to easily look around 360 degrees without causing any discomfort.

The video viewed was the same video which was used in user studies one and two (see Chapter 3, section 3.3 for details of the video). For any participant that was unfamiliar with VR and had not used a VR HMD before, a demonstration video about London's Chinatown was shown to participants in order to familiarise them with HMD and 360° video navigation mechanisms such as moving the head to look in different directions etc. This was shown before the feature video, 'The Resistance of Honey', using the HMD.

Each participant was assigned a viewing condition combination and proceeded to watch the feature video using the first viewing condition. Once the video had finished, the participant took part in a semi-structured interview comprising several questions which can be found in Appendix D, D.4. While partaking in the interviews, each participant was recorded via an audio recording device to allow future transcription of the audio. Following the interview, the participant filled out the IPQ (Appendix E). The participant then watched the feature video, 'The Resistance of Honey', using the second viewing condition and once completed, the interview was administered and on completion of the interview, the IPQ was filled out. Finally, a debriefing was provided to the participant, (see appendix D, D.5).

There was a total of 16 participants for the study: 7 male and 9 Female. The youngest participant was 20 years old, and the oldest participant was 41 years old; one participant did not provide their age. Of the 16 participants, 11 had previously tried VR and 12 participants had previously viewed 360° video 4 of which using a VR device.

6.5 Results

This section presents the results and analysis of the user study.

6.5.1 Thematic analysis results

Once again, the interviews were transcribed from the audio and a thematic analysis was performed using the Braun and Clarke method (Braun and Clarke, 2006). The same nodes from the first two user studies were used again in the NVIVO coding. The final seven themes from the previous thematic analyses were again considered in this thematic analysis. They were as follows:

- Presence
- Attention
- Engagement
- Concentration on story
- Certainty (about what should be attended to)
- Comfort
- Social ease

It is fair to assume that the subjective nature of the thematic analysis method could contribute to small differences when considering attributing codes/nodes/themes to sentences and quotes from the transcripts. Additionally, knowledge of the domain, exposure to more similar user studies, the previous results of the user studies executed by the author and the fact that there were eight less participants in user study three than user study one, are all contributing factors. The transcripts from the participants' interviews were analysed with regard to their content and were allocated to the existing themes respectively as per the thematic analysis method. Following the mind mapping process, the themes were found to be suitable. There were one or two new themes/nodes which arose from the study; however, they did not appear to be very significant due to the low number of references.

6.5.2 Questionnaire results

In general, the results of the IPQ appeared to support the thematic analysis findings in relation to what was said by the participants during their interviews regarding presence. A statistical analysis was carried out on the results of the IPQ using a two-sample assuming equal variances t-test between the two viewing conditions for each question/statement and category. This test was chosen as the sample sizes were small and the variances were assumed to be equal. The main objective of the tests was to discover if there was a significant difference in the responses for each category and viewing condition. A mean score was calculated for each category and viewing condition in the IPQ. It was also possible to calculate the mean scores for each category in terms of viewing condition order. A table containing all mean scores can be viewed in Appendix F.

6.6 Discussion

From the results of the statistical analysis, it became clear that there were two main discussion points; the platform used to view the 360° video and the viewing order effects. This section firstly discusses the viewing platforms, HMD, and phone, and then the order effects which became apparent.

6.6.1 Viewing platform

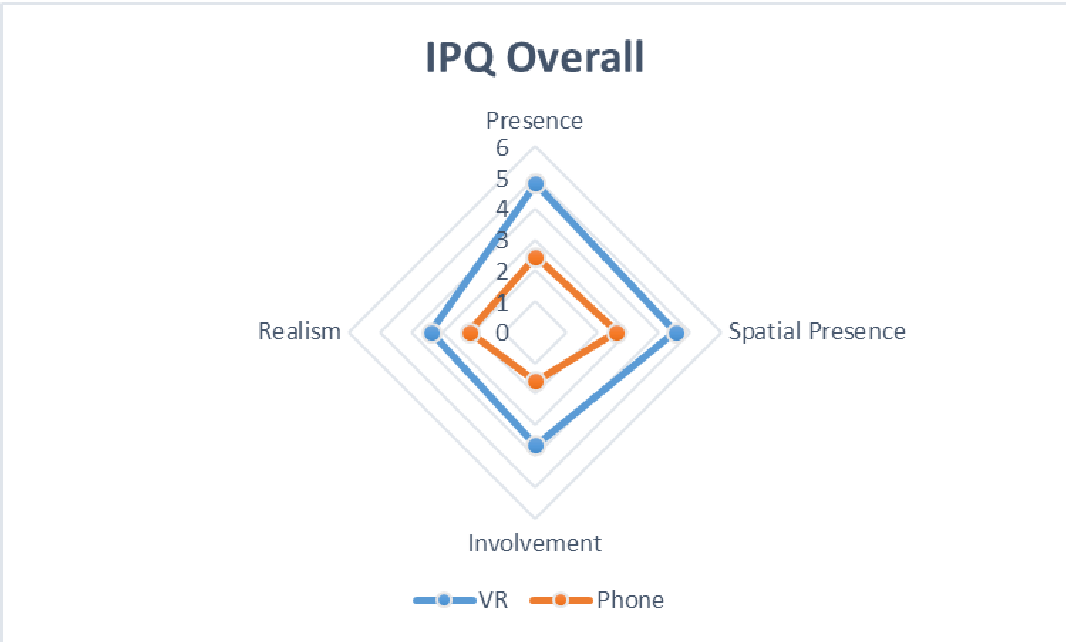


Figure 6.1: The overall mean scores for each category in the IPQ according to viewing condition.

In the radar diagram in Figure 6.1 it is evident that there is a clear difference between the VR and phone viewing condition scores for each category. It was expected that participants would very likely experience higher levels of presence when using the VR HMD compared to the phone. This was due to the results of the previous studies. It should be noted here that a score of 5 is the highest possible score that can be attributed to any of the responses in the IPQ. The mean scores that the phone viewing condition received in two of the four categories were approximately half of those attributed to the VR viewing condition. Notably, those two categories were General Presence (G) and Spatial Presence (SP), suggesting that participants still felt relatively high levels of presence while using the phone.

Table 6.1 displays the mean, Standard Deviation (SD), degrees of freedom, t-value and p-value from the two-sample assuming equal variances t-tests which were carried out on the VR and Phone viewing conditions for each of the categories in the IPQ.

IPQ Category – Viewing Condition A / Viewing Condition B	*Viewing Condition (A) Mean /SD*	*Viewing Condition (B) Mean /SD*	*Degrees of freedom*	*t-value*	*p-value*
General Presence (G) – VR / Phone	*4.812 /0.72*	*2.437 / 1.76*	*30*	*4.8*	*P < 0.05*
Spatial Presence (SP) – VR / Phone	*4.525 / 0.65*	*2.621 / 1.20*	*30*	*5.3*	*P < 0.05*
Involvement (INV) – VR / Phone	*3.640 / 1.56*	*1.578 / 0.76*	*30*	*4.5*	*P < 0.05*
Realism (REAL) – VR / Phone	*3.359 / 0.66*	*2.125 / 0.79*	*30*	*4.6*	*P < 0.05*

Table 6.1: The two-sample assuming equal variances t-test results for the IPQ – overall viewing platform.

The first t-test was performed to compare General Presence (G) in the VR and phone viewing conditions. There was a significant difference in G between the VR and phone viewing conditions (Table 6.1). This was expected due to the widely known heightened sense of presence typically associated with VR. The mean score for the VR condition was slightly below the maximum possible score, suggesting that the level of presence felt was extremely high.

The next t-test was performed to compare Spatial Presence (SP) in the VR viewing condition and the phone viewing condition. There was a significant difference in SP between the VR and phone viewing conditions (Table 6.1). Again, an expected result which was slightly lower compared to G. This may be due to the SP category containing more than just the one statement (five statements total), thus increasing the likelihood of a lower mean value. The individual scores for SP are low in the majority for the phone condition, with one or two higher scores and one outlier being participant P9 who gave a higher mean score to the phone condition for SP. From the interview transcripts, it is not clear why this was, as P9 appeared less enthused with the phone experience. However, this was their first experience of VR, so it may have been familiarity with the device used to watch the video.

Following Spatial Presence, the t-test was performed to compare Involvement (INV) in the VR and phone viewing conditions. There was a significant difference in INV between the VR and phone viewing conditions (Table 6.1). The low scores in both viewing conditions from the INV category was expected as the video has no interaction with the virtual environment, beyond looking around, throughout.

Finally, the t-test was performed to compare Realism (REAL) in the VR and phone viewing conditions. There was a significant difference in REAL between the VR and phone viewing conditions (Table 6.1). This could be attributed to the participant experiencing a higher amount of presence when watching the video using the VR HMD and therefore feeling more as though they were actually in the virtual environment, heightening their perception of realism.

The video contained scenes in a shed, in an open space which had trees and plants, in a park with trees and grass, inside a flat with general musical equipment, a moving shot which followed a bee moving, inside and outside of a beehive. Some effects were used in the park scene which sped up time and added visual effects. Therefore, the majority of the film was in, what could be referred to as, normal environments. It could be said that the realism of the environments was as close to normal as possible, excluding the aforementioned 'follow the bee' scene, the added effects in the park scene and the inside the beehive scene.

Overall, the REAL scores were quite low (Figure 6.2 and Figure 6.3). This could be attributed to viewers being quite comfortable in the belief that what they were watching was a film and was not real but was adequately 'real' for the purpose that the film was expected to serve i.e., an entertainment piece.

6.6.2 Order effects

After analysing the data gathered from the IPQ responses and executing the two-sample assuming equal variances t-tests, it became clear that some order effects existed regarding the two viewing conditions (VR and phone). The results are presented and discussed here using selected radar diagrams and the results of the t-tests. Each radar diagram is a representation of the mean scores from the results of the IPQ for selected respective viewing condition pairs.

Figure 6.2 shows the phone viewing condition and exhibits the mean scores for when the phone was used first to view the video and when the phone was used second to view the video. It is quite clear that the viewer responses were higher when the phone was used first in all but the involvement categories. This difference is likely due to the comparison made to the VR condition when the phone was used second, resulting in lower scores for the respective experiential categories. Involvement was almost identical for both phone first and phone second conditions.

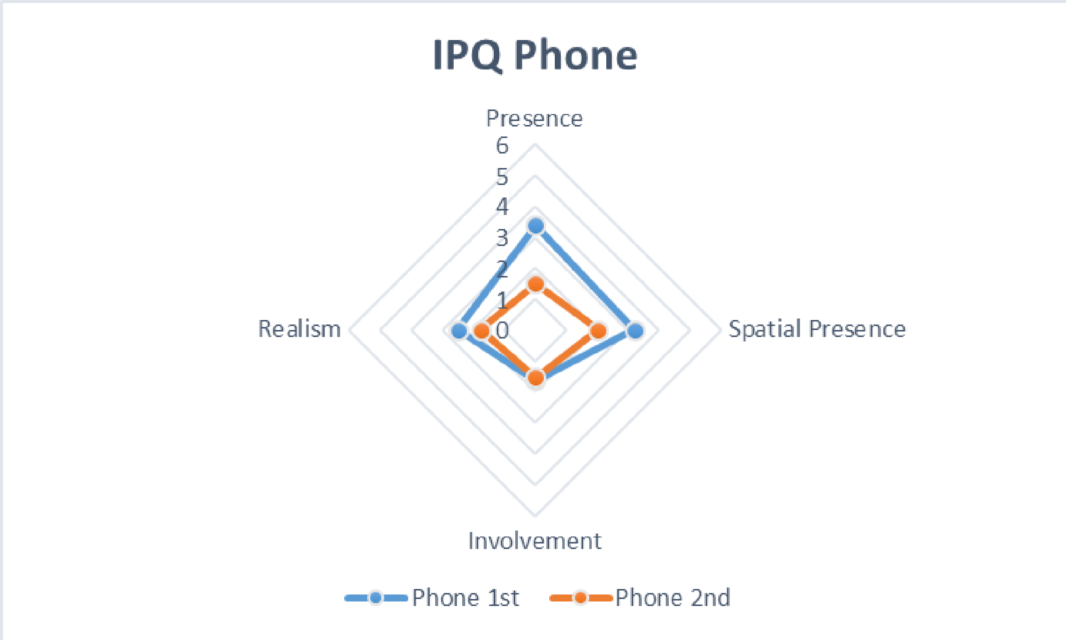


Figure 6.2: The overall mean scores for each category of the IPQ according to the phone first and phone second viewing condition ordering.

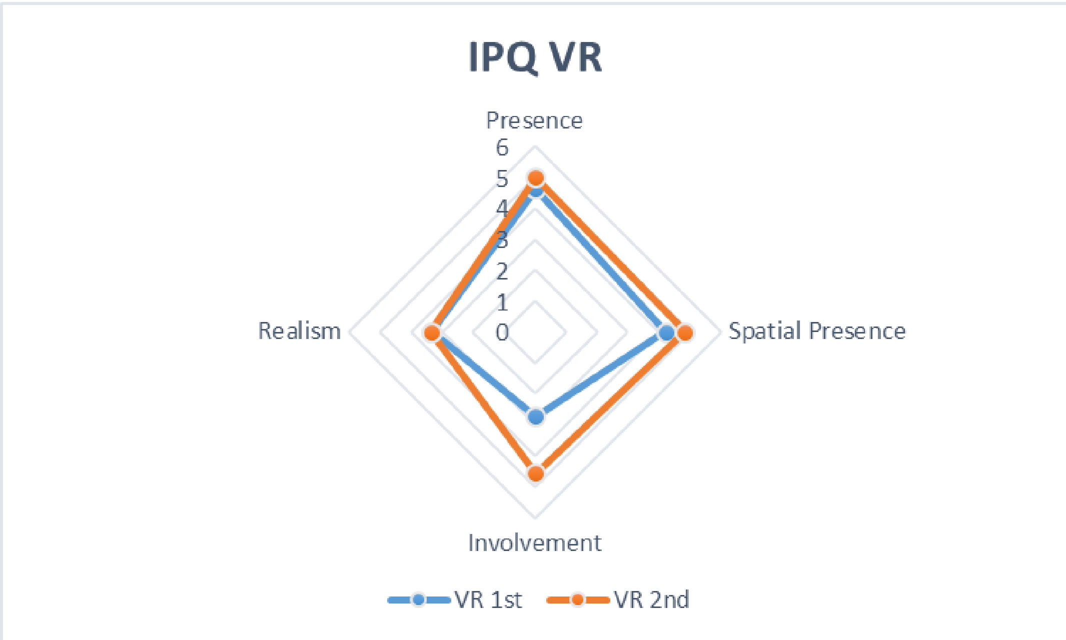


Figure 6.3: The overall mean scores for each category of the IPQ according to the VR first and VR second viewing condition ordering.

Figure 6.3 shows the VR viewing condition and exhibits the mean scores for when the VR HMD was used first to view the video and when the VR HMD was used second to view the video. Aside from Realism, there is a higher score for Presence, Spatial Presence and Involvement when the VR HMD was used to view the video second. This could be attributed to the user having experienced the video using the phone and being able to compare the experience of the VR HMD to it; which was somewhat expected.

Figure 6.4 displays the mean scores for when the VR HMD viewing condition was used first to view the video and when the phone viewing condition was also used first to view the video. The scores for each are a very similar shape with increased scores for the VR first condition. This indicates that the user's experiences of the categories were more intense when using the VR HMD, though were present to some degree when using the phone.

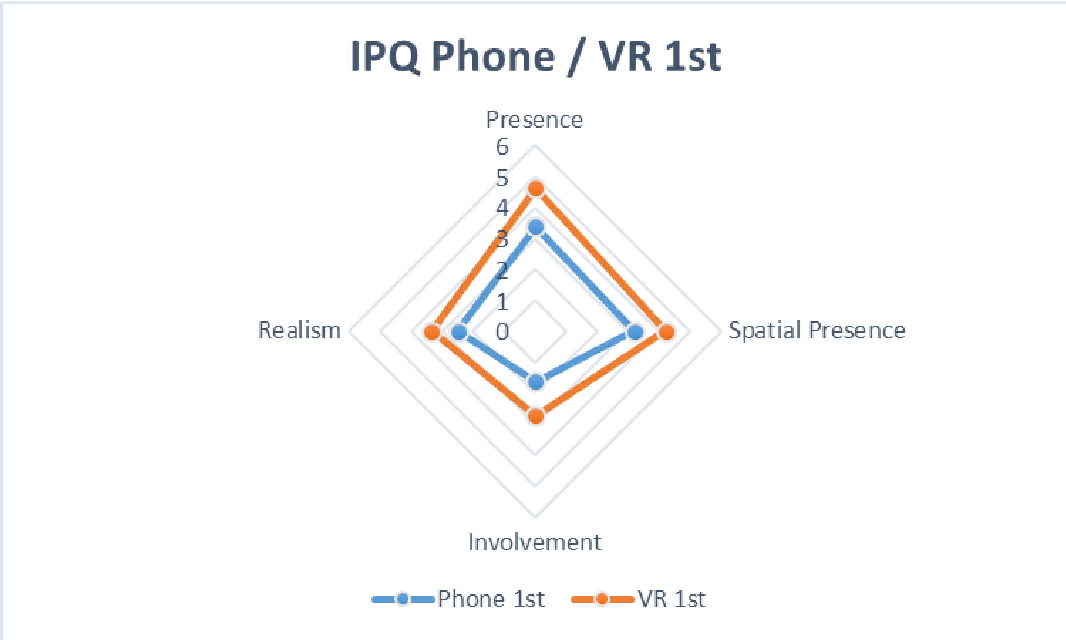


Figure 6.4: The overall mean scores for each category of the IPQ according to the phone first and VR first viewing condition ordering.

Figure 6.5 displays the mean scores for when the VR HMD viewing condition was used second to view the video and when the phone viewing condition was also used second to view the video. The scores for each are, again, quite a similar shape, with increased scores for the VR second condition. Again, this indicates that users experience in these categories were present, even if quite low, when using the phone but were a lot more intense when using the VR HMD; excluding Realism – which is much closer in score difference. The main reason for this increase in scores for the VR second condition is the user having the comparison to the phone first condition. It was expected that the user would respond with higher scores when VR was used second to view the video. Similarly, lower scores for the phone second viewing condition were expected in comparison to the phone first viewing condition due to the comparison to viewing the video on the VR HMD first.

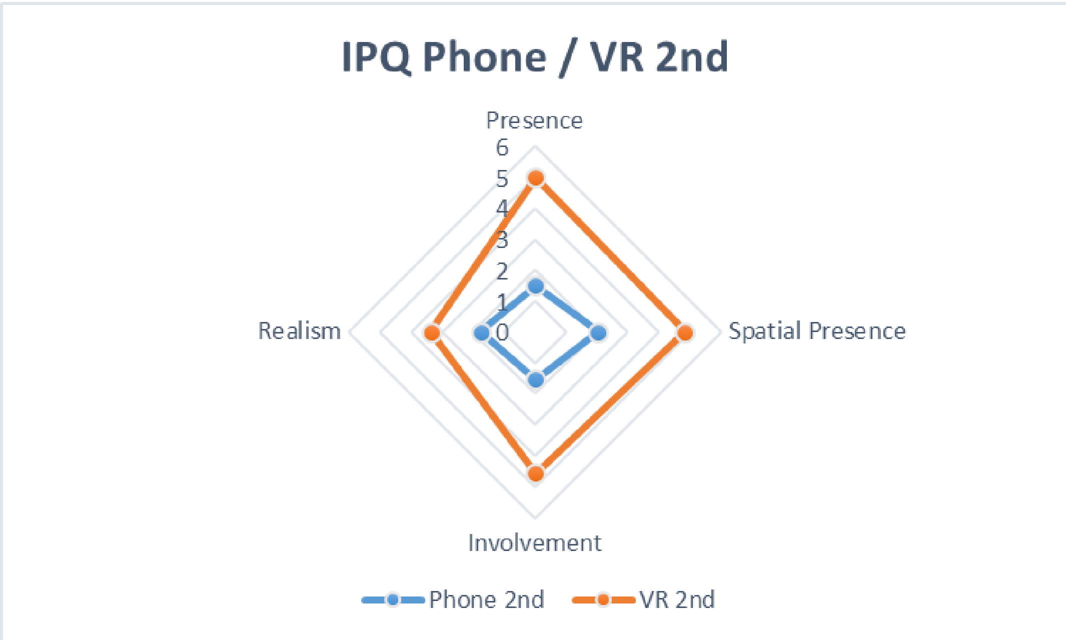


Figure 6.5: The overall mean scores for each category of the IPQ according to the phone second and VR second viewing condition ordering.

What was interesting however, was the relatively high level of presence felt by several participants when using the phone first. This can be attributed to not having experienced the VR condition and therefore not having that as a reference point i.e., something to compare it to.

6.6.2.1 General Presence (G)

The phone received a higher mean score on G when the phone was used first (3.375) (Figure 6.6). When the phone was used second, the mean G score (1.5) was less than half of the phone first mean G score (Figure 6.7). The difference in the mean G scores between the phone first and phone second was 1.875 (Figure 6.2). The t-test was performed to compare G in the phone first and phone second viewing conditions. There was a significant difference in G between phone first and phone second viewing conditions (Table 6.2).

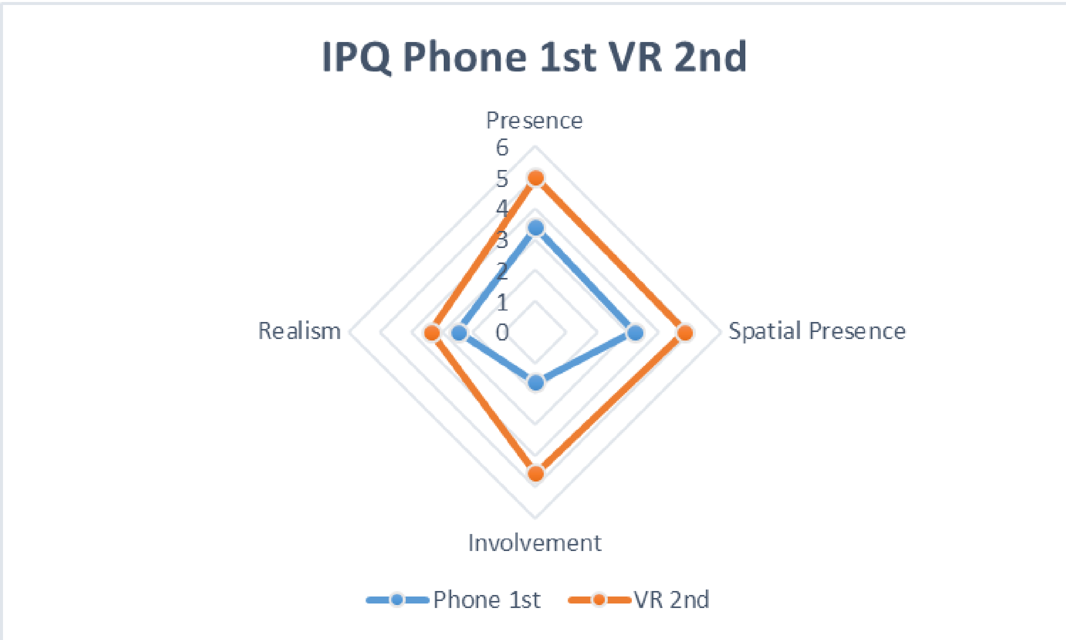


Figure 6.6: The overall mean scores for each category of the IPQ according to the phone first and VR second viewing condition ordering.

The VR viewing condition received a higher mean score on G when the VR was used second (5) (Figure 6.6). When VR was used first, the mean G score was slightly lower than the VR second mean G score (4.625). The difference in the mean G scores between the VR first and VR second was 0.375. The t-test was performed to compare G in VR first and VR second viewing conditions. There was not a significant difference in G between VR first and VR second viewing conditions (Table 6.2).

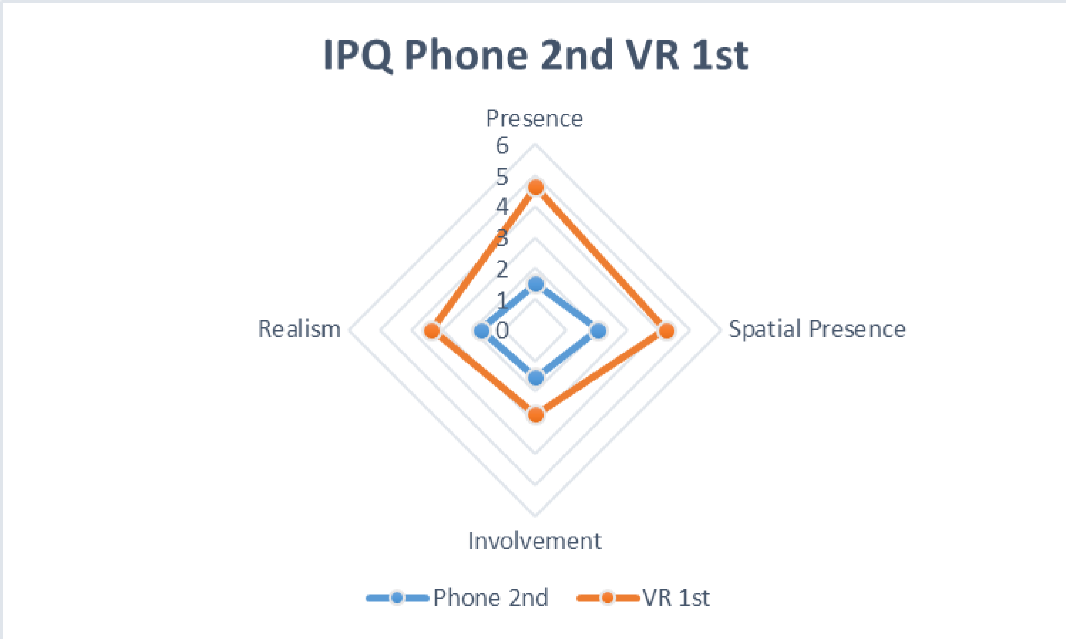


Figure 6.7: The overall mean scores for each category of the IPQ according to the phone second and VR first viewing condition ordering.

This slight difference between the VR first and VR second G mean score was most likely due to having a point of reference, namely the presence experienced when using the phone first. The increase in the G score for VR was evident with every participant who had been allocated the phone first, VR second condition. Likewise, the phone second G score was lower for all participants with the exception of one participant, P9, who scored the phone and VR equally in G – a 6 in both, the highest rating. Every participant gave a higher score for G when using the VR regardless of whether they used the phone first or second, excluding participant P9.

IPQ Category – Viewing Condition A / Viewing Condition B	*Viewing Condition (A) Mean /SD*	*Viewing Condition (B) Mean /SD*	*Degrees of freedom*	*t-value*	*p-value*
General Presence (G) – Phone 1st / Phone 2nd	*3.375 / 0.99*	*1.5 / 1.87*	*14*	*2.3*	*P < 0.05*
General Presence (G) – VR 1st / VR 2nd	*4.625 / 0.85*	*5 / 0.5*	*14*	*-1*	*P = 0.33*
Spatial Presence (SP) – Phone 1st / Phone 2nd	*3.2 / 0.90*	*2.04 / 1.19*	*14*	*2.0*	*P = 0.06*
Spatial Presence (SP) – VR 1st / VR 2nd	*4.225 / 0.52*	*4.825 / 0.64*	*14*	*-1.9*	*P = 0.07*
Involvement (INV) – Phone 1st / Phone 2nd	*1.625 / 0.51*	*1.531 / 0.95*	*14*	*0.2*	*P = 0.82*
Involvement (INV) – VR 1st / VR 2nd	*2.718 / 1.53*	*4.562 / 0.89*	*14*	*-2.7*	*P < 0.05*
Realism (REAL) – Phone 1st / Phone 2nd	*2.5 / 0.25*	*1.75 / 0.95*	*14*	*2.0*	*P = 0.06*
Realism (REAL) – VR 1st / VR 2nd	*3.343 / 0.62*	*3.375 / 0.69*	*14*	*-0.08*	*P = 0.9*

Table 6.2: The two-sample assuming equal variances t-test results for the IPQ by viewing platform order.

6.6.2.2 Spatial Presence (SP)

There were no significant differences in the means of SP scores between VR first and VR second or phone first and phone second conditions respectively (Table 6.2).

The trend of higher scores when VR was the second condition continued in the SP category; again attributed to having experienced the video on the phone first and being able to compare the increased sense of presence in the virtual environment to the relative lower presence when using the phone to view the video (Figure 6.6). Likewise for the phone second condition, the scores for the VR first were higher

(Figure 6.7). There is a very low mean score for spatial presence when the phone was used to view the video second, following viewing the video using the VR device; this was expected.

6.6.2.3 Involvement (INV)

It could be assumed that involvement scores may have been based on how much the viewer felt they were concentrating on the video and not getting distracted. Of course, this would imply a higher score for the VR condition, and this was actually the case (Figure 6.1 and Figure 6.3). This result could be attributed to being 'cut off' from the actual world, thus increasing the opportunity to concentrate on the video alone and not being distracted by the actual world. Conversely, while using the phone, viewers are exposed to the actual world around them and could potentially be distracted, hence the lower scores (Figure 6.2).

There was also a significant difference between the VR first and VR second viewing conditions in the INV category. The t-test was performed to compare INV in the VR first and VR second viewing conditions. There was a significant difference in INV between the VR first and VR second viewing conditions (Table 6.2). This can be attributed to having the comparison to the phone condition and the aforementioned 'cut off' from the actual world.

6.6.2.4 Realism (REAL)

There were no significant differences in the means of REAL scores between VR first and VR second or phone first and phone second conditions respectively. However, the VR second mean score was slightly higher than the VR first score which continues the trend of participants having a comparison to the phone condition. Likewise, the phone second mean score was lower than the phone first mean score (Table 6.2).

6.7 Conclusions

It was interesting to carry out the user study following the same protocol from the first two user studies and discover that the responses from the participants had not changed a great deal over the period of 3 years or so; the participants of this study were not the same participants of the previous studies, however. This would suggest that the technology is still rather niche and not mainstream, as only four of the 16 participants had viewed a 360° video using a VR device. There had been more exposure to VR and 360° video in general however, in the relatively small sample size of participants. The addition of the IPQ provided an alternative method of analysis and proved itself to be very interesting and useful. Interesting in its construction to break the statements up into categories and useful via the ability to distil the user experience of presence into a number and compare them to the results of the qualitative methods; accentuating the efficiency of the questionnaire in terms of time spent in execution and analysis.

It was found that a relatively high amount of presence was experienced using the phone in comparison to the VR HMD, which was not expected. Participants felt quite involved with the video, even though there was no direct interaction with the video. Finally, the participants were quite aware that the video was just that, a video, and did not report high scores in the realism category. From a general overview, the questionnaire results did align with what was said by the participants in their interviews.

As the name suggests, the IPQ focuses on the presence concept of the user experience. As was discovered throughout the user studies, although presence is central to, and contributes a large portion to, the overall UX of 360° video, there are several other contributing concepts and elements which affect the overall UX of 360° video and are not covered by the IPQ. The IPQ does not, for example, cover comfort of the device, something that was found to be quite prominent in what participants of the user studies had said during their interviews. The comfort of wearing the HMD, viewing a 360° video in a CAVE, or watching a 360° video on a flat screen or on a smart phone, elicited remarks relating to the comfort of the device used which were both positive and negative.

Other elements of UX of 360° video which also emerged from the user studies and are not covered by the IPQ are engagement, concentration on story, certainty, and social ease. Remarks related to these elements have proven to be quite frequent in a user's overall experience of 360° video whether viewed on a flat screen, smart phone, CAVE or HMD prompting responses that contributed to the development of the 7 themes from user study one (see Chapter 3). Engagement contributes a lot to the UX of 360° video and is mentioned throughout the user study participant responses. However, the impact of engagement and the other aforementioned themes on the UX of 360° video cannot be inferred from the IPQ and therefore require another method of acquiring such information.

The method used to gather the information in user studies one and two proved to be effective and was replicated in this study. By not influencing the participants with already established concepts it was possible to discover the numerous elements of the experience through the participant's own words. In terms of triangulation, the IPQ is an effective tool for eliciting information regarding a user's experience of presence when viewing a 360° video in an efficient and precise way. However, as was discovered through the three user studies, there is a lot more to the UX of 360° video than presence alone. The similarities regarding the experience of presence, as well as other recurring themes such as engagement, comfort, and attention (for example), in the results between the qualitative and quantitative methods assisted in the understanding and conviction in the themes which had emerged from the first two studies and their projected use in the UX360 framework. The other categories of the IPQ (Spatial Presence, Involvement and Realism) do relate to some of the evident experiential concepts such as engagement and immersion and these can be inferred, directly or indirectly, from both the IPQ results and from the participant responses and then attributed to the previous themes. The statements in the IPQ from the Spatial Presence category relate to the immersion and engagement themes/concepts. The Involvement category statements also relate to the immersion and engagement themes/concepts, as well as the attention, certainty, and concentration on story themes/concepts. Finally, the statements in the Realism category could be related to the immersion and possibly familiarity themes/concepts. Some of the more nuanced concepts and themes in the UX360 framework do not appear to be covered by the IPQ however, such as comfort, FOMO, and social ease. Therefore, the use of triangulation helped to identify efficient ways of measuring presence alone using a quantitative method, the IPQ, to gather useful results, but also provided confidence in the results of the qualitative methods used previously, the thematic analysis.

Overall, the thematic analysis supported the results from user study one and user study two reaffirming confidence that the final seven themes were adequately justified to carry forward into the development of the conceptual framework. Less time was spent on the thematic analysis due to the concentration of just one theme/concept; presence. However, the coding method was the same as the two previous user studies. The participant interviews were quite similar in content to those from the first and second studies in terms of the overall UX of 360° video and the themes which arose were very similar. The inclusion of the IPQ proved to be as efficient as expected – the participants filled in the IPQ each time with minimal issues or questions regarding the questionnaire. The answer to the research question is in a positive light; quantitative measures of presence *do* support the results returned from the methods used in the qualitative studies. The IPQ results supported the thematic analysis results in terms of presence experienced. The results also supported the themes and concepts which were expected to appear in the conceptual framework, providing confidence in the UX360 framework.

Chapter 7 Proposed conceptual framework

This chapter addresses research question five: Can a model or conceptual framework of user experience of 360° video be developed in order to inform content creators and researchers?

Firstly, some research into conceptual frameworks and models in the area of UX are presented with some analysis of their structure and purpose. The development, structure and appearance of the initial conceptual framework followed by the final conceptual framework with an accompanying word model is then presented and discussed. Continually, the expected usage of the conceptual framework will be demonstrated via the presentation of some research directions which could be acted upon by researchers. Finally, some considerations for 360° video content producers which have been extracted from the conceptual framework, word model and directly from some of the user studies will be presented.

7.1 Conceptual framework and model research

It is important to state that the research carried out in this thesis was intended to be an exploration of UX of 360° video without the use of any pre-existing VR concepts. Therefore, a theory was not the basis of the development of the initial conceptual framework. Rather, the results of each user study contributed to the development of an understanding of the UX of 360° video when viewed using various devices and viewing platforms. The emerging models and frameworks from the studies led to the realisation that the development of an initial conceptual framework which illustrated the user experience of 360° video in VR would be a suitable solution. Following this decision, an investigation into existing models and frameworks related to UX was undertaken. To contextualise the work on UX thus far, existing models and frameworks related to user experience were reviewed. The selection process used was based on covering a wide variety of structural elements used in models and frameworks with the intention of assessing their structural attributes, application in the field and ease of understanding (in the subjective opinion of the author). The following six were chosen as a diverse representation of user experience models and frameworks.

In 1999, Norman coined the classic definition for UX: "all aspects of the user's interaction with the product: how it is perceived, learned, and used." (Norman, 1999). Xu states that "this definition suggests that UX is beyond UI design and usability." (Xu, 2012, p. 172). Therefore, Xu has extended Norman's definition of UX to a scope of Total User Experience (TUX) in a broader UX ecosystem context. The illustration in Figure 7.1 presents the TUX concept in a UX ecosystem context. This model considers a product which has a UI, such as system software. The intention of this model was to illustrate the TUX and the author desired to convey that "from the perspective of a UX ecosystem, end users actually receive UX through an overall TUX, instead of through any single interaction touch point with a product." (Xu, 2012, p. 173).

Xu, (2012), produced a model which exhibits the Total User Experience (TUX) concept in a UX ecosystem context i.e., interaction with a product. The model has the TUX at the centre of the diagram with an icon representing the user. Surrounding the user are the aspects of UX contained in a circle. Surrounding the circle is an arrow which begins at the 'Marketing touchpoint' and ends at the 'Removal touchpoint'. There are several other 'touchpoints' of interaction with the product along the way. Xu attempts to convey "UX through an overall TUX, instead of through any single interaction touch point with a product" (Xu, 2012, p.

173). This was not immediately apparent and required reading several paragraphs to fully understand the model and its desired intention (Xu, 2012).

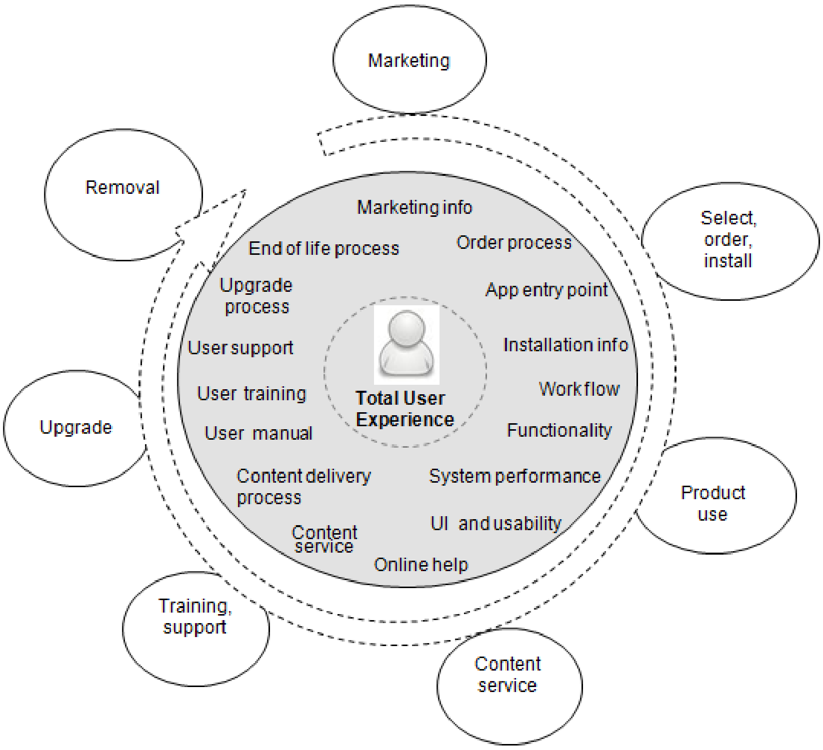


Figure 7.1: The Total User Experience (TUX) concept in a UX ecosystem context model (Xu, 2012).

In Figure 7.2, Alomari et al. (2020) present a framework which "identifies key concepts of cyberlearning and the important attributes associated with each concept." (Alomari et al., 2020, p. 5). The aim of the framework was to evaluate cyberlearning environments in general and the SEP-CyLE environment specifically. The authors wished to measure both SEP-CyLE's utility and SEP-CyLE's usability via four user studies. The framework was used to evaluate SEP-CyLE's usability and validate its effectiveness. The framework uses a central focus point which has arrows pointing away from the central focus point towards concepts in rectangular boxes. These concepts have arrows pointing away from them towards attributes of those concepts in rectangular boxes. This suggests a flow of how to view the framework and was the easiest of the six to understand (Alomari et al., 2020).

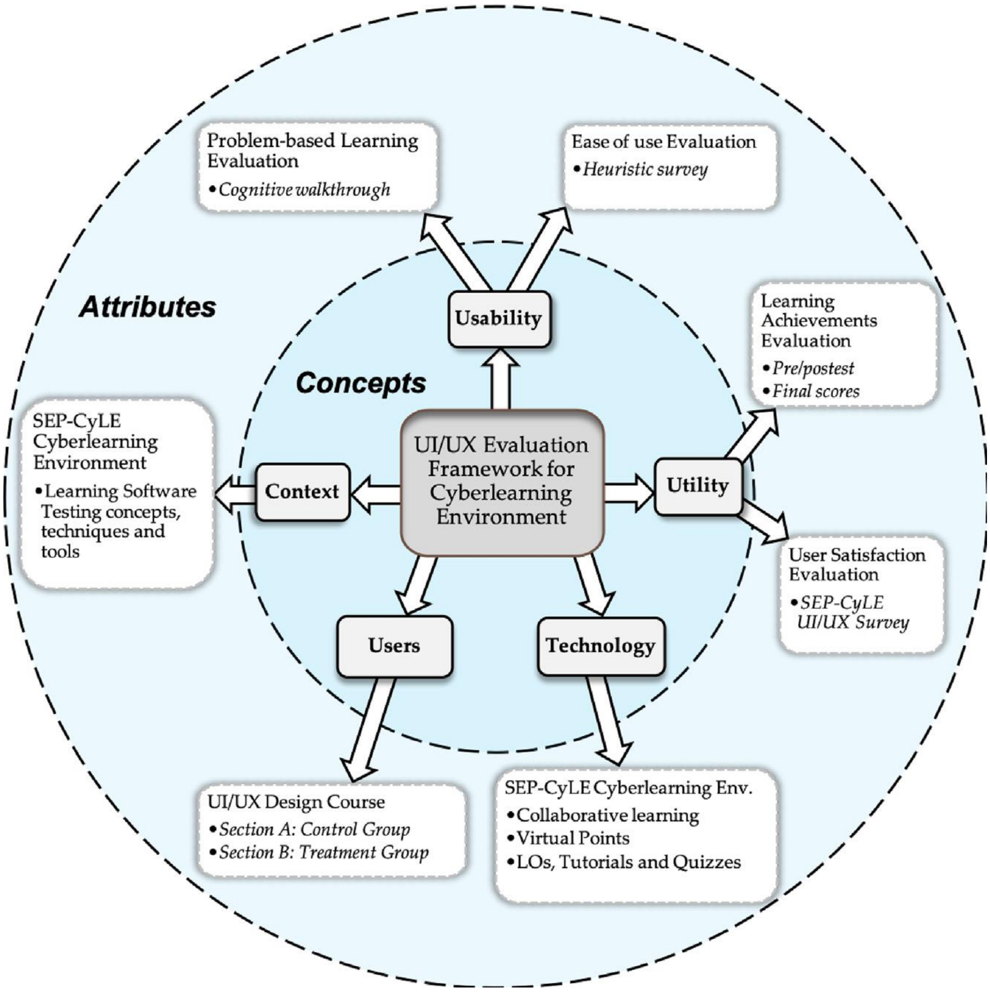


Figure 7.2: The UI/UX evaluation framework of a cyberlearning environment (Alomari et al., 2020).

The components of User Experience conceptual framework (Figure 7.3) by Beauregard and Corriveau, (2007), was created to conceptualise the components of user experience with a view to "communicate with UX stakeholders and advance goal setting and measurement within applied settings." (Beauregard and Corriveau, 2007, p. 325). Via a deeper understanding of the components of UX, they aimed to educate stakeholders and wished to "provide a greater ability to set strategic direction for the user experience, guide design goals, and assess user experience outcomes." (Beauregard and Corriveau, 2007, p. 325).

Beauregard and Corriveau's, (2007), components of User Experience conceptual framework integrated several different components such as circles containing concepts, a flow of actions, and icons used to represent two elements of the framework. It appeared to be quite intuitive in terms of how to interpret what was intended due to the visual nature and clarity of familiar elements (Beauregard and Corriveau, 2007).

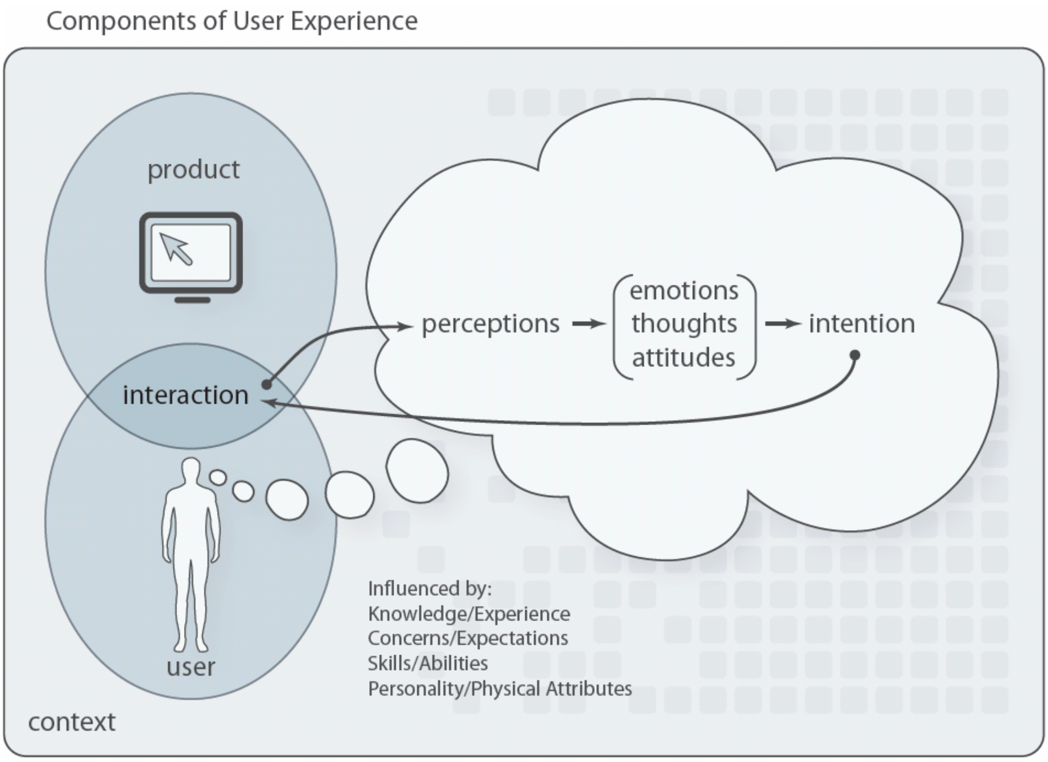


Figure 7.3: A conceptual framework of the components of user experience (Beauregard and Corriveau, 2007).

Hellweger and Wang, (2015), created a UX conceptual framework based on a collection of 21 papers, the majority of which were from software engineering related fields, with some from design and psychology, which contain original definitions of UX. 114 UX-related terms were extracted and following a bottom-up approach, the following emergent dimensions were decided upon: Impacting Factors that affect UX, UX Characteristics and the Effects produced by UX. The resulting UX conceptual framework can be viewed in Figure 7.4 (Hellweger and Wang, 2015).

The UX Conceptual Framework by Hellweger and Wang, (2015), used a legend which assisted the viewer in the interpretation of what each differently coloured line or arrow meant in terms of the relationships between words in rectangles. The words represent various subject matter including concepts, experiences, and emotions. The legend assisted in the understanding of the framework as, without it, the framework appeared to be just a huge collection of coloured arrows connected to words in rectangles (Hellweger and Wang, 2015).

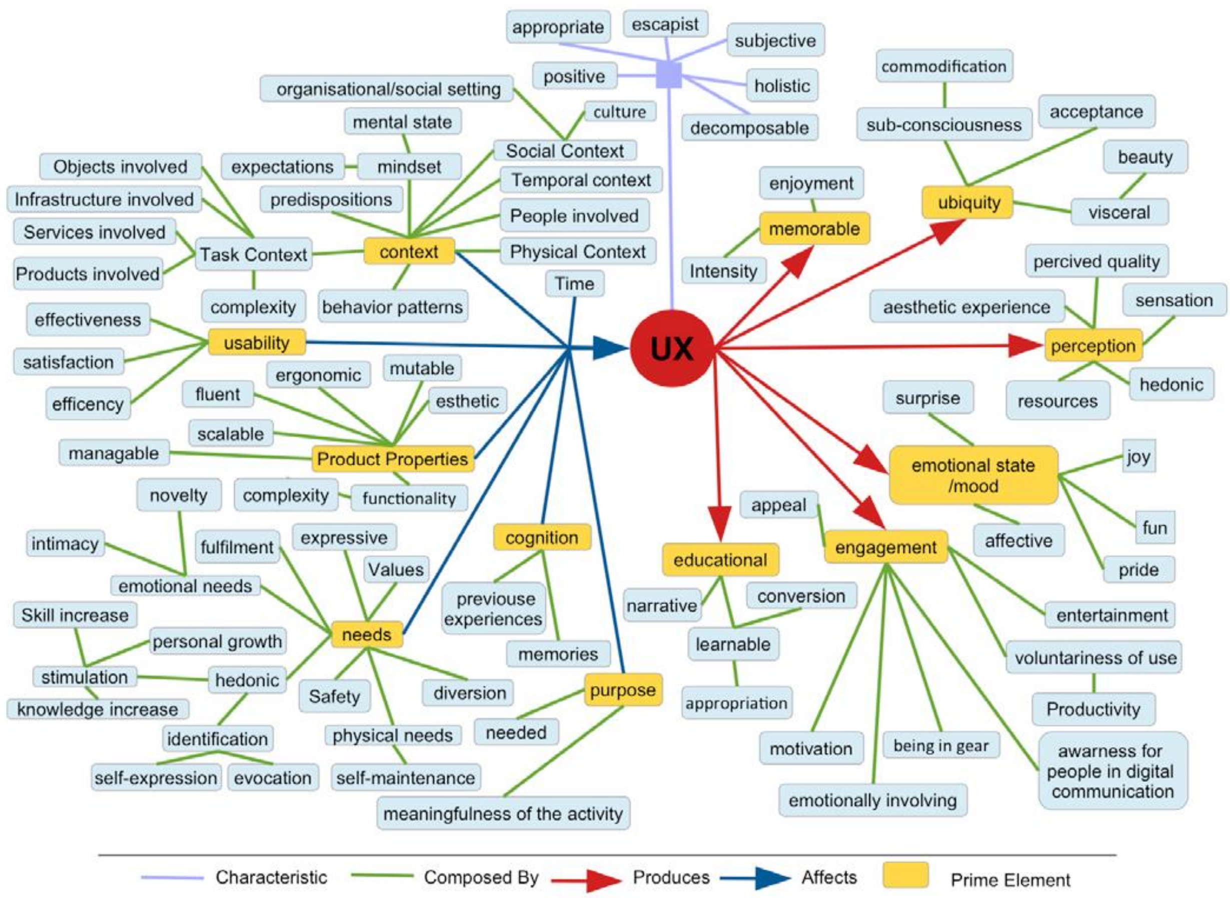


Figure 7.4: The UX conceptual framework (Hellweger and Wang, 2015).

Klimmt et al. (2012) created a conceptual model of the future user experience in Interactive Storytelling (IS). The aim of this model was to forecast how interactive narrative may facilitate enjoyable user experiences in order to assist research into how interactive storytelling entertainment media could be structured more effectively.

The model, exhibited in Figure 7.5, attempts to forecast how interactive narrative may facilitate enjoyable user experiences by predicting connections between both mediator processes (effectance and empathy/identification) and all more specific user experiences such as suspense and flow (Klimmt et al., 2012). The author states that the "primary value of the model, however, will be its availability for a historic comparison of past expectations concerning the evolution of entertainment technology with what has actually hit the markets and has been adopted as mainstream entertainment in a few years." (Klimmt et al., 2012, p. 204).

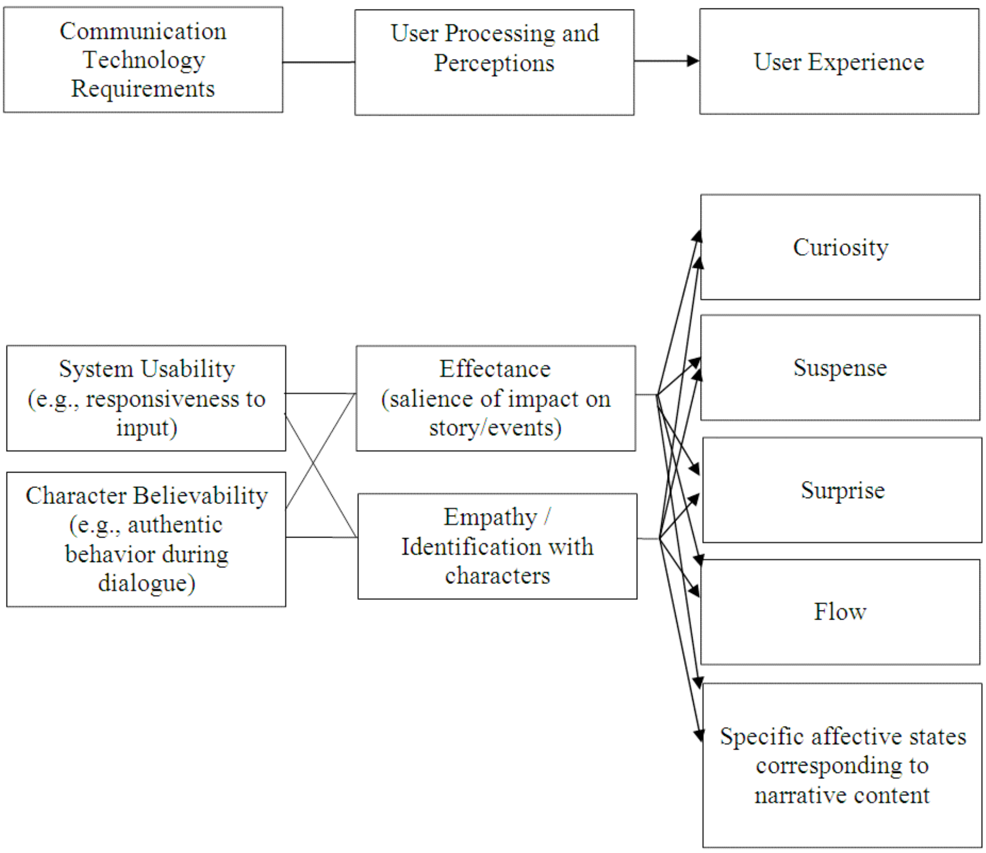


Figure 7.5: A conceptual model of the future user experience in Interactive Storytelling (IS) (Klimmt et al., 2012).

The conceptual model appeared to be split into two parts. The relationship between the two parts was not immediately obvious and only really made sense once the relevant parts of the paper had been read. This accentuated how important it is for a framework or model to appear as intuitive as possible without having to investigate the paper/article in depth to arrive at an understanding of the framework/model (Klimmt et al., 2012).

In Figure 7.6, Zarour and Alharbi, (2017), aimed to create a framework which would consolidate previous findings related to UX aspects and dimensions, along with measurement methods which they had identified, into one simplified UX theoretical framework. The framework was also intended to better understand the relationship between UX dimensions, UX Aspects and UX measurement methods; identified as issues when considering four non-orthogonal UX issues: definition, modeling, method selection, and the interplay between evaluation and development (Zarour and Alharbi, 2017).

Zarour and Alharbi, (2017), used a circular model, divided into sections which was intended to be viewed, read, and interpreted from the centre of the circle outwards, one colour coded layer at a time. The model does not have a specific accompanying text or word model and it was necessary to read a large amount of the paper to adequately understand the construction of, and how to interpret, the model (Zarour and Alharbi, 2017).

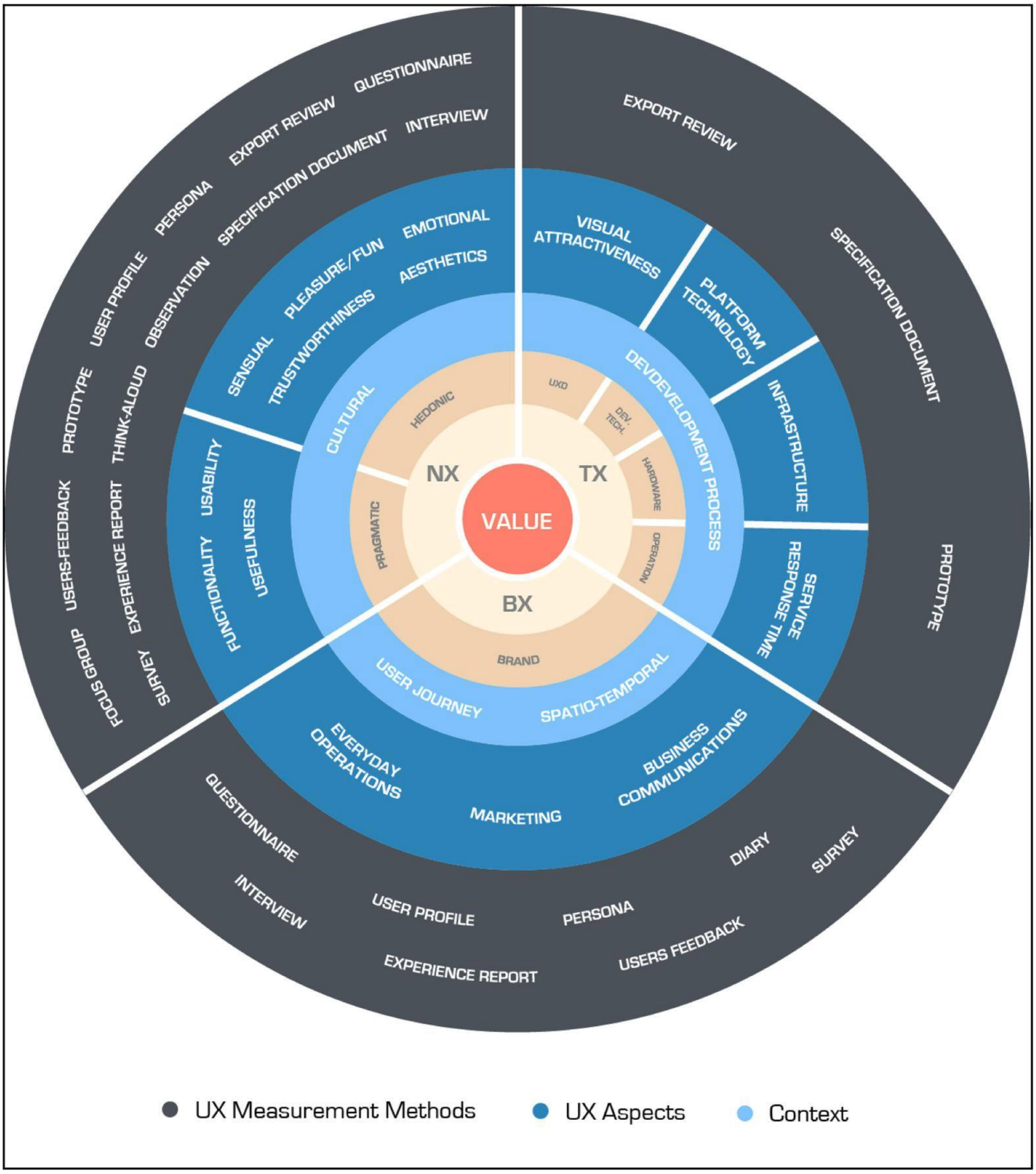


Figure 7.6: A framework that covers gathered UX dimensions, aspects categories, aspects, and measurement methods (Zarour and Alharbi, 2017).

From the review of the UX models and frameworks, several similarities and common attributes were discovered. The following are the most prominent observations regarding the notation used:

- There was very often a central focus point.
- Rectangles were often used to contain the concepts/elements/attributes of the model/framework. However, the rectangles could be circles or ovals, as they serve the same purpose; a container to separate each concept, element or attribute from one another.
- Arrows were used to signify a relationship between concepts/elements of the model/framework or a flow of progression from one concept/element to the next or general flow of the model/framework which prompted the viewer to follow that flow.
- Most of the models and frameworks required additional reading, explanations, or legends to fully comprehend.

These observations were influential in the initial development of the UX360 framework. It seemed appropriate to integrate tried and tested structural attributes of existing UX models to assist in the general understanding of the UX360 conceptual framework. It was also important to consider negative aspects of the models and frameworks in an attempt to make the UX360 conceptual framework as intuitive as possible.

At the conclusion of the analysis of the models, it had become apparent that the inclusion of familiar structural elements and an accompanying text, in the form of a word model – a description of each concept or construct in the framework, would be required to ensure an adequate understanding of the final UX360 conceptual framework.

7.2 The initial conceptual framework – the UX360 framework

The basis for the initial conceptual framework was the seven themes which had emerged from user study one, the sub-themes which belonged to the seven themes from user studies one, two and three, the framework for understanding UX of panoramic video from user study two, what had been learned from the case study in terms of 360° filming literacy and the knowledge gained throughout the research. This was all synthesised into the UX360 conceptual framework which is presented in Figure 7.7. Features of the framework have emerged from each user study. User study one provided seven themes which were integrated into the various groups. User study two discovered device/viewing platform specific themes, some of which built on those found in user study one. CAVE specific themes were not included as the framework was to be general and not based upon the UX of any particular device or viewing platform. The cinematic literacy case study explored 360° video filming techniques and uncovered the importance of film language in the UX of 360° video. Finally, user study three helped to provide confidence in the thematic analyses results of the previous studies by returning similar results using the IPQ before going on to develop the UX360 framework.

The initial conceptual framework, version 1.0, (Figure 7.7) was devised with reference to the data and results from the user studies and summarises the data which included mind maps, thematic analyses of interview transcripts, thematic maps, viewer response profiles, radar diagrams and conceptual models. The conceptual framework was produced in order to consolidate the prominent themes and concepts from the user studies into a single visual representation. The themes and concepts were chosen by the frequency of which they were referred to during the interview stage of the user studies and from the results of the IPQ; high scores in specific categories (see Chapters 4, 5 and 6 for further details).

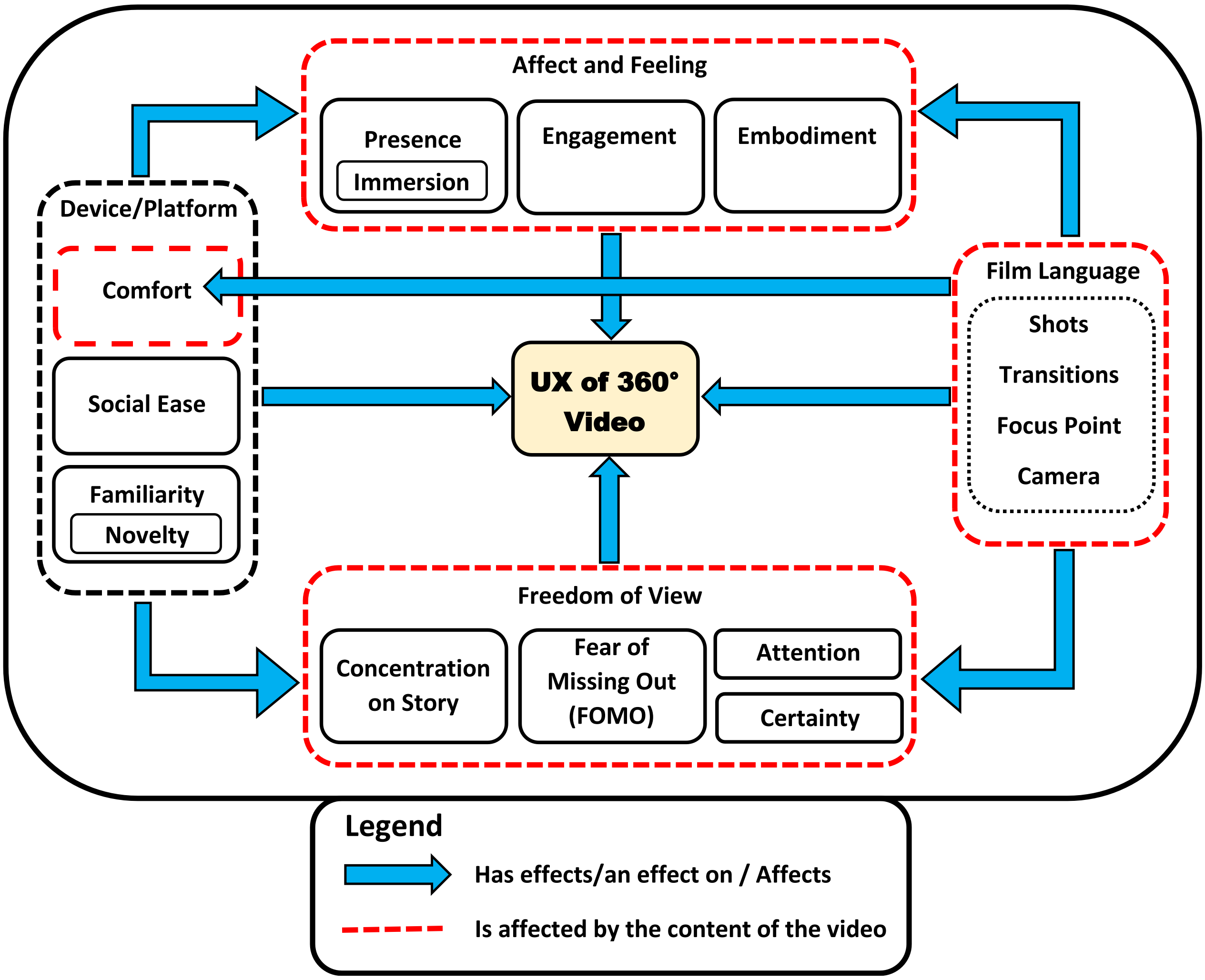


Figure 7.7: The initial User Experience of 360° video conceptual framework (version 1.0) – The UX360 framework.

At first, the prominent themes and concepts, in word form, were separated and sorted into groups which bore similarities. The contents of the groups were iteratively refined by amalgamating them into similar themes and concepts until they were satisfactorily distributed into a number of groups which had the closest associations to each other. Each of the four resulting groups were then given a name based upon what best described the contents of the group e.g., Film Language contains shots, transitions, focus point and camera. The final four groups were 'Device/Platform', 'Affect and Feeling', 'Film Language' and 'Freedom of View'. The groups and their contents were decided and placed into rectangles, similar to user study two (Figure 7.8: A group of themes.).

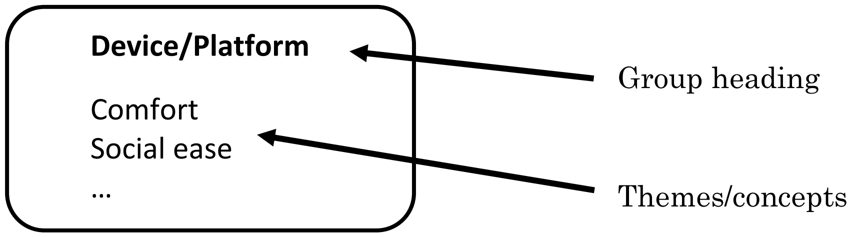


Figure 7.8: A group of themes.

To assist the understanding of the conceptual framework, Figure 7.9 displays all of the attributes which appear in the conceptual framework.

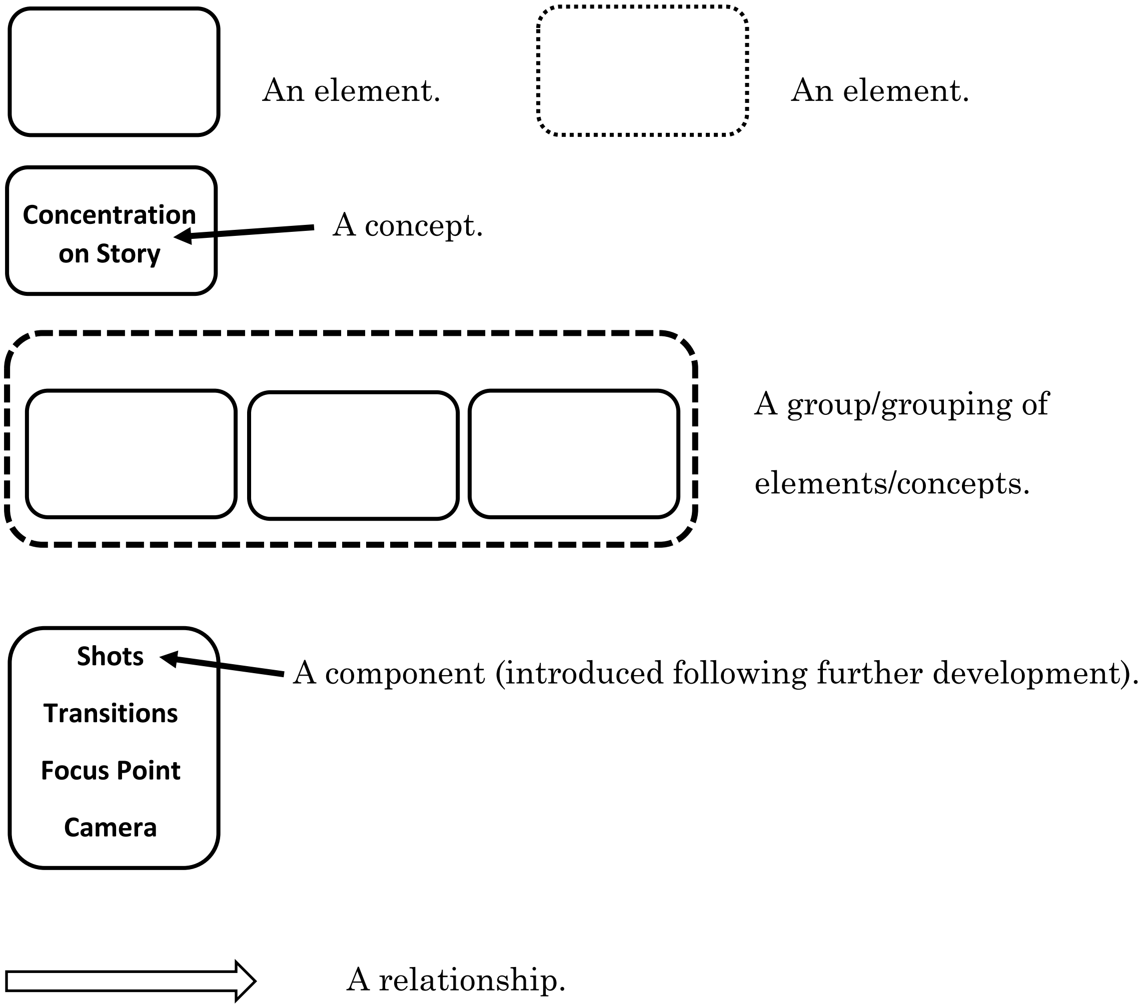


Figure 7.9: Attributes which appear in the conceptual framework.

Although the themes and concepts belonged to the group, it was felt that there was a requirement to signify that the themes and concepts were individual and had differences that should be made clear; even though they were connected by the group heading. Therefore, it was decided to separate them from each other. To this end, concepts which made up the groups were placed into rectangles with curved corners. In terms of the conceptual framework, these are referred to as 'elements' (Figure 7.9).

Continually, the groups of concepts, and some concepts which were contained in each group, could affect, or have an effect on groups of concepts or concepts within other groups. Therefore, a relationship between these groups was required to be represented in the framework and arrows were used to denote the relationship. The relationships between the groups were directly based on findings from the series of studies. For example, what participants had said about how the HMD allowed more focus and attention on the video and less distraction from the actual world – [Device/Platform effect on Attention].

One particular group, 'Film Language', is connected to an individual element, 'Comfort', in the 'Device/Platform' group via an arrow. This relationship is an exception, as in every other relationship, a full group of elements affects another full group of elements. The arrows also connect each group, individually, to the central focus point of the conceptual framework, namely the 'User Experience of 360° video'.

The groups are surrounded by a round cornered rectangle which has a dashed line. This is used to differentiate the groups from the individual concepts of a group; words surrounded by round cornered rectangles which have a solid black line. Some concepts within a group contained another concept which was also a word contained in a round cornered rectangle with a solid black line. These signified a concept which was very closely related to, or had been often mentioned together in the user studies with, the containing concept e.g., 'Familiarity' which contained 'Novelty'. The size of these rectangles has no significance other than to fit within the larger rectangle. Similarly, the 'Attention' and 'Certainty' rectangles are smaller in order to fit better and provide a more uniform appearance in relation to the rest of the groups and the framework overall.

The legend provides meaning to the arrows with respect to which grouping they originate from and to which grouping/element they are pointing to. For instance, there is an arrow which originates from the 'Film Language' group. The arrowhead is pointing towards the 'Freedom of View' grouping. With the use of the legend, this connection of the 'Film Language' group, to the 'Freedom of View' group via an arrow is interpreted as 'Film Language' [Has an effect on] 'Freedom of View'. Furthermore, one can extract a single element from the 'Film Language' group and, via the same process, arrive at the understanding of, for example, 'Shots' [Affects] 'Concentration on Story' or 'Focus Point' [Has effects on] 'Attention'.

It was noticed that the Film Language group did not contain concepts as the other groupings did. What this group contains are actually components of film language. Therefore, to differentiate the non-concept contents of this group from the other groups, the surrounding rectangle of the film language element is a dotted black line.

Of the four groupings of elements, 'Device/Platform', 'Affect and Feeling', 'Film Language' and 'Freedom of View', one group, 'Device/Platform' is surrounded by a dashed line which is the colour black. The other three groups of elements are surrounded by a dashed line which is the colour red. The significance of the red dashed line which surrounds the three groupings, 'Affect and Feeling', 'Film Language' and 'Freedom of View', is that these groups are affected by the content of the video. A single element, which belongs to the 'Device/Platform' group, is also surrounded by a red dashed line, namely 'Comfort'. This is due to the fact that

‘Comfort’ can be affected by the content of the video. This important addition to the UX360 framework was implemented as, while analysing the user study findings and developing the conceptual framework, it became very common to consider the extent to which an element or grouping could be affected depending on the content of the video.

The content of 360° video, as with any video, movie, or programme, can vary wildly and will affect some or all of the specified groupings/elements in various ways and to various extents. What follows are some examples of how content affects the groupings and elements which are depicted by their surrounding dashed red line.

The video used in the user studies (Chapters 3, 4 and 6), The Resistance of Honey, provoked some interesting responses from many of the participants. Some felt slightly uncomfortable due to the proximity of the bees in one particular scene which was inside a beehive and used an extreme close up of the bees moving around inside the hive; the effect of content on ‘Comfort’. Some participants mentioned that one scene, where the camera was situated quite close to the floor and featured the entrance to the hive at a relatively close proximity, made them feel small; the content can affect the ‘Affect and Feeling’ and ‘Film Language’ groups. The effect on ‘Affect and Feeling’ here is quite obvious as it affected the participant’s ‘Embodiment’. However, the way in which ‘Film Language’ is affected is slightly more complex. The film language used, i.e., the choice of the low camera position, was a choice made based on the producer’s idea of what they wanted to be included in the video (content). Therefore, that content producer’s idea of what they desire to be a part of the content of the video affects the film language which is/was used.

It was often mentioned by participants that they were not sure where they should be looking while watching the video. The shots used in the numerous scenes of the video were quite different to each other, especially when following a transition. In most instances of a scene which followed a transition, the view was centred on the point of interest which was relative to the narration. However, the participant was free to look in whichever direction they wanted before, during and after the transition, as there were lots of points of interest in most scenes of the video; the effect of content on 'Freedom of View'. There are many more examples of how the content of the video affected the viewer, some of which can be found in the user study chapters (Chapters 3, 4 and 6) and the published papers (Appendix A) as direct quotes from participants of the user studies.

7.4.1 The final UX360 framework

Having reviewed the first version of the framework, more thought was given to which aspects of the framework were a part of the user experience and which aspects were external. As a result, the conceptual framework was refined to define aspects which were external to user experience. Hence, a new element was introduced to the framework which replaced the central focal point element 'UX of 360° video'; the 'Hardware / Device Used to View 360° video' (attributes of the framework can be reviewed in Figure 7.9).

The hardware/device used to view 360° video:

- Has effects on the user experience of 360° video.
- Is external to the user experience of the actual 360° video.
- Is not considered an element of the user experience of the 360° video as far as the UX360 framework is concerned.

The hardware/device is the vehicle which enables the user experience of the 360° video and could be any piece of hardware or any device, each with their own user experience. The hardware/device has effects on, or affects, the groups and elements of the UX of 360° video framework and these are what contributes to the overall user experience of the 360° video (not the user experience of the hardware/device itself). So rather than being a part of the user experience of 360° video, and therefore inside the boundary of the User Experience of 360° video area in the framework, the hardware/device used to View 360° Video is external to that area. The framework aims to identify the elements of the user experience of 360° video and their relationships but does not aim to define those relationships; the user experiences of devices is limited to viewing 360° video only.

Similarly, the Film Language group is not a part of, and is external to the user experience of 360° video. The components of the Film Language group have an effect on, or affect, the user experience of 360° video. However, unlike the three other groups, they are not a subjective element of the experience. As a result, the Film Language group is situated outside the boundary of the User Experience of 360° Video area.

Finally, the Device/Platform group has been renamed to 'Device Effects'. This was a result of the aforementioned developments which accentuated the differences in the user experience of the hardware/device and the user experience of the 360° video. The hardware/device used to view 360° video has effects on the elements of the Device Effects group which in turn affect the user experience of the 360° video.

In order to ensure the framework could be equally readable in grayscale and by colourblind readers, some additional cosmetic changes were implemented. The groups and element which are affected by the content of the video are now also shaded light grey. This shading differentiates the affected groups and element from the Device Effects group - which has a black dashed line surrounding the group and is not shaded. The final UX360 conceptual framework is presented in Figure 7.10.

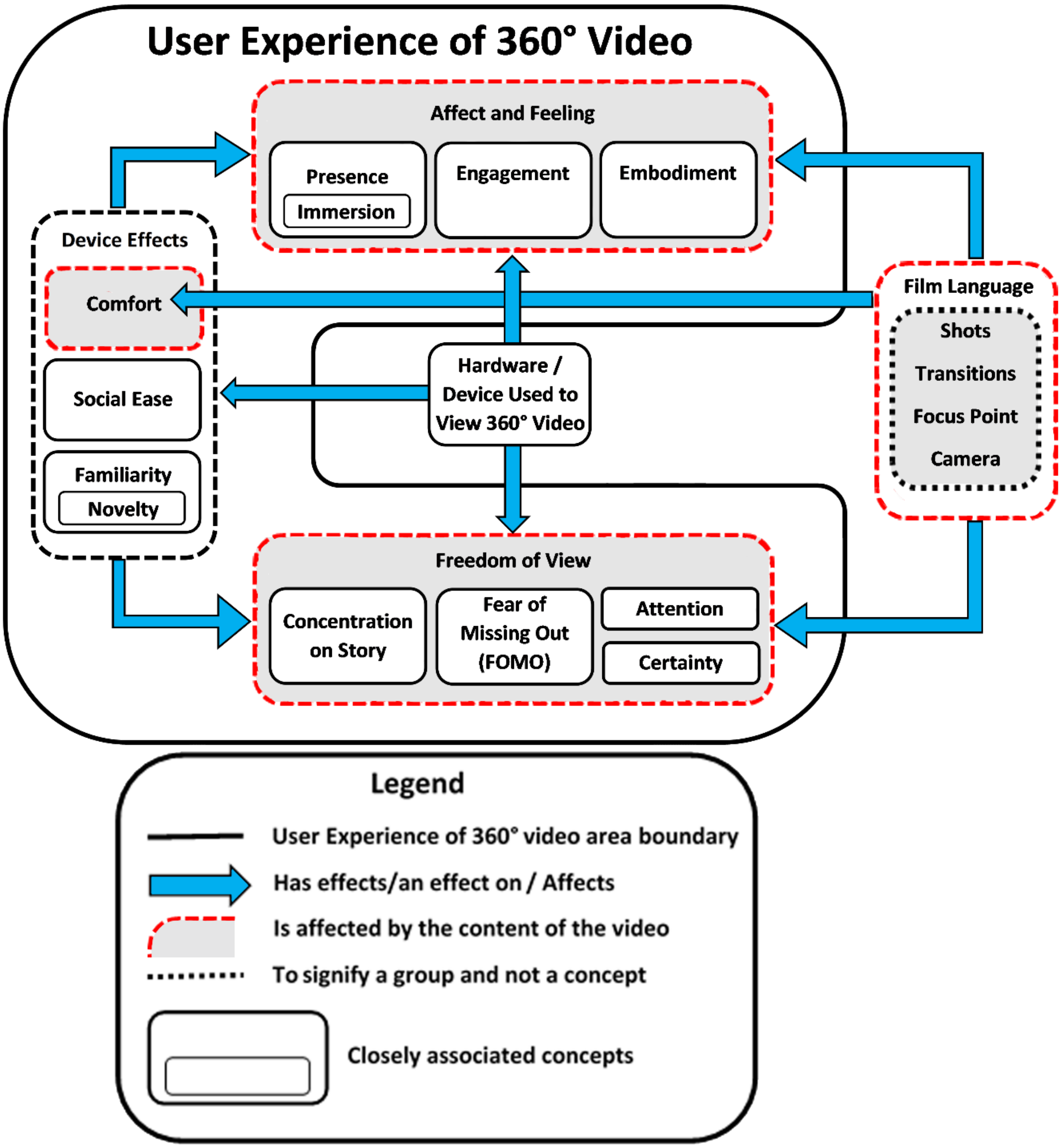


Figure 7.10: The final UX360 framework (version 2.0).

7.4.1.1 A note on 'Affect and Feeling'

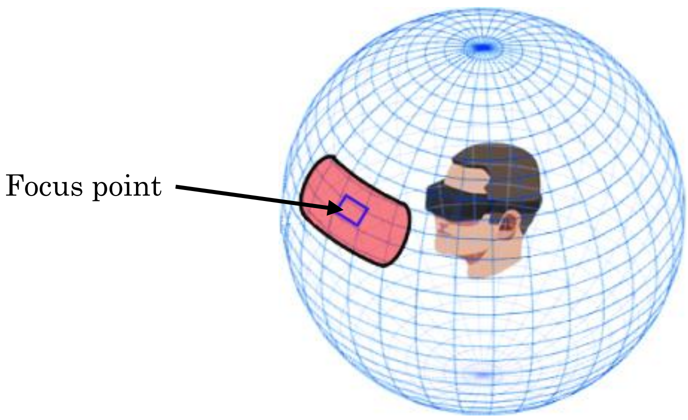
The terms 'affect' and 'feeling' have been used together as a group heading in the UX360 framework. These terms are often used interchangeably and sometimes without realising that there is a difference between them, though they are closely related. It is beyond the scope of this theses to delve into the definitions, meaning and discussion around 'affect', 'emotion', 'feeling' and 'mood'. However, some clarification is forthcoming. According to Shouse (2005), "An affect is a non-conscious experience of intensity; it is a moment of unformed and unstructured potential… Affect is the body's way of preparing itself for action in a given circumstance by adding a quantitative dimension of intensity to the quality of an experience." And "a feeling is a sensation that has been checked against previous experiences and labelled. It is personal and biographical because every person has a distinct set of previous sensations from which to draw when interpreting and labelling their feelings" (Shouse, 2005). Where the UX360 is concerned, 'affect' relates to the affect that the particular concept has on the viewer and 'feeling' relates to the resulting feelings that the viewer experiences through exposure to the particular concept.

7.4.2 The UX360 Word Model

A word model is a clear statement and description of each concept or construct in the framework. The contents of the word model are produced from the results of the user studies and includes information which was derived from the experiences of the participants of the user studies.

The word model follows no particular ordering of groups – they were arranged to fit wholly onto the pages. Each group will be presented along with the elements contained within that particular group ordered from either left to right or top to bottom, dependent on the structuring of the group (attributes of the framework can be reviewed in Figure 7.9).

Group: Device Effects	
This group is a collection of concepts which relate to the device or platform used to view the 360° video. Devices and platforms may include, but are not limited to, HMDs, Smart Phones, CAVEs, Flat Screen Monitors, Projectors and Tablets.	
Element	**Description**
Concept - Comfort	The physical comfort of using the device when wearing/handling the particular device. In relation to the content – the psychological comfort of the user as a response to the content of the video; what they have seen or heard, and how that makes them feel.
Concept - Social Ease	How the user feels when using the device in the presence of other people; familiar people – at home, work etc., and/or strangers – on the bus, in social spaces e.g., coffee shop etc.
Concept - Familiarity	The user has/has not experienced using the device before. The user is/is not familiar with VR/AR technology and or 360° video in general. The user owns the particular device used to view the 360° video and is accustomed to how to use it and the viewing experience with the specific device.
Concept - Novelty	The novelty of the device used to view the 360° video. The user may not have used the viewing device in the past. The device may: be a technology not encountered by the user before; enable a method of viewing or type of media which the user may not have experienced before; be completely new to the user e.g., VR, AR 360° video.

Group: Film Language	
This group contains a single element which is comprised of several components of film language which are likely to all be utilised when producing 360° video footage. Each component within the element contains further sub-components which are not listed here in an exhaustive measure; some examples are provided (specifics of each component may be investigated further by the reader).	
Element	**Description**
Component - Shots	The type of shot selected to capture footage for the respective scene. For example, long shot, close-up, wide shot etc.
Component - Transitions	The transitions used between scenes of the video. For example, fade in/out, jump cut, cutaway etc.
Component - Focus Point	The focus point can be one or more of the following: • The centre of the view which the viewer sees when their head is stationary in its 'natural' position looking straight ahead Figure 7.11. • The location in the scene where the view is directed when the respective scene begins, and the viewer's head is stationary in its 'natural' position looking straight ahead. • The location in the scene where the viewing direction of the viewer is intended to be.
	 Figure 7.11: The approximate suitable area for the focus point (Adapted from Chakareski et al., 2018).
Component - Camera	Any attribute relating to the camera which includes, but is not limited to: • The position of the camera i.e., height, location, direction, • The type of camera used i.e., monoscopic or stereoscopic, • The quality of camera used, • The type of lens used e.g., fisheye.

Group: Affect and Feeling	
This grouping contains the most prominent concepts which pertain to the effects and feelings that the user experiences when watching a 360° video.	
Element	**Description**
Concept - Presence	The presence experienced by the viewer when watching the 360° video.
Concept - Immersion	The immersion experienced by the viewer when watching the 360° video.
Concept - Engagement	The engagement of the viewer with the environment, and/or the characters, and/or the story/narrative of the 360° video.
Concept - Embodiment	The viewer's feeling as though they are embodied as themselves, a character or an actor in the 360° video. This also applies when an avatar or representation of a body is not apparent in the 360° video.

Group: Freedom of View	
This group contains concepts which are related to the freedom of view which a viewer can experience when viewing a 360° video. The freedom of view is under the control of the viewer and the method used to control the view varies with the device used to view the 360° video.	
Element	**Description**
Concept - Concentration on Story	The viewer's ability to concentrate on and understand what is happening in terms of the story or narrative of the 360° video.
Concept - Fear of Missing Out (FOMO)	The feeling of not knowing if something else is happening somewhere else in the video/scene, i.e., not in the direction that the viewer is looking, when a viewer is watching a particular scene and is viewing in a particular direction. This creates a fear of missing out on some important action, dialogue, detail, or information which is critical to the understanding of the narrative or story.
Concept - Attention	The viewer's ability to pay attention to what is happening in the video without being distracted by the opportunity/ability afforded to look in any direction that they desire (other distractions such as environment, phone notifications etc. are included).
Concept - Certainty (of where to look/what to look at)	Whether the viewer believes that they have focussed on where they are expected to be looking (as intended by the content producer) in order to see what they are expected to be seeing (as intended by the content producer).

7.5 Proposed usage of the final conceptual framework and word model

This section is divided into two sections; Section 7.5.1 is primarily focussed on how the UX360 framework can assist researchers in the field to further their research into the user experience of 360° video. Section 7.5.2 is concerned with eliciting and providing considerations from the UX360 framework in order to assist 360° video content producers with their productions.

7.5.1 Research directions derived from the final UX360 framework for researchers

It is envisioned by the author that the UX360 framework can be used by researchers to conduct further research into the UX of 360° video. On the surface, the framework provides an understanding of which individual, and groups of, elements and components have effects on other individual, and groups of, elements in the framework. However, further investigation of such effects and their results could prove to uncover a greater understanding of the UX of 360° video.

This section presents and discusses some research directions derived from the final UX360 framework which were of interest to the author. There are many possible combinations of elements and components in the framework to test, by way of experimentation, to discover the effects on other elements of the framework. Such research could be undertaken to investigate how useful the UX360 framework is as a tool to research the UX of 360° video. The UX360 framework could be used to plan experiments, develop hypotheses, and possibly discover new elements, concepts, themes, and components to add to and expand the framework.

7.5.1.1 Manipulation of the Film Language group components

The manipulation of a single component from the Film Language group may have an effect on any single, and possibly every, element [concept] in the Affect and Feeling group.

Example i

By manipulating the height of the camera [Camera (component) – Film Language (group)] the user's perception of self [Embodiment (concept) – Affect and Feeling (group)] in the virtual environment (360° video) will be affected. If the camera was to be placed very high up in the scene, it is expected that the viewer would feel very tall, as the camera height is often positioned at an average eye level. It would be expected that the viewer would get the feeling that they are looking down on the scene. Conversely, if the camera was to be placed very low down in the scene, it is expected that the viewer would feel very short (Philpot, 2017).

Example ii

The specific transition [Transition (component) – Film Language (group)] used by the producer in their video will affect the presence [Presence (concept) – Affect and Feeling (group)] experienced by the viewer; sometimes negatively. If a transition, for example a jump cut, abruptly changes the environment, height of camera, direction in which the viewer is intended to be facing, proximity of the viewer to the subject or a combination of these attributes, any presence which the viewer was experiencing can be abruptly ended.

7.5.1.2 Device effects on Affect and Feeling and Freedom of View groups

The type of device used to watch the 360° video may have an immense effect on any, and most likely every, concept in the Affect and Feeling group and the Freedom of View group. This idea has been partly explored by the author in user studies (see Chapters 3, 4 and 6), and although it may seem obvious, the effects can range from very subtle to extreme, as can be observed from the results of the user studies.

Example i

It would be fair to assume that the majority of people do not own a VR HMD or equipment required to adapt their smartphone into a VR viewing device e.g., Google Cardboard. Therefore, further research into the UX of 360° video using flat screen devices e.g., monitors, smartphones, and tablets, is required. During user study three, it was quite surprising to discover that participants reported relatively high scores for presence when using a smartphone. Users reported higher than expected scores for spatial presence using the IPQ when viewing 360° video using a smartphone. These scores were higher than what was expected based upon qualitative results from the previous user studies (user studies one and two) which were executed by the author. However, it must be noted that these scores in particular were recorded after the video had been viewed on the smartphone first and before viewing the 360° video on a VR HMD; removing the opportunity for direct comparison to the arguably superior HMD viewing experience. This was not investigated in depth during, or after, the series of user studies and to investigate this further would be a worthwhile undertaking.

Example ii

The novelty of the device, especially where a HMD is concerned, can influence the intensity of a user's experience of a particular concept. For example, it is likely that a first time VR user will report very intense feelings of presence. This is expected due to the novelty of the experience. Further studies which could be executed over longer periods of time may provide differing results once the user is more familiar with the HMD and the experience of VR.

7.5.2 Considerations for 360° video content producers

This section will present considerations for 360° video content producers to bear in mind when creating 360° video. The considerations have been elicited from the UX360 framework, word model and from what participants said during the user studies carried out by the author and were chosen as a sample to represent each of the components from the Film Language group. Hence, the components from the Film Language group serve as the structure of the considerations, each of which begins with a title and statement which presents the subject matter for the content creator to consider. If any guidelines exist that relate to the subject, a respective reference to the 'FaceBook Better Practices for 360' blog and/or 'The Cinematic VR Field Guide' by Jaunt and/or the BBC's 'How do I make 360 videos?' article (BBC, 2022; Facebook, 2016; Jaunt, 2018) is stated. Following this, relative information from the UX360 framework in terms of concept/s, and component/s and the group to which they belong e.g., [Attention (concept) – Freedom of View (group)] is presented and discussed.

Consideration A – Shots

The choice of shots used in a video will undoubtedly have an impact on the overall user experience of 360° video and on most of the groups and their elements. Due to the vast number, and variations, of shots which could be used in the production of 360° video, this consideration is a broad suggestion for application when choosing shot types.

There is not much in the 'FaceBook Better Practices for 360' blog regarding specific shots. The following relates to a close-up shot, but is not a general statement:

> **Shooting Direct to Camera**
>
> Looking straight down the barrel of the lens has much more intensity in 360. Acknowledging the viewer this way can give the feeling of intimacy and closeness the way a close-up shot does in a 2D frame. Playing with this can be a powerful storytelling tool (Facebook, 2016).

When choosing a shot, take into consideration the various groups of concepts and bear in mind what the potential effects could be as a result of the particular choice of shot. For example, a close-up shot in a confined space could induce feelings of claustrophobia. This may be an effect which is desirable in order to increase presence [Presence – Affect and Feeling], immersion [Immersion – Affect and Feeling] and engagement [Engagement – Affect and Feeling]. However, due to the realism and heightened sense of presence and immersion that many viewers experience when viewing 360° video using a HMD, the negative effects should also be considered. It may be uncomfortable [Comfort – Device Effects] for some viewers and could lead to an overall negative experience. The discomfort could lead to distraction from the content of the video [Attention – Freedom of View] and cause the viewer to miss important details related to the story or narrative [Concentration on Story – Freedom of View] of the video.

Consideration B – Transitions

Similar to shots, due to the vast number, and variations, of transitions which could be used in the production of 360° video, this consideration is a broad suggestion for application when choosing transition types.

According to the 'FaceBook Better Practices for 360' blog, it is a good idea to minimise the number, and the nature, of cuts that a video has:

> **Minimize Cuts**
>
> Abrupt and quick cuts are very jarring. The editing techniques we are accustomed to don't always work well in 360. Gentle cuts with the subjects of a scene at a distance are the least disturbing. When the action is very close to camera, the abrupt cut can increase dizziness and story disorientation (Facebook, 2016).

The 'How do I make 360 videos?' article by the BBC states:

> If your 360 shot is interesting, a great deal of your audience's energy is spent exploring the scene. Keeping a high pace of edits, narration, and contributions from your subject while your audience are busy looking around will lessen the impact (BBC, 2022).

When a transition is used in a traditional video viewed on a flat screen, such as a television or computer monitor, the effect of the transition on the viewer is arguably very low or possibly negligible, dependent on the content, of course. For example, a transition which is used to cut from one location to another – inside a room to outside in a park. The viewer can understand instantly that the location has changed, a little time may have passed, and are generally able to adapt quickly to the new, different surroundings.

In the example of transitioning suddenly from inside a room to outside in a park, the viewer is likely to instantly understand that the location has changed. However, the sudden change may require more adjustment in comparison to the flat screen equivalent due to the user possibly feeling as though they have changed their position in space. This can be especially true if the focus point is not determined quickly by the viewer. The focus point may have been set in video production, but the viewer may have moved their head during the transition for some reason. These small movements can add to the time it takes to adjust to the new location and have varying effects on a number of the elements in the UX360 framework.

When viewing a 360° video using a HMD, the change in location, and change in space, is dramatically increased due to the viewer's FoV and visual disconnection from the actual world [Engagement – Affect and Feeling]. The viewer may be highly immersed [Immersion – Affect and Feeling] and currently experiencing high levels of presence [Presence – Affect and Feeling] leading into a transition. If a sudden transition, such as a cutaway occurs, an interruption of the scene with the insertion of another scene, possibly in a different location, which plays out and returns to the original scene, can lead to a viewer experiencing a sudden feeling of disorientation which can impact negatively on their experience. This is due to being, very suddenly, 'thrown' into an unfamiliar environment without warning or adequate opportunity to visually adjust to the new scene [Comfort – Device Effects]. The focus point, the position of the viewer within the scene, the other characters, the scenery, the narrative, all may have changed. The viewer is very likely to have the desire to look around to assess the environment and try to make sense of what is happening and to find the focus point [Film Language – Focus Point] by looking around [Attention – Freedom of View]. To this end, they may miss something important in terms of the story or narrative [Concentration on Story – Freedom of View] which is likely to arouse a feeling of FOMO [FOMO – Freedom of View]. This can leave the viewer feeling uncomfortable as a result of disorientation or motion sickness [Comfort – Device Effects]. They may also find it difficult to concentrate on the story [Concentration on Story – Freedom of View] and may become distracted [Attention – Freedom of View]; ultimately leading to a negative experience. For the same reasons as have been mentioned, other transitions to be wary of are jump cuts.

Consideration C – Focus Point

When the scene begins, regardless of transition used, the focus point [Focus Point – Film Language] should be where the 'action' is taking place. Alternatively, the focus point should be in the general direction of where the content producer wishes the viewer to be looking at the beginning of the scene.

The 'FaceBook Better Practices for 360' blog provides the following in relation to focus point:

> **Look This Way**
>
> If you want the viewer to focus on a particular action be sure to keep the canvas uncluttered and allow them time to realize where the action is. Once you have their attention, purposeful choreography will allow you to keep it (Facebook, 2016).

If the focus point is not established, the viewer will have no indication of where they should be looking and may become disorientated [Certainty – Freedom of View], become distracted [Attention – Freedom of View], miss important details related to the story or narrative [Concentration on Story – Freedom of View], and will spend time attempting to locate the 'action' which will very likely cause the viewer to experience FOMO [FOMO – Freedom of View], ultimately leading to a negative overall experience. A further consequence of a lack of a focus point is a negative effect on the viewer's sense of presence [Presence – Affect and Feeling].

The viewer will likely find themselves less engaged in the environment [Engagement – Affect and Feeling] due to constantly looking around, trying to detect the focus point, and attempting to make sense of their surroundings; additionally breaking the viewer's immersion [Immersion – Affect and Feeling].

Consideration D - Camera - position

Placement of the camera [Film Language - Camera] in any given scene is one of, if not the, most important things to consider as it can affect a large number of UX attributes in both positive, and negative ways.

According to the 'FaceBook Better Practices for 360' blog:

> **Camera Placement**
>
> Selecting the camera placement is one of your first critical decisions. Where you place the camera is where you place the viewer. Consider where the camera placement will best capture your story. What is happening in front, around and behind? What is compelling about seeing a 360 image in the world you are capturing? (Facebook, 2016).

'The Cinematic VR Field Guide' by Jaunt does not refer to camera placement explicitly. Rather, suggestions for what techniques and cameras to use for particular situations are mentioned:

> Likewise, when shooting in the confines of a car where things are going to be very close quarters you usually have a better shot using a smaller GoPro style rig and stitching the material in mono. Most cameras have a minimum distance to subject that you must respect in order to get a quality stitch and

these distances are generally greater when stitching in 3D. If you need to get very close to a subject it may be better to go the mono route (Jaunt, 2018).

A camera which is placed too high in relation to a viewer's general eye level can make the viewer feel tall. This can distract the viewer from the content of the video [Attention – Freedom of View] and cause them to miss important details related to the story or narrative [Concentration on Story – Freedom of View] of the video. In PoV shots, this can also provide a negative experience as a result of the viewer feeling uncomfortable [Comfort – Device Effects] due to vertigo or feeling taller [Embodiment – Affect and Feeling] than they actually are. Conversely, this can be used to achieve a positive effect where such an experience is desired. For example, if it is intended for the viewer to feel tall [Embodiment – Affect and Feeling] or for the viewer to be situated in, or feel as though they are in, a high location [Presence – Affect and Feeling].

A camera which is placed too low in relation to a viewer's general eye level can make the viewer feel short or small. This can distract the viewer from the content of the video [Attention – Freedom of View] and cause them to miss important details related to the story or narrative [Concentration on Story – Freedom of View] of the video. In PoV shots, this can also provide a negative experience due to the viewer feeling uncomfortable [Comfort – Device Effects] as a result of the unfamiliar feeling of being smaller or shorter [Embodiment – Affect and Feeling] than they actually are. Conversely, this can be used to achieve a positive effect where such an experience is desired. For example, if it is intended for the viewer to feel short or small [Embodiment – Affect and Feeling] or for the viewer to be situated in, or feel as though they are in, a location which is close to floor level [Presence – Affect and Feeling].

A camera which is positioned too close to the subject can cause the viewer to feel small. This feeling arises via the viewer's perception of the size of the subject/object/person that the viewer sees/experiences. If the subject/object/person appears to be larger than they would appear to the viewer in the actual world, this may cause negative effects in relation to how the viewer perceives themselves in the virtual environment. The feeling of being smaller than the viewer is in the actual world may cause discomfort and ultimately lead to negative effects which can distract the viewer from the content of the video [Attention – Freedom of View] and cause them to miss important details related to the story or narrative [Concentration on Story – Freedom of View] of the video. Conversely, this can be used to achieve a positive effect where such an experience is desired.

A camera which is positioned too far from the subject can cause the viewer to feel big or tall. This feeling arises via the perception of the size of the subject/object/person that the viewer experiences. If the subject/object/person appears to be smaller or shorter than they would appear to the viewer in the actual world, this may cause negative effects in relation to how the viewer perceives themselves in the virtual environment. The feeling of being taller or bigger than the viewer is in the actual world may cause discomfort and ultimately lead to negative effects which can distract the viewer from the content of the video [Attention – Freedom of View] and cause them to miss important details related to the story or narrative [Concentration on Story – Freedom of View] of the video. Conversely, this can be used to achieve a positive effect where such an experience is desired.

A camera which is positioned closely behind a subject or close up, over the shoulder of a subject from behind can cause the viewer to feel as though they are actually the subject performing the task/activity that the subject is undertaking [Presence – Affect and Feeling] [Engagement – Affect and Feeling] [Embodiment – Affect and Feeling]. A camera which is positioned close up in front of a subject can cause the viewer to feel as though they are participating in the task/activity/conversation that the subject is undertaking [Presence – Affect and Feeling] [Engagement – Affect and Feeling] [Embodiment – Affect and Feeling]. This can increase the viewer's engagement with the video in a positive way [Engagement – Affect and Feeling]. However, it should be considered that this can distract the viewer from the content of the video [Attention – Freedom of View] and cause them to miss important details related to the story or narrative [Concentration on Story – Freedom of View] of the video.

7.6 Summary

This chapter has presented some existing UX frameworks and models with some discussion in terms of structural attributes. Following this, the development of the UX360 framework from its initial form through to the final version is shown. The features of the development have been discussed, along with the conceptual framework in its final form. An accompanying word model has also been presented which is directly associated with the UX360 framework. Finally, the usage of the UX360 framework and word model has been outlined using research directions and considerations derived and elicited from the UX360 framework.

Chapter 8 Conclusions and future work

This research has culminated in the UX360 framework, the User Experience of 360° video conceptual framework, and its accompanying word model. The proposed use for the UX360 framework is to inform 360° video content creators and researchers with valuable information to consider when creating 360° video and further researching the UX of 360° video respectively. This chapter will conclude the thesis with a discussion about the contribution to knowledge, conclusions, and future work.

8.1 Chapter conclusions – Contributions to knowledge

During this thesis, a number of research questions were asked. The answers to these research questions have been answered in Chapters 3 – 6 with the development of various models and frameworks from the data produced by user studies and case study. Chapter 7 synthesises all of the contributions to knowledge into the UX360 framework and accompanying word model.

Chapter 3 presents the first of the three user studies which addressed research question one – How does platform affect the user experience of 360° video when viewing a 360° video on a PC, phone, or VR headset?

This was an exploratory study which used three viewing devices: a HMD, a smartphone and a flat screen. The study established the themes and concepts that would feature throughout the research for this thesis. The results of the study did not provide a single answer to the research question, more so a range of experiential responses were elicited from the participant responses, culminating in an initial understanding of user experience of 360° video via a series of mind maps, the seven themes, and a viewer response profile. The viewer response profile is a radar diagram which displays the seven themes and summarises the responses of the participants in an easy-to-read format, providing the viewer with an overview of how much each particular theme was referred to by participants in their interviews. This user study was the basis for the conference paper entitled "Effects of Viewing Condition on User Experience of Panoramic Video" by Passmore, P.J., Glancy, M., Philpot, A., Roscoe, A., Wood, A., Fields, B., 2016. (Passmore et al., 2016).

The user study in Chapter 4 introduced a unique viewing platform, the CAVE and aimed to answer research question two – How does platform affect the user experience of 360° video when viewing a 360° video on a VR headset or in a CAVE?

This research question was answered with a wide range of responses from the participants of the user study. The effects of the platform on user experience of 360° video were quite varied and both positive and negative. The CAVE evoked some interesting and unique themes which provided a good basis of comparison to the HMD – some of which were completely unique to the CAVE. Some similar themes to those discovered in the first study also emerged and helped to clearer define the user experience of 360° video on a range of devices. The recurring themes provided good support to a developing understanding of the UX of 360° video. The themes and findings were presented in a framework for understanding user experience of panoramic video in a HMD and CAVE. The framework accentuated the prominence of presence as the central theme of the UX of 360° video. This user study was the basis for the conference paper entitled "User Experience of Panoramic Video in CAVE-like and Head Mounted Display Viewing

Conditions" by Philpot, A., Glancy, M., Passmore, P.J., Wood, A., Fields, B., 2017. (Philpot et al., 2017).

Chapter 5 sought to answer research question three – What can be inferred about 360° cinematic literacy following user studies one (Chapter 3) and two (Chapter 4)?

The chapter presented a case study which investigated the film literacy of 360° video in relation to the user studies which had been carried out up to that time. The case study resulted in a further model which contributed to the overall visualisation of the UX of 360° video. The resulting model of user experience in the sensemaking of 360° video via HMD viewing depicts the experience of presence in the 360° video and its relation to making sense of the video in terms of classic film literacy and 360° film literacy, highlighting the differences between the two. This case study was the basis for the conference paper entitled "Cinematic literacy: A case study" by Passmore, P.J., Glancy, M., Philpot, A., Fields, B., 2017 (Passmore et al., 2017).

Chapter 6 presented user study three, in which the protocol was adapted to include a quantitative method in addition to the qualitative methods used to analyse the study results. The research question four – Does quantitative measurement of presence support the results returned from the methods used in the qualitative studies – study one (Chapter 3) and study two (Chapter 4)? – was the focus of this chapter.

The quantitative method used was a popular questionnaire in the field; the IPQ. The IPQ has been administered in a number of studies since its creation in the late 90s/early 00s (Alapakkam Govindarajan et al., 2022; Alsina-Jurnet et al., 2011; Ling et al., 2013, 2012; Men et al., 2017; Riecke et al., 2009, 2005; Schaik et al., 2004; Schwind et al., 2019). Following a thematic analysis of the interview transcriptions, and a statistical analysis of the IPQ results, it was evident that the questionnaire results supported the themes and concepts from the thematic analysis as well as the themes which had emerged throughout the user studies. Additionally, the administration and analysis of the IPQ proved to be a more efficient way of investigating presence in terms of time spent. Following the analysis and review of the questionnaire results, participant interview transcripts and thematic analysis, it was clear that the quantitative IPQ results did support the qualitative thematic results, especially in terms of presence, ultimately providing confidence in the user study results which would be used to inform the conceptual framework.

Chapter 7 addresses research question five – Can a model or conceptual framework of user experience of 360° video be developed in order to inform content creators and researchers?

The chapter presents the initial conceptual framework, it's structure and elements. The development of the framework and its modifications are detailed, leading to the final version of the UX360 framework – a conceptual framework which aims to inform researchers and 360° video content creators about the user experience of 360° video. User studies one and two, and the case study had all provided visual results which contributed to the final conceptual framework. User study three was able to reinforce the themes that had been found throughout the series of user and case studies as well as provide statistical support to the main concept of presence. All the results were synthesised into the UX360 conceptual framework; a novel contribution to knowledge. The UX360 framework is accompanied by a word model, along with some examples of proposed usage of the framework for both researchers and 360° video content creators. The research question was answered by the creation of the UX360 framework and its accompanying word model which intends to provide an understanding of, and valuable information about, the UX of 360° video to 360° video researchers and content creators.

The UX360 framework is a conceptual framework which presents the predominant elements (concepts and components) of the user experience of 360° video and their relationships to each other. The accompanying word model provides explanations of the elements i.e., the concepts, groups of concepts and components of the UX360 framework, to assist in the understanding of the UX360 framework. Additionally, over the course of the research, four conference papers were published and presented at their respective conferences. The published papers can be found in Appendix A.

The UX360 framework and word model can be utilised by both researchers and 360° video content producers. The UX360 framework and word model provide research directions to 360° video researchers and considerations to 360° video content creators; assisting in the understanding of the UX of the relatively new media. By understanding which elements of UX are affected by choices made in 360° video production, content creators can tailor their choices in filming techniques to achieve specific effects on particular experience elements. For example, if a content creator wishes to disorientate the viewer, they could manipulate the Focus Point of the video, in the Film Language Group; affecting the Attention, Certainty and Concentration on Story elements in the Freedom of View group. Alternatively, the choice of shot can affect multiple elements of the user's experience of 360° video by providing feelings of Presence or Embodiment, or by assisting the viewer to focus on parts of the scene that they wish the viewer to pay attention to. Researchers can use the UX360 framework and word model as a reference to provide knowledge within the domain and opportunity to further investigate the concepts and filming components and the effects that they have on each other according to the framework.

Although presence was found to be the central theme of the UX of 360° video following the execution of the user studies, additional insights into the UX of 360° video were also discovered. The filming techniques chosen and their application to the 360° video during production can have profound effects on the viewers experience of the video, some of which are not connected to presence. For example, the frequency of transitions between scenes can impact the viewer's attention and ability to concentrate on the story, the height at which a camera is positioned can affect how tall or short a viewer feels while watching the video, and where a viewer actually chooses to focus their attention can affect their understanding of the video and provide FOMO; which can lead to a negative experience. The UX360 framework and word model highlight prominent experiential elements of the UX of 360° video and endeavours to provide research directions and considerations to further explore those elements.

8.2 Limitations

The user studies which were carried out during this research (user studies one, two and three) all used the same 360° video in all of the viewing conditions. This was a limitation of the research as it was from a single genre i.e. a documentary. The repeat viewing of the same video in all viewing conditions made the user susceptible to viewing fatigue whereby they knew what to expect and may have not liked the content on the first viewing and then had to watch it again. This was less evident when participants used a more novel device (such as the HMD) when viewing for the second time, however.

All of the user studies were carried out using a relatively small number of participants; user study one – 24 participants, user study two and three – 16 participants each. Although they were exploratory studies, a higher number of samples is always advantageous in order to elicit more compelling results.

When coding the qualitative data, inter-rater reliability was carried out by other members of the research team. The data was coded by the author and one, and in user study one, two, of the members. The resulting codes were then compared and discussed. However, established measures of inter-rater reliability, such as Cohen's kappa or Fleiss' kappa, were not applied. In retrospect, these measures could have provided even more validity to the results of the thematic analyses.

Finally, there was no objective data gathered from participants during the user studies; only subjective self-reported data. An objective method of data collection, such as eye-tracking would be a good consideration for future work. This would provide some further opportunity for investigation and analysis.

8.3 Future Work

The research did not extend to testing the UX360 framework in terms of reliability and effectiveness in relation to its aims. Therefore, future work would include identifying some 360° video content producers and providing them with the UX360 framework and word model and gathering feedback on the effectiveness of the framework and word model in terms of their 360° video production. The proposal of execution would be to use a case study approach which would include interviews with the producers and the producers keeping a log of the decisions that were required to be made and whether they consulted the framework and word model. If they did consult the framework and word model, how they implemented them and the effects that they had on the production would be recorded. This would provide data to the author with which to assess the impact that the UX360 framework and word model had on the production of the video. It could also inform any improvements or modifications to the framework and/or word model.

It could be possible for a 360° video creator to produce a 360° video following the considerations presented in the thesis (Chapter 7, section 7.5.2). They could also make a video which does not follow the considerations or does the opposite to them. The two videos could be viewed by participants of a user study to investigate the user experience of the videos and whether the video which used the considerations was preferred to the video which did not use them. The participants could also carry out questionnaires such as the IPQ and results could be analysed and compared. The results of the user study could provide some further confidence in the considerations. Furthermore, the UX360 framework, word model and considerations could be shown to various 360° video creators in order to receive feedback on the content and expected application. Questions could be asked such as whether they would employ any of the considerations in their filmmaking, how useful they find the UX360 framework and word model, and suggestions for possible improvements or whether they believe anything is missing.

There is arguably a lot more future work for researchers as the framework can be tested in several ways by way of user studies. It has been mentioned previously that by manipulating individual filming components, the effects on individual, and groups of, concepts could be tested. Such testing would really discover whether the framework is reliable and justified; as well as the potential discovery of other effects which were not uncovered in the user studies carried out in this research.

The user studies which were carried out in this research were all conducted using a single 360° video. It would be good to carry out the user studies again, following the same protocols and research methodologies, with several different videos from various genres and investigate the results. Comparisons could then be made to the findings from the collection of user studies in order to discover similarities, differences and possible nuances relating to particular genres, filming techniques or shot and transition types which were used. The results could be used to modify or improve the UX360 and could provide further understanding of the user experience of 360° video.

Another investigation to carry out would be to discover whether the UX360 framework can extend to AR. This research did not cover AR in any capacity (though AR has been experienced through other non-connected research work) and concentrated on the user experience of 360° video using VR and the comparison with other devices. AR provides a completely unique experience whereby the virtual world is mixed with the actual world. This would bring with it multiple avenues of investigation including questions such as how is a user's attention affected?, how would the video be viewed?, and would the video be stationary or 'mounted' somewhere similar to a TV? Devices including a flat screen, smart phone, CAVE and HMD were investigated during the user studies and were focussed on VR. Viewing 360° video using AR would be an exciting area to research and could lead to the development of a completely different, unique framework for the UX of 360° video in AR.

The domain of VR and AR is continually growing, improving and changing day to day with more powerful and more accessible technology. The devices will always need content for the consumer and 360° video is just one media to consume with the new and powerful devices. Creating entertaining and enjoyable experiences for these devices is very important and requires information and guidance in order to achieve such goals. The UX360 framework and word model can be used to help to achieve these goals, improve the quality of 360° video content and assist the research of the UX of 360° video.

References

360Rize, 2021. 360Penguin - 360° Action Camera [WWW Document]. URL https://shop.360rize.com/product/360-penguin/ (accessed 6.25.21).

360Rize, 2019. 360RIZE Pro10B 360° Plug-n-Play Rig for GoPro™ HERO4/3+/3 [WWW Document]. 360Rize. URL https://shop.360rize.com/product/360rize-pro10b-360-plug-n-play-rig-for-gopro-hero4-3-3/ (accessed 8.16.20).

Aboulafia, A., Bannon, L.J., 2004. Understanding affect in design: an outline conceptual framework. Theor. Issues Ergon. Sci. 5, 4–15. https://doi.org/10.1080/1463922031000086708

Affinity Media Inc, 2016. EYE™ Professional VR Camera – Full 3-Axis Package [WWW Document]. Affin. Media Inc. URL http://360designs.io/product/eye-vr-camera-full-3-axis-package/ (accessed 8.16.20).

Afzal, S., Chen, J., Ramakrishnan, K.K., 2017. Characterization of 360-degree Videos, in: Proceedings of the Workshop on Virtual Reality and Augmented Reality Network - VR/AR Network '17. Presented at the the Workshop, ACM Press, Los Angeles, CA, USA, pp. 1–6. https://doi.org/10.1145/3097895.3097896

Alapakkam Govindarajan, M.A., Archambault, P.S., Laplante-El Haili, Y., 2022. Comparing the usability of a virtual reality manual wheelchair simulator in two display conditions. J. Rehabil. Assist. Technol. Eng. 9, 205566832110671. https://doi.org/10.1177/20556683211067174

Albert, W., Tullis, T., Safari, an O.M.C., 2013. Measuring the User Experience, 2nd Edition.

Alomari, H.W., Ramasamy, V., Kiper, J.D., Potvin, G., 2020. A User Interface (UI) and User eXperience (UX) evaluation framework for cyberlearning environments in computer science and software engineering education. Heliyon 6, e03917. https://doi.org/10.1016/j.heliyon.2020.e03917

Alsina-Jurnet, I., Gutiérrez-Maldonado, J., Rangel-Gómez, M.-V., 2011. The role of presence in the level of anxiety experienced in clinical virtual environments. Comput. Hum. Behav. 27, 504–512. https://doi.org/10.1016/j.chb.2010.09.018

Arzy, S., Thut, G., Mohr, C., Michel, C.M., Blanke, O., 2006. Neural Basis of Embodiment: Distinct Contributions of Temporoparietal Junction and Extrastriate Body Area. J. Neurosci. 26, 8074–8081. https://doi.org/10.1523/JNEUROSCI.0745-06.2006

Attfield, S., Lalmas, M., Piwowarski, B., 2011. Towards a science of user engagement., in: UMWA 2011: Workshop on User Modelling for Web Applications. Presented at the UMWA 2011, Hong Kong, China.

Axelsson, A.S., Regan, T., 2006. Playing Online. Play. Video Games Motiv. Responses Consequences 291–306.

B & H Foto & Electronics Corp, 2021. Z CAM V1 Pro Cinematic VR Camera [WWW Document]. URL https://www.bhphotovideo.com/c/product/1385853-REG/z_cam_zcamv1pro_v1_pro_cinematic_vr.html/overview (accessed 6.25.21).

Bailenson, J.N., Blascovich, J., Beall, A.C., Loomis, J.M., 2003. Interpersonal Distance in Immersive Virtual Environments. Pers. Soc. Psychol. Bull. 29, 819–833. https://doi.org/10.1177/0146167203029007002

Barfield, W., Hendrix, C., 1995. The effect of update rate on the sense of presence within virtual environments. Virtual Real. 1, 3–15. https://doi.org/10.1007/BF02009709

BBC, 2022. How do I make 360 videos? [WWW Document]. Acad. Guid. URL https://www.bbc.com/academy-guides/how-do-i-make-360-videos/ (accessed 10.21.22).

BBC, 2019. Google and BBC scrap VR projects [WWW Document]. BBC News. URL https://www.bbc.co.uk/news/technology-50080594 (accessed 7.22.20).

Beauregard, R., Corriveau, P., 2007. User Experience Quality: A Conceptual Framework for Goal Setting and Measurement, in: Duffy, V.G. (Ed.), Digital Human Modeling, Lecture Notes in Computer Science. Springer Berlin Heidelberg, Berlin, Heidelberg, pp. 325–332. https://doi.org/10.1007/978-3-540-73321-8_38

Bell, M.W., 2008. Toward a Definition of "Virtual Worlds." J. Virtual Worlds Res. 1. https://doi.org/10.4101/jvwr.v1i1.283

Bessa, M., Melo, M., Narciso, D., Barbosa, L., Vasconcelos-Raposo, J., 2016. Does 3D 360 video enhance user's VR experience?: An Evaluation Study, in: Proceedings of the XVII International Conference on Human Computer Interaction - Interacción '16. Presented at the the XVII International Conference, ACM Press, Salamanca, Spain, pp. 1–4. https://doi.org/10.1145/2998626.2998669

Biocca, F., 1997. The Cyborg's Dilemma: Progressive Embodiment in Virtual Environments. J. Comput.-Mediat. Commun. 3, 0–0. https://doi.org/10.1111/j.1083-6101.1997.tb00070.x

Biocca, F., Burgoon, J., Harm, C., Stoner, M., 2001. Criteria and scope conditions for a theory and measure of social presence. Media Interface and Network Design (M.I.N.D.) Labs, E. Lansing, MI.

Blakemore, S.-J., Wolpert, D.M., Frith, C.D., 2002. Abnormalities in the awareness of action. Trends Cogn. Sci. 6, 237–242. https://doi.org/10.1016/S1364-6613(02)01907-1

Blanke, O., Metzinger, T., 2009. Full-body illusions and minimal phenomenal selfhood. Trends Cogn. Sci. 13, 7–13. https://doi.org/10.1016/j.tics.2008.10.003

Botvinick, M., Cohen, J., 1998. Rubber hands ‘feel’ touch that eyes see. Nature 391, 756–756. https://doi.org/10.1038/35784

Bouras, C., Tsiatsos, T., 2006. Educational virtual environments: design rationale and architecture. Multimed. Tools Appl. 29, 153–173. https://doi.org/10.1007/s11042-006-0005-7

Bowman, D.A., McMahan, R.P., 2007. Virtual Reality: How Much Immersion Is Enough? Computer 40, 36–43. https://doi.org/10.1109/MC.2007.257

Braun, V., Clarke, V., 2006. Using thematic analysis in psychology. Qual. Res. Psychol. 3, 77–101. https://doi.org/10.1191/1478088706qp063oa

Brockmyer, J.H., Fox, C.M., Curtiss, K.A., McBroom, E., Burkhart, K.M., Pidruzny, J.N., 2009. The development of the Game Engagement Questionnaire: A measure of engagement in video game-playing. J. Exp. Soc. Psychol. 45, 624–634. https://doi.org/10.1016/j.jesp.2009.02.016

Broeck, M.V. den, Kawsar, F., Schöning, J., 2017. It’s All Around You: Exploring 360° Video Viewing Experiences on Mobile Devices, in: Proceedings of the 2017 ACM on Multimedia Conference - MM ’17. Presented at the the 2017 ACM, ACM Press, Mountain View, California, USA, pp. 762–768. https://doi.org/10.1145/3123266.3123347

Brooke, J., 1996. SUS: A “Quick and Dirty” Usability Scale, in: Jordan, P.W., Thomas, B., McClelland, I.L., Weerdmeester, B. (Eds.), Usability Evaluation In Industry. CRC Press, pp. 207–212. https://doi.org/10.1201/9781498710411-35

Buzan, T., 2005. Mind map handbook. Thorsons, London.

Cabrera-Nguyen, P., 2010. Author Guidelines for Reporting Scale Development and Validation Results in the *Journal of the Society for Social Work and Research*. J. Soc. Soc. Work Res. 1, 99–103. https://doi.org/10.5243/jsswr.2010.8

Carter, N., Bryant-Lukosius, D., DiCenso, A., Blythe, J., Neville, A.J., 2014. The Use of Triangulation in Qualitative Research. Oncol. Nurs. Forum 41, 545–547. https://doi.org/10.1188/14.ONF.545-547

Choi, D., Kim, J., 2004. Why People Continue to Play Online Games: In Search of Critical Design Factors to Increase Customer Loyalty to Online Contents. Cyberpsychol. Behav. 7, 11–24. https://doi.org/10.1089/109493104322820066

Clagnut, 2016. Peter in Conversation with Don Norman About UX & Innovation [WWW Document]. huffduffer. URL https://huffduffer.com/clagnut/370516 (accessed 6.17.21).

Cowan, L.D., 2014. e-Leadership: Leading in a Virtual Environment--Guiding Principles For Nurse Leaders. Nurs Econ 32, 312–9.

Cruz-Neira, C., Sandin, D.J., DeFanti, T.A., 1993. Surround-screen projection-based virtual reality: the design and implementation of the CAVE, in: Proceedings of the 20th Annual Conference on Computer Graphics and Interactive Techniques - SIGGRAPH '93. Presented at the the 20th annual conference, ACM Press, Not Known, pp. 135–142. https://doi.org/10.1145/166117.166134

Csikszentmihalyi, M., 1997. Finding flow: the psychology of engagement with everyday life, 1st ed. ed, MasterMinds. BasicBooks, New York.

Csikszentmihalyi, M., 1990. Flow: The psychology of optimal experience.

Csikszentmihalyi, M., 1975. Beyond boredom and anxiety, 1st ed. ed, The Jossey-Bass behavioral science series. Jossey-Bass Publishers, San Francisco.

Csikszentmihalyi, M., Csikszentmihalyi, I.S. (Eds.), 1988. Optimal experience: psychological studies of flow in consciousness. Cambridge University Press, Cambridge ; New York.

Csikszentmihalyi, M., LeFevre, J., 1989. Optimal experience in work and leisure. J. Pers. Soc. Psychol. 56, 815–822. https://doi.org/10.1037/0022-3514.56.5.815

Dark Corner Studios, 2015. Catatonic [WWW Document]. Catatonic. URL https://www.darkcornerstudios.com/catatonic (accessed 9.10.20).

de Vignemont, F., 2011. Embodiment, ownership and disownership. Conscious. Cogn. 20, 82–93. https://doi.org/10.1016/j.concog.2010.09.004

Disz, T.L., Papka, M.E., Pellegrino, M., Stevens, R., 1996. Sharing Visualization Experiences among Remote Virtual Environments, in: Chen, M., Townsend, P., Vince, J.A. (Eds.), High Performance Computing for Computer Graphics and Visualisation. Springer London, London, pp. 217–237. https://doi.org/10.1007/978-1-4471-1011-8_15

Dooley, K., 2017. Storytelling with virtual reality in 360-degrees: a new screen grammar. Stud. Australas. Cine. 11, 161–171. https://doi.org/10.1080/17503175.2017.1387357

Ellis, S.R., 1994. What are virtual environments? IEEE Comput. Graph. Appl. 14, 17–22. https://doi.org/10.1109/38.250914

Ellis, S.R., 1991. Nature and origins of virtual environments: a bibliographical essay. Comput. Syst. Eng. 2, 321–347. https://doi.org/10.1016/0956-0521(91)90001-L

Erdem, A., 2017. Mind Maps as a Lifelong Learning Tool. Univers. J. Educ. Res. 5, 1–7. https://doi.org/10.13189/ujer.2017.051301

Facebook, 2016. Better Practices for 360 [WWW Document]. Better Pract. 360 Facebook Media. URL https://www.facebook.com/facebookmedia/blog/better-practices-for-360 (accessed 4.10.20).

Facebook Technologies, LLC, 2021. Quest 2 by Facebook [WWW Document]. URL https://www.oculus.com/quest-2/ (accessed 7.7.21).

Facebook Technologies, LLC, 2020. Legal Documents [WWW Document]. Oculus.com. URL https://www.oculus.com/legal/health-and-safety-warnings/?locale=en_GB (accessed 9.22.20).

Fearghail, C.O., Ozcinar, C., Knorr, S., Smolic, A., 2018. Director's Cut - Analysis of Aspects of Interactive Storytelling for VR Films, in: Rouse, R., Koenitz, H., Haahr, M. (Eds.), Interactive Storytelling, Lecture Notes in Computer Science. Springer International Publishing, Cham, pp. 308–322. https://doi.org/10.1007/978-3-030-04028-4_34

Febretti, A., Nishimoto, A., Thigpen, T., Talandis, J., Long, L., Pirtle, J.D., Peterka, T., Verlo, A., Brown, M., Plepys, D., Sandin, D., Renambot, L., Johnson, A., Leigh, J., 2013. CAVE2: a hybrid reality environment for immersive simulation and information analysis, in: Dolinsky, M., McDowall, I.E. (Eds.), . Presented at the IS&T/SPIE Electronic Imaging, Burlingame, California, USA, p. 864903. https://doi.org/10.1117/12.2005484

Feurstein, M., 2018. Towards an Integration of 360-degree Video in Higher Education, in: DeLFI Workshops 2018 Co-Located with 16th e-Learning Conference of the German Computer Society. Presented at the DeLFI, Frankfurt, Germany.

Fong, K., Mar, R.A., 2015. What does my avatar say about me? Inferring personality from avatars. Pers. Soc. Psychol. Bull. 41, 237–249. https://doi.org/10.1177/0146167214562761

Fonseca, D., Kraus, M., 2016. A comparison of head-mounted and hand-held displays for 360° videos with focus on attitude and behavior change, in: Proceedings of the 20th International Academic Mindtrek Conference on - AcademicMindtrek '16. Presented at the the 20th International Academic Mindtrek Conference, ACM Press, Tampere, Finland, pp. 287–296. https://doi.org/10.1145/2994310.2994334

Forlizzi, J., Battarbee, K., 2004. Understanding experience in interactive systems, in: Proceedings of the 2004 Conference on Designing Interactive Systems Processes, Practices, Methods, and Techniques - DIS '04. Presented at the the 2004 conference, ACM Press, Cambridge, MA, USA, p. 261. https://doi.org/10.1145/1013115.1013152

Franck, N., Farrer, C., Georgieff, N., Marie-Cardine, M., Daléry, J., d'Amato, T., Jeannerod, M., 2001. Defective Recognition of One's Own Actions in Patients With Schizophrenia. Am. J. Psychiatry 158, 454–459. https://doi.org/10.1176/appi.ajp.158.3.454

Gajadhar, B.J., de Kort, Y.A.W., IJsselsteijn, W.A., 2008. Shared Fun Is Doubled Fun: Player Enjoyment as a Function of Social Setting, in: Markopoulos, P., de Ruyter, B., IJsselsteijn, W., Rowland, D. (Eds.), Fun and Games, Lecture Notes in Computer Science. Springer Berlin Heidelberg, Berlin, Heidelberg, pp. 106–117. https://doi.org/10.1007/978-3-540-88322-7_11

Gallagher, S., 2000. Philosophical conceptions of the self: implications for cognitive science. Trends Cogn. Sci. 4, 14–21. https://doi.org/10.1016/S1364-6613(99)01417-5

Garcia-Palacios, A., Hoffman, H., Carlin, A., Furness, T.A., Botella, C., 2002. Virtual reality in the treatment of spider phobia: a controlled study. Behav. Res. Ther. 40, 983–993. https://doi.org/10.1016/S0005-7967(01)00068-7

Glaser, B.G., 1965. The Constant Comparative Method of Qualitative Analysis. Soc. Probl. 12, 436–445. https://doi.org/10.2307/798843

Gödde, M., Gabler, F., Siegmund, D., Braun, A., 2018. Cinematic Narration in VR – Rethinking Film Conventions for 360 Degrees, in: Chen, J.Y.C., Fragomeni, G. (Eds.), Virtual, Augmented and Mixed Reality: Applications in Health, Cultural Heritage, and Industry, Lecture Notes in Computer Science. Springer International Publishing, Cham, pp. 184–201. https://doi.org/10.1007/978-3-319-91584-5_15

GoPro Inc, 2020. GoPro Max [WWW Document]. URL https://gopro.com/en/us/shop/cameras/max/CHDHZ-201-master.html (accessed 8.16.20).

Grand View Research, Inc, 2020. Virtual Reality Market Size, Share & Trends Analysis Report By Device (HMD, GTD), By Technology (Semi & Fully Immersive, Non-immersive), By Component, By Application, By Region, And Segment Forecasts, 2020 - 2027 [WWW Document]. Gd. View Res. URL https://www.grandviewresearch.com/industry-analysis/virtual-reality-vr-market (accessed 7.22.20).

Gromer, D., Madeira, O., Gast, P., Nehfischer, M., Jost, M., Müller, M., Mühlberger, A., Pauli, P., 2018. Height Simulation in a Virtual Reality CAVE System: Validity of Fear Responses and Effects of an Immersion Manipulation. Front. Hum. Neurosci. 12, 372. https://doi.org/10.3389/fnhum.2018.00372

Hall, E.T., 1969. The hidden dimension: man's use of space in public and private.

Hassenzahl, M., 2008. User experience (UX): towards an experiential perspective on product quality, in: Proceedings of the 20th International Conference of the Association Francophone d'Interaction Homme-Machine on - IHM '08. Presented at the the 20th International Conference of the Association Francophone d'Interaction Homme-Machine, ACM Press, Metz, France, p. 11. https://doi.org/10.1145/1512714.1512717

Hassenzahl, M., Burmester, M., Koller, F., 2003. AttrakDiff: Ein Fragebogen zur Messung wahrgenommener hedonischer und pragmatischer Qualität, in: Szwillus, G., Ziegler, J. (Eds.), Mensch & Computer 2003, Berichte Des German Chapter of the ACM. Vieweg+Teubner Verlag, Wiesbaden, pp. 187–196. https://doi.org/10.1007/978-3-322-80058-9_19

Hassenzahl, M., Tractinsky, N., 2006. User experience - a research agenda. Behav. Inf. Technol. 25, 91–97. https://doi.org/10.1080/01449290500330331

Heeter, C., 1992. Being There: The Subjective Experience of Presence. Presence Teleoperators Virtual Environ. 1, 262–271. https://doi.org/10.1162/pres.1992.1.2.262

Held, R.M., Durlach, N.I., 1992. Telepresence. Presence Teleoperators Virtual Environ. 1, 109–112. https://doi.org/10.1162/pres.1992.1.1.109

Hellweger, S., Wang, X., 2015. What is User Experience Really: towards a UX Conceptual Framework. https://doi.org/10.6084/M9.FIGSHARE.1319576

Herault, R.C., Lincke, A., Milrad, M., Forsgärde, E.-S., Elmqvist, C., 2018. Using 360-degrees interactive videos in patient trauma treatment education: design, development and evaluation aspects. Smart Learn. Environ. 5, 26. https://doi.org/10.1186/s40561-018-0074-x

Hinkin, T.R., 1995. A Review of Scale Development Practices in the Study of Organizations. J. Manag. 21, 967–988. https://doi.org/10.1177/014920639502100509

Holton, J.A., 2007. The Coding Process and Its Challenges, in: The SAGE Handbook of Grounded Theory. SAGE Publications Ltd, 1 Oliver's Yard, 55 City Road, London England EC1Y 1SP United Kingdom, pp. 265–289. https://doi.org/10.4135/9781848607941.n13

Huang, J., Chen, Z., Ceylan, D., Jin, H., 2017. 6-DOF VR videos with a single 360-camera, in: 2017 IEEE Virtual Reality (VR). Presented at the 2017 IEEE Virtual Reality (VR), IEEE, Los Angeles, CA, USA, pp. 37–44. https://doi.org/10.1109/VR.2017.7892229

Huang, M.-H., 2003. Designing website attributes to induce experiential encounters. Comput. Hum. Behav. 19, 425–442. https://doi.org/10.1016/S0747-5632(02)00080-8

human-eyes, 2020. The Remarkable 180°/360° Hybrid Camera [WWW Document]. vuze.camera. URL https://vuze.camera/camera/vuze-xr-camera (accessed 8.16.20).

Hutchins, E.L., Hollan, J.D., Norman, D.A., 1985. Direct Manipulation Interfaces. Human–Computer Interact. 1, 311–338. https://doi.org/10.1207/s15327051hci0104_2

IDC, 2020. AR & VR Headsets Market Share [WWW Document]. IDC. URL https://www.idc.com/promo/arvr (accessed 7.22.20).

igroup.org, 2016. igroup presence questionnaire (IPQ) overview [WWW Document]. igroup.org. URL http://www.igroup.org/pq/ipq/index.php

IHS Markit, 2018. Augmented and Virtual Reality Consumer Content and Apps Market Hits $3.2 Billion in 2017, IHS Markit Says [WWW Document]. IHS Markit. URL https://news.ihsmarkit.com/prviewer/release_only/slug/technology-augmented-and-virtual-reality-consumer-content-and-apps-market-hits-32-bill (accessed 7.22.20).

IJsselsteijn, W., De Kort, Y., Poels, K., 2013. The Game Experience Questionnaire.

Immersion VR, n.d. MONOSCOPIC VS STEREOSCOPIC 360 VR [WWW Document]. Immers. VR. URL https://immersionvr.co.uk/blog/monoscopic-vs-stereoscopic-360-vr/ (accessed 8.16.20).

insta360.com, 2022. Insta360 Titan [WWW Document]. Insta360 Titan. URL https://www.insta360.com/product/insta360-titan (accessed 6.1.22).

ISO 9241-110:2020, 2020. Ergonomics of human-system interaction — Part 110: Interaction principles. International Organization for Standardization (ISO), Switzerland.

ISO DIS 9241-11, 2018. Ergonomics of human system interaction - Part 11: Usability: Definitions and concepts. International Organization for Standardization (ISO), Switzerland.

Jacobson, J., Hwang, Z., 2002. Unreal tournament for immersive interactive theater. Commun. ACM 45. https://doi.org/10.1145/502269.502292

Jacques, R., Preece, J., Carey, T., 1995. Engagement as a Design Concept for Multimedia. Can. J. Learn. Technol. Rev. Can. L'apprentissage Technol. 24. https://doi.org/10.21432/T2VG77

Jacques, R.D., 1996. The Nature of Engagement and its Role in Hypermedia Evaluation and Design. Doctoral Dissertation, South Bank University, London.

Jaunt, 2018. The Cinematic VR Field Guide [WWW Document]. Oculus. URL https://creator.oculus.com/learn/cinematic-vr-field-guide/ (accessed 4.10.20).

Jennings, M., 2000. Theory and models for creating engaging and immersive ecommerce Websites, in: Proceedings of the 2000 ACM SIGCPR Conference on Computer Personnel Research - SIGCPR '00. Presented at the the 2000 ACM SIGCPR conference, ACM Press, Chicago, Illinois, United States, pp. 77–85. https://doi.org/10.1145/333334.333358

Jerald, J., 2016. The VR book: human-centered design for virtual reality, First edition. ed, ACM books. acm, Association for Computing Machinery, New York.

Katsouri, I., Tzanavari, A., Herakleous, K., Poullis, C., 2015. Visualizing and Assessing Hypotheses for Marine Archaeology in a VR CAVE Environment. J. Comput. Cult. Herit. 8, 1–18. https://doi.org/10.1145/2665072

Ketelhut, D.J., Nelson, B.C., Clarke, J., Dede, C., 2010. A multi-user virtual environment for building and assessing higher order inquiry skills in science: Building and assessing higher order inquiry skills in science. Br. J. Educ. Technol. 41, 56–68. https://doi.org/10.1111/j.1467-8535.2009.01036.x

Khor, W.S., Baker, B., Amin, K., Chan, A., Patel, K., Wong, J., 2016. Augmented and virtual reality in surgery—the digital surgical environment: applications, limitations and legal pitfalls. Ann. Transl. Med. 4, 454–454. https://doi.org/10.21037/atm.2016.12.23

Kickstarter, PBC, 2012. Oculus Rift: Step Into the Game [WWW Document]. URL https://www.kickstarter.com/projects/1523379957/oculus-rift-step-into-the-game

Kilteni, K., Groten, R., Slater, M., 2012. The Sense of Embodiment in Virtual Reality. Presence Teleoperators Virtual Environ. 21, 373–387. https://doi.org/10.1162/PRES_a_00124

Klein, G., Phillips, J.K., Rall, E.L., Peluso, D.A., 2007. A data-frame theory of sensemaking., in: Hoffman, R.R. (Ed.), Expertise out of Context: Proceedings of the Sixth International Conference on Naturalistic Decision Making. Lawrence Erlbaum Associates., Mahwah, NJ, pp. 113–155.

Klimmt, C., Roth, C., Vermeulen, I., Vorderer, P., Roth, F.S., 2012. Forecasting the Experience of Future Entertainment Technology: "Interactive Storytelling" and Media Enjoyment. Games Cult. 7, 187–208. https://doi.org/10.1177/1555412012451123

Kuikkaniemi, K., Laitinen, T., Turpeinen, M., Saari, T., Kosunen, I., Ravaja, N., 2010. The influence of implicit and explicit biofeedback in first-person shooter games, in: Proceedings of the 28th International Conference on Human Factors in Computing Systems - CHI '10. Presented at the the 28th international conference, ACM Press, Atlanta, Georgia, USA, p. 859. https://doi.org/10.1145/1753326.1753453

Lang, B., 2021a. Quest 2 Now the Most Used on Steam, Monthly-connected Headsets Hit Record High of 2.8 Million [WWW Document]. Road VR. URL https://www.roadtovr.com/quest-2-most-used-vr-headset-steam-record-high/ (accessed 6.17.21).

Lang, B., 2021b. Facebook's Bosworth: Quest 2 Has Outsold All Oculus Headsets Combined [WWW Document]. Road VR. URL https://www.roadtovr.com/oculus-quest-2-sales-bosworth-bloomberg/ (accessed 6.17.21).

Lang, B., 2020. 5 Million PlayStation VR Units Sold, Sony Announces [WWW Document]. Road VR. URL https://www.roadtovr.com/playstation-vr-sales-5-million-milestone-psvr-units-sold/ (accessed 7.22.20).

Laugwitz, B., Held, T., Schrepp, M., 2008. Construction and Evaluation of a User Experience Questionnaire, in: Holzinger, A. (Ed.), HCI and Usability for Education and Work, Lecture Notes in Computer Science. Springer Berlin Heidelberg, Berlin, Heidelberg, pp. 63–76. https://doi.org/10.1007/978-3-540-89350-9_6

Law, E.L.-C., Brühlmann, F., Mekler, E.D., 2018. Systematic Review and Validation of the Game Experience Questionnaire (GEQ) - Implications for Citation and Reporting Practice, in: Proceedings of the 2018 Annual Symposium on Computer-Human Interaction in Play. Presented at the CHI PLAY '18: The annual symposium on Computer-Human Interaction in Play, ACM, Melbourne VIC Australia, pp. 257–270. https://doi.org/10.1145/3242671.3242683

Law, E.L.-C., Roto, V., Hassenzahl, M., Vermeeren, A.P.O.S., Kort, J., 2009. Understanding, scoping and defining user experience: a survey approach, in: Proceedings of the 27th International Conference on Human Factors in Computing Systems - CHI 09. Presented at the the SIGCHI Conference, ACM Press, Boston, MA, USA, p. 719. https://doi.org/10.1145/1518701.1518813

Lazar, J., 2017. Research methods in human computer interaction, 2nd edition. ed. Elsevier, Cambridge, MA.

Lee, K.M., 2004. Presence, Explicated. Commun. Theory 14, 27–50. https://doi.org/10.1111/j.1468-2885.2004.tb00302.x

Lenggenhager, B., Mouthon, M., Blanke, O., 2009. Spatial aspects of bodily self-consciousness. Conscious. Cogn. 18, 110–117. https://doi.org/10.1016/j.concog.2008.11.003

Ling, Y., Brinkman, W.-P., Nefs, H.T., Qu, C., Heynderickx, I., 2012. Effects of Stereoscopic Viewing on Presence, Anxiety, and Cybersickness in a Virtual Reality Environment for Public Speaking. Presence Teleoperators Virtual Environ. 21, 254–267. https://doi.org/10.1162/PRES_a_00111

Ling, Y., Nefs, H.T., Brinkman, W.-P., Qu, C., Heynderickx, I., 2013. The relationship between individual characteristics and experienced presence. Comput. Hum. Behav. 29, 1519–1530. https://doi.org/10.1016/j.chb.2012.12.010

Lombard, M., Ditton, T., 2006. At the Heart of It All: The Concept of Presence. J. Comput.-Mediat. Commun. 3, 0–0. https://doi.org/10.1111/j.1083-6101.1997.tb00072.x

Lombard, M., Ditton, T., 1997. At the Heart of It All: The Concept of Presence. J. Comput.-Mediat. Commun. 3, 0–0. https://doi.org/10.1111/j.1083-6101.1997.tb00072.x

Lopez, C., Halje, P., Blanke, O., 2008. Body ownership and embodiment: Vestibular and multisensory mechanisms. Neurophysiol. Clin. Neurophysiol. 38, 149–161. https://doi.org/10.1016/j.neucli.2007.12.006

Lutz, B., Weintke, M., 1999. Virtual Dunhuang Art Cave: A Cave within a CAVE. Comput. Graph. Forum 18, 257–264. https://doi.org/10.1111/1467-8659.00346

MacQuarrie, A., Steed, A., 2017. Cinematic virtual reality: Evaluating the effect of display type on the viewing experience for panoramic video, in: 2017 IEEE Virtual Reality (VR). Presented at the 2017 IEEE Virtual Reality (VR), IEEE, Los Angeles, CA, USA, pp. 45–54. https://doi.org/10.1109/VR.2017.7892230

Mahlke, S., Minge, M., 2008. Consideration of Multiple Components of Emotions in Human-Technology Interaction, in: Peter, C., Beale, R. (Eds.), Affect and Emotion in Human-Computer Interaction, Lecture Notes in Computer Science. Springer Berlin Heidelberg, Berlin, Heidelberg, pp. 51–62. https://doi.org/10.1007/978-3-540-85099-1_5

Mahlke, S., Thüring, M., 2007. Studying antecedents of emotional experiences in interactive contexts, in: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems - CHI '07. Presented at the the SIGCHI Conference, ACM Press, San Jose, California, USA, pp. 915–918. https://doi.org/10.1145/1240624.1240762

Makkonen, P., 1997. Does collaborative hypertext support better engagement in learning of the basics in informatics?, in: Proceedings of the 2nd Conference on Integrating Technology into Computer Science Education - ITiCSE '97. Presented at the the 2nd conference, ACM Press, Uppsala, Sweden, pp. 130–132. https://doi.org/10.1145/268819.268857

Mandryk, R.L., Atkins, M.S., 2007. A fuzzy physiological approach for continuously modeling emotion during interaction with play technologies. Int. J. Hum.-Comput. Stud. 65, 329–347. https://doi.org/10.1016/j.ijhcs.2006.11.011

Mania, K., 2004. Simulating perception with interactive virtual environments, in: 2004 IEEE International Conference on Systems, Man and Cybernetics (IEEE Cat. No.04CH37583). Presented at the 2004 IEEE International Conference on Systems, Man and Cybernetics (IEEE Cat. No.04CH37583), IEEE, The Hague, Netherlands, pp. 2770–2776. https://doi.org/10.1109/ICSMC.2004.1400752

Markets and Markets Research Private Ltd, 2019. Virtual Reality Market by Offering (Hardware and Software), Technology, Device Type (Head-Mounted Display, Gesture-Tracking Device), Application (Consumer, Commercial, Enterprise, Healthcare, Aerospace & Defense) and Geography - Global Forecast to 2024 [WWW Document]. Mark. Mark. URL https://www.marketsandmarkets.com/Market-Reports/reality-applications-market-458.html (accessed 7.22.20).

Matlin, M.W., 1994. Cognition. Harcourt Brace Jovanovich.

Matsentidou, S., Poullis, C., 2014. Immersive Visualizations in a VR Cave Environment for the Training and Enhancement of Social Skills for Children with Autism:, in: Proceedings of the 9th International Conference on Computer Vision Theory and Applications. Presented at the International Conference on Computer Vision Theory and Applications, SCITEPRESS - Science and and Technology Publications, Lisbon, Portugal, pp. 230–236. https://doi.org/10.5220/0004844602300236

McCarthy, J., Wright, P., 2004. Technology as experience. MIT Press, Cambridge, Mass.

Men, L., Bryan-Kinns, N., Hassard, A.S., Ma, Z., 2017. The impact of transitions on user experience in virtual reality, in: 2017 IEEE Virtual Reality (VR). Presented at the 2017 IEEE Virtual Reality (VR), IEEE, Los Angeles, CA, USA, pp. 285–286. https://doi.org/10.1109/VR.2017.7892288

Meyer, J., 2017. Jaunt ONE VR camera now available for purchase… for $95,000 [WWW Document]. Jabber Digit. Media Ltd. URL https://camerajabber.com/jaunt-one-camera-price-available-purchase/ (accessed 8.16.20).

Miles, M.B., Huberman, A.M., 1994. Qualitative data analysis: An expanded sourcebook, 2nd ed., Qualitative data analysis: An expanded sourcebook, 2nd ed. Sage Publications, Inc, Thousand Oaks, CA, US.

Minge, M., Thüring, M., Wagner, I., Kuhr, C.V., 2017. The meCUE Questionnaire: A Modular Tool for Measuring User Experience, in: Soares, M., Falcão, C., Ahram, T.Z. (Eds.), Advances in Ergonomics Modeling, Usability & Special Populations, Advances in Intelligent Systems and Computing. Springer International Publishing, Cham, pp. 115–128. https://doi.org/10.1007/978-3-319-41685-4_11

Moneta, G.B., Csikszentmihalyi, M., 1999. MODELS OF CONCENTRATION IN NATURAL ENVIRONMENTS: A COMPARATIVE APPROACH BASED ON STREAMS OF EXPERIENTIAL DATA. Soc. Behav. Personal. Int. J. 27, 603–637. https://doi.org/10.2224/sbp.1999.27.6.603

Moneta, G.B., Csikszentmihalyi, M., 1996. The Effect of Perceived Challenges and Skills on the Quality of Subjective Experience. J. Pers. 64, 275–310. https://doi.org/10.1111/j.1467-6494.1996.tb00512.x

Nacke, L.E., Grimshaw, M.N., Lindley, C.A., 2010. More than a feeling: Measurement of sonic user experience and psychophysiology in a first-person shooter game. Interact. Comput. 22, 336–343. https://doi.org/10.1016/j.intcom.2010.04.005

Nahl, D., 2007. The centrality of affect in information behavior, in: Information and Emotion: The Emergent Affective Paradigm in Information Behavior Research and Theory. Medford, NJ: Information Today, pp. 3–38.

Nebel, S., Schneider, S., Rey, G.D., 2016. From duels to classroom competition: Social competition and learning in educational videogames within different group sizes. Comput. Hum. Behav. 55, 384–398. https://doi.org/10.1016/j.chb.2015.09.035

Newport, R., Pearce, R., Preston, C., 2010. Fake hands in action: embodiment and control of supernumerary limbs. Exp. Brain Res. 204, 385–395. https://doi.org/10.1007/s00221-009-2104-y

Norman, D.A., 1999. The invisible computer: why good products can fail, the personal computer is so complex, and information appliances are the solution, 1. MIT Press paperback ed. ed. Cambridge, Mass. [u.a.] MIT.

Norman, D.A., 1988. The design of everyday things, 1st Doubleday/Currency ed. ed. Doubleday, New York.

Novak, T.P., Hoffman, D.L., 1997. Measuring the flow experience among web users, in: Proceedings of the Interval Research Corporation.

O'Brien, H., 2016. Theoretical Perspectives on User Engagement, in: O'Brien, H., Cairns, P. (Eds.), Why Engagement Matters. Springer International Publishing, Cham, pp. 1–26. https://doi.org/10.1007/978-3-319-27446-1_1

O'Brien, H., Cairns, P. (Eds.), 2016. Why engagement matters: cross-disciplinary perspectives of user engagement with digital media. Springer, Cham Heidelberg New York Dordrecht London.

O'Brien, H., Cairns, P., 2015. An empirical evaluation of the User Engagement Scale (UES) in online news environments. Inf. Process. Manag. 51, 413–427. https://doi.org/10.1016/j.ipm.2015.03.003

O'Brien, H.L., 2011. Chapter 4 Weaving the Threads of Experience into Human Information Interaction (HII): Probing User Experience (UX) for New Directions in Information Behaviour, in: Spink, A., Heinström, J. (Eds.), Library and Information Science. Emerald Group Publishing Limited, pp. 69–92. https://doi.org/10.1108/S1876-0562(2011)002011a007

O'Brien, H.L., 2008. Defining and Measuring Engagement in User Experiences with Technology. PhD Dissertation. Dalhousie University, Halifax, NS.

O'Brien, H.L., Cairns, P., Hall, M., 2018. A practical approach to measuring user engagement with the refined user engagement scale (UES) and new UES short form. Int. J. Hum.-Comput. Stud. 112, 28–39. https://doi.org/10.1016/j.ijhcs.2018.01.004

O'Brien, H.L., Lebow, M., 2013. Mixed-methods approach to measuring user experience in online news interactions. J. Am. Soc. Inf. Sci. Technol. 64, 1543–1556. https://doi.org/10.1002/asi.22871

O'Brien, H.L., McLean, K., 2009. Measuring the User Engagement Experience., in: Engagement by Design Pre-Conference Workshop. Presented at the CHI 2009 Digital Life New World, Boston.

O'Brien, H.L., Toms, E.G., 2010a. The development and evaluation of a survey to measure user engagement. J. Am. Soc. Inf. Sci. Technol. 61, 50–69. https://doi.org/10.1002/asi.21229

O'Brien, H.L., Toms, E.G., 2010b. Is there a universal instrument for measuring interactive information retrieval?: the case of the user engagement scale, in: Proceeding of the Third Symposium on Information Interaction in Context - IIiX '10. Presented at the Proceeding of the third symposium, ACM Press, New Brunswick, New Jersey, USA, p. 335. https://doi.org/10.1145/1840784.1840835

O'Brien, H.L., Toms, E.G., 2008. What is user engagement? A conceptual framework for defining user engagement with technology. J. Am. Soc. Inf. Sci. Technol. 59, 938–955. https://doi.org/10.1002/asi.20801

Ogawa, N., Narumi, T., Hirose, M., 2017. Distortion in perceived size and body-based scaling in virtual environments, in: Proceedings of the 8th Augmented Human International Conference. Presented at the AH '17: 8th Augmented Human International Conference, ACM, Silicon Valley California USA, pp. 1–5. https://doi.org/10.1145/3041164.3041204

Pace, S., 2004. A grounded theory of the flow experiences of Web users. Int. J. Hum.-Comput. Stud. 60, 327–363. https://doi.org/10.1016/j.ijhcs.2003.08.005

Passmore, P.J., Glancy, M., Philpot, A., Fields, B., 2017. 360 Cinematic literacy: A case study. Amsterdam, The Netherlands.

Passmore, P.J., Glancy, M., Philpot, A., Roscoe, A., Wood, A., Fields, B., 2016. Effects of Viewing Condition on User Experience of Panoramic Video. ICAT-EGVE 2016 - Int. Conf. Artif. Real. Telexistence Eurographics Symp. Virtual Environ. 8 pages. https://doi.org/10.2312/EGVE.20161428

Phan, M.H., Keebler, J.R., Chaparro, B.S., 2016. The Development and Validation of the Game User Experience Satisfaction Scale (GUESS). Hum. Factors J. Hum. Factors Ergon. Soc. 58, 1217–1247. https://doi.org/10.1177/0018720816669646

Philpot, A., 2017. Effects of Camera Position on Perception of Self In 360 Degree Video and Virtual Environments, in: Adjunct Publication of the 2017 ACM International Conference on Interactive Experiences for TV and Online Video. Presented at the TVX '17: ACM International Conference on Interactive Experiences for TV and Online Video, ACM, Hilversum The Netherlands, pp. 87–91. https://doi.org/10.1145/3084289.3084290

Philpot, A., Glancy, M., Passmore, P.J., Wood, A., Fields, B., 2017. User Experience of Panoramic Video in CAVE-like and Head Mounted Display Viewing Conditions, in: Proceedings of the 2017 ACM International Conference on Interactive Experiences for TV and Online Video - TVX '17. Presented at the the 2017 ACM International Conference, ACM Press, Hilversum, The Netherlands, pp. 65–75. https://doi.org/10.1145/3077548.3077550

Poels, K., De Kort, Y., IJsselsteijn, W., 2007. D3.3 : Game Experience Questionnaire: development of a self-report measure to assess the psychological impact of digital games. Technische Universiteit Eindhoven, Eindhoven.

Prothero, J.D., Hoffman, H.D., 1995. Widening the field-of-view increases the sense of presence within immersive virtual environments (Human Interface Technology Laboratory Technical Report No. R-95-4). University of Washington, Seattle, Washington.

Ranasinghe, N., Jain, P., Thi Ngoc Tram, N., Koh, K.C.R., Tolley, D., Karwita, S., Lien-Ya, L., Liangkun, Y., Shamaiah, K., Eason Wai Tung, C., Yen, C.C., Do, E.Y.-L., 2018. Season Traveller: Multisensory Narration for Enhancing the Virtual Reality Experience, in: Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems. Presented at the CHI '18: CHI Conference on Human Factors in Computing Systems, ACM, Montreal QC Canada, pp. 1–13. https://doi.org/10.1145/3173574.3174151

Ratan, R., Beyea, D., Li, B.J., Graciano, L., 2020. Avatar characteristics induce users' behavioral conformity with small-to-medium effect sizes: a meta-analysis of the proteus effect. Media Psychol. 23, 651–675. https://doi.org/10.1080/15213269.2019.1623698

Reber, A.S., Reber, E.S., 2001. The Penguin dictionary of psychology, 3rd ed. ed. Penguin Books, London ; New York.

Regenbrecht, H., Schubert, T., 2002. Real and Illusory Interactions Enhance Presence in Virtual Environments. Presence Teleoperators Virtual Environ. 11, 425–434. https://doi.org/10.1162/105474602760204318

Riecke, B.E., Schulte-Pelkum, J., Avraamides, M.N., von der Heyde, M., Bülthoff, H.H., 2005. Scene consistency and spatial presence increase the sensation of self-motion in virtual reality, in: Proceedings of the 2nd Symposium on Appied Perception in Graphics and Visualization - APGV '05. Presented at the the 2nd symposium, ACM Press, A Coroña, Spain, p. 111. https://doi.org/10.1145/1080402.1080422

Riecke, B.E., Väljamäe, A., Schulte-Pelkum, J., 2009. Moving sounds enhance the visually-induced self-motion illusion (circular vection) in virtual reality. ACM Trans. Appl. Percept. 6, 1–27. https://doi.org/10.1145/1498700.1498701

Roettgers, J., 2019. Google Ships Pixel 4 Without Daydream VR Support, Stops Selling Daydream Viewer [WWW Document]. Variety. URL https://variety.com/2019/digital/news/pixel-4-google-daydream-vr-1203371182/ (accessed 7.22.20).

Roettgers, J., 2015. Skybound, Wevr and Samsung Release 'Gone', a Serialized Virtual Reality Thriller [WWW Document]. Variety. URL https://variety.com/2015/digital/news/skybound-wevr-samsung-gone-1201653307/ (accessed 7.21.20).

Roettl, J., Terlutter, R., 2018. The same video game in 2D, 3D or virtual reality – How does technology impact game evaluation and brand placements? PLOS ONE 13, e0200724. https://doi.org/10.1371/journal.pone.0200724

Rupp, M.A., Kozachuk, J., Michaelis, J.R., Odette, K.L., Smither, J.A., McConnell, D.S., 2016. The effects of immersiveness and future VR expectations on subjec-tive-experiences during an educational 360° video. Proc. Hum. Factors Ergon. Soc. Annu. Meet. 60, 2108–2112. https://doi.org/10.1177/1541931213601477

Sallnäs, E.-L., 2005. Effects of Communication Mode on Social Presence, Virtual Presence, and Performance in Collaborative Virtual Environments. Presence Teleoperators Virtual Environ. 14, 434–449. https://doi.org/10.1162/105474605774785253

Samsung, 2020. 360 Round [WWW Document]. Samsung.com. URL https://www.samsung.com/us/business/products/mobile/virtual-reality/360-round/360-round-sm-r260nzkaxar/ (accessed 8.16.20).

Sato, A., Yasuda, A., 2005. Illusion of sense of self-agency: discrepancy between the predicted and actual sensory consequences of actions modulates the sense of self-agency, but not the sense of self-ownership. Cognition 94, 241–255. https://doi.org/10.1016/j.cognition.2004.04.003

Schaik, P.V., Turnbull, T., Wersch, A.V., Drummond, S., 2004. Presence Within a Mixed Reality Environment. Cyberpsychol. Behav. 7, 540–552. https://doi.org/10.1089/cpb.2004.7.540

Schild, J., LaViola, J., Masuch, M., 2012. Understanding user experience in stereoscopic 3D games, in: Proceedings of the 2012 ACM Annual Conference on Human Factors in Computing Systems - CHI '12. Presented at the the 2012 ACM annual conference, ACM Press, Austin, Texas, USA, p. 89. https://doi.org/10.1145/2207676.2207690

Schoenau-Fog, H., 2011a. The Player Engagement Process: An Exploration of Continuation Desire in Digital Games, in: DiGRA 2011 Conference: Think Design Play: Fifth International Conference of the Digital Games Research Association.

Schoenau-Fog, H., 2011b. Hooked! – Evaluating Engagement as Continuation Desire in Interactive Narratives, in: Si, M., Thue, D., André, E., Lester, J.C., Tanenbaum, J., Zammitto, V. (Eds.), Interactive Storytelling, Lecture Notes in Computer Science. Springer Berlin Heidelberg, Berlin, Heidelberg, pp. 219–230. https://doi.org/10.1007/978-3-642-25289-1_24

Schroeder, R., 2008. Defining Virtual Worlds and Virtual Environments. J. Virtual Worlds Res. 1. https://doi.org/10.4101/jvwr.v1i1.294

Schroeder, R., 2006. Being There Together and the Future of Connected Presence. Presence Teleoperators Virtual Environ. 15, 438–454. https://doi.org/10.1162/pres.15.4.438

Schroeder, R. (Ed.), 2002. The Social Life of Avatars, Computer Supported Cooperative Work. Springer London, London. https://doi.org/10.1007/978-1-4471-0277-9

Schubert, T., Friedmann, F., Regenbrecht, H., 2001. The Experience of Presence: Factor Analytic Insights. Presence Teleoperators Virtual Environ. 10, 266–281. https://doi.org/10.1162/105474601300343603

Schubert, T., Friedmann, F., Regenbrecht, H., 1999. Embodied Presence in Virtual Environments, in: Paton, R., Neilson, I. (Eds.), Visual Representations and Interpretations. Springer London, London, pp. 269–278. https://doi.org/10.1007/978-1-4471-0563-3_30

Schubert, T., Regenbrecht, H., 2002. Wer hat Angst vor virtueller Realität? Virtuelle Realitäten 255–74.

Schubert, T.W., 2003. The sense of presence in virtual environments:: A three-component scale measuring spatial presence, involvement, and realness. Z. Für Medien. 15, 69–71. https://doi.org/10.1026//1617-6383.15.2.69

Schuemie, M.J., van der Straaten, P., Krijn, M., van der Mast, C.A.P.G., 2001. Research on Presence in Virtual Reality: A Survey. Cyberpsychol. Behav. 4, 183–201. https://doi.org/10.1089/109493101300117884

Schultheis, M.T., Rizzo, A.A., 2001. The application of virtual reality technology in rehabilitation. Rehabil. Psychol. 46, 296–311. https://doi.org/10.1037/0090-5550.46.3.296

Schwind, V., Knierim, P., Haas, N., Henze, N., 2019. Using Presence Questionnaires in Virtual Reality, in: Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems. Presented at the CHI '19: CHI Conference on Human Factors in Computing Systems, ACM, Glasgow Scotland Uk, pp. 1–12. https://doi.org/10.1145/3290605.3300590

SGO, 2022. Mistika-VR [WWW Document]. Mist. Vr. URL https://www.sgo.es/mistika-vr/ (accessed 6.1.22).

Shenzhen ImagineVision, Technology Limited, 2021. Z CAM V1 Pro Cinematic VR Camera [WWW Document]. URL https://www.z-cam.com/360-vr-camera-v1-pro/ (accessed 6.25.21).

Sheridan, T.B., 1995. Teleoperation, telerobotics and telepresence: A progress report. Control Eng. Pract. 3, 205–214. https://doi.org/10.1016/0967-0661(94)00078-U

Sheridan, T.B., 1992. Musings on Telepresence and Virtual Presence. Presence Teleoperators Virtual Environ. 1, 120–126. https://doi.org/10.1162/pres.1992.1.1.120

Shouse, E., 2005. Feeling, Emotion, Affect. MC J. 8. https://doi.org/10.5204/mcj.2443

Sivunen, A., Hakonen, M., 2011. Review of Virtual Environment Studies on Social and Group Phenomena. Small Group Res. 42, 405–457. https://doi.org/10.1177/1046496410388946

Slater, M., 2018. Immersion and the illusion of presence in virtual reality. Br. J. Psychol. 109, 431–433. https://doi.org/10.1111/bjop.12305

Slater, M., 2004. How Colorful Was Your Day? Why Questionnaires Cannot Assess Presence in Virtual Environments. Presence Teleoperators Virtual Environ. 13, 484–493. https://doi.org/10.1162/1054746041944849

Slater, M., Garau, M., 2007. The Use of Questionnaire Data in Presence Studies: Do Not Seriously Likert. Presence Teleoperators Virtual Environ. 16, 447–456. https://doi.org/10.1162/pres.16.4.447

Slater, M., Lotto, B., Arnold, M.M., Sanchez-Vives, M.V., 2009. How we experience immersive virtual environments: The concept of presence and its measurement. Anu. Psicol. 40, 193–210.

Slater, M., Sanchez-Vives, M.V., 2014. Transcending the Self in Immersive Virtual Reality. Computer 47, 24–30. https://doi.org/10.1109/MC.2014.198

Slater, M., Wilbur, S., 1997. A Framework for Immersive Virtual Environments (FIVE): Speculations on the Role of Presence in Virtual Environments. Presence Teleoperators Virtual Environ. 6, 603–616. https://doi.org/10.1162/pres.1997.6.6.603

Stage, J., 2006. Defining and Measuring User Experience: Are They Two Sides of the Same Coin?, in: Proceedings of the Workshop on User Experience, NordiCHI 2006. Oslo, Norway, pp. 146–149.

Stone, D.L., Jarrett, C., Woodroffe, M., Minocha, S., 2005. User interface design and evaluation, Morgan Kaufmann series in interactive technologies. Elsevier : Morgan Kaufmann, Amsterdam ; Boston, Mass.

Theelen, H., Beemt, A., Brok, P., 2019. Using 360-degree videos in teacher education to improve preservice teachers' professional interpersonal vision. J. Comput. Assist. Learn. 35, 582–594. https://doi.org/10.1111/jcal.12361

Tsakiris, M., 2010. My body in the brain: A neurocognitive model of body-ownership. Neuropsychologia 48, 703–712. https://doi.org/10.1016/j.neuropsychologia.2009.09.034

Tsakiris, M., Haggard, P., 2005. The Rubber Hand Illusion Revisited: Visuotactile Integration and Self-Attribution. J. Exp. Psychol. Hum. Percept. Perform. 31, 80–91. https://doi.org/10.1037/0096-1523.31.1.80

Tsakiris, M., Prabhu, G., Haggard, P., 2006. Having a body versus moving your body: How agency structures body-ownership. Conscious. Cogn. 15, 423–432. https://doi.org/10.1016/j.concog.2005.09.004

Usoh, M., Catena, E., Arman, S., Slater, M., 2000. Using Presence Questionnaires in Reality. Presence Teleoperators Virtual Environ. 9, 497–503. https://doi.org/10.1162/105474600566989

Vallar, G., Ronchi, R., 2009. Somatoparaphrenia: a body delusion. A review of the neuropsychological literature. Exp. Brain Res. 192, 533–551. https://doi.org/10.1007/s00221-008-1562-y

Valve, 2021. Steam Hardware & Software Survey: May 2021 [WWW Document]. Steam. URL https://store.steampowered.com/hwsurvey (accessed 6.17.21).

Valve Corporation, 2021. Valve Index [WWW Document]. URL https://store.steampowered.com/valveindex (accessed 7.7.21).

Vasconcelos-Raposo, J., Bessa, M., Melo, M., Barbosa, L., Rodrigues, R., Teixeira, C.M., Cabral, L., Sousa, A.A., 2016. Adaptation and Validation of the Igroup Presence Questionnaire (IPQ) in a Portuguese Sample. Presence Teleoperators Virtual Environ. 25, 191–203. https://doi.org/10.1162/PRES_a_00261

Vermeeren, A.P.O.S., Law, E.L.-C., Roto, V., Obrist, M., Hoonhout, J., Väänänen-Vainio-Mattila, K., 2010. User experience evaluation methods: current state and development needs, in: Proceedings of the 6th Nordic Conference on Human-Computer Interaction Extending Boundaries - NordiCHI '10. Presented at the the 6th Nordic Conference, ACM Press, Reykjavik, Iceland, p. 521. https://doi.org/10.1145/1868914.1868973

VRdirect, 2019. Stereoscopic vs. Monoscopic 360° Video for VR experiences [WWW Document]. VRdirect. URL https://www.vrdirect.com/blog/vr-hardware-content-production/stereoscopic-vs-monoscopic-360-video-for-vr-experiences/ (accessed 8.16.20).

VRS, 2017. Who Coined the Term "Virtual Reality"? [WWW Document]. Virtual Real. Soc. URL https://www.vrs.org.uk/virtual-reality/who-coined-the-term.html (accessed 7.22.20).

Watercutter, A., 2015. 6 Things You Should Know About the VR Horror Film Catatonic [WWW Document]. Wired. URL https://www.wired.com/2015/03/catatonic-vr-horror-film/ (accessed 9.10.20).

Webster, J., Ho, H., 1997. Audience engagement in multimedia presentations. ACM SIGMIS Database 28, 63–77. https://doi.org/10.1145/264701.264706

Webster, M., 2020. Interest [WWW Document]. Merriam-Webster. URL https://www.merriam-webster.com/dictionary/interest (accessed 9.2.20).

Weiß, S., 2017. Get pixel-count in FoV inside VR-Sphere [WWW Document]. Stack Exch. Inc. URL https://i.stack.imgur.com/f2Iza.jpg (accessed 8.16.20).

Williams, K.D., 2014. The effects of dissociation, game controllers, and 3D versus 2D on presence and enjoyment. Comput. Hum. Behav. 38, 142–150. https://doi.org/10.1016/j.chb.2014.05.040

Witmer, B.G., Singer, M.J., 1998. Measuring Presence in Virtual Environments: A Presence Questionnaire. Presence Teleoperators Virtual Environ. 7, 225–240. https://doi.org/10.1162/105474698565686

Worthington, R.L., Whittaker, T.A., 2006. Scale Development Research: A Content Analysis and Recommendations for Best Practices. Couns. Psychol. 34, 806–838. https://doi.org/10.1177/0011000006288127

Wycoff, J., 1991. Mindmapping: your personal guide to exploring creativity and problem-solving, Berkley trade pbk. ed. ed. Berkley Books, New York.

Xu, W., 2012. User Experience Design: Beyond User Interface Design and Usability, in: Nunes, I.L. (Ed.), Ergonomics - A Systems Approach. InTech. https://doi.org/10.5772/35041

Yee, N., Bailenson, J., 2007. The Proteus Effect: The Effect of Transformed Self-Representation on Behavior. Hum. Commun. Res. 33, 271–290. https://doi.org/10.1111/j.1468-2958.2007.00299.x

Yuen, K.K., Choi, S.H., Yang, X.B., 2010. A Full-immersive CAVE-based VR Simulation System of Forklift Truck Operations for Safety Training. Comput.-Aided Des. Appl. 7, 235–245. https://doi.org/10.3722/cadaps.2010.235-245

Zarour, M., Alharbi, M., 2017. User experience framework that combines aspects, dimensions, and measurement methods. Cogent Eng. 4, 1421006. https://doi.org/10.1080/23311916.2017.1421006

Zhang, S., Demiralp, C., Keefe, D.F., DaSilva, M., Laidlaw, D.H., Greenberg, B.D., Basser, P.J., Pierpaoli, C., Chiocca, E.A., Deisboeck, T.S., 2001. An immersive virtual environment for DT-MRI volume visualization applications: a case study, in: Proceedings Visualization, 2001. VIS ’01. Presented at the VIS 2001. Visualization 2001, IEEE, San Diego, CA, USA, pp. 437–584. https://doi.org/10.1109/VISUAL.2001.964545

Glossary

2D – Two-Dimensional; a flat plane that has two dimensions – length and width.

3D – Three-Dimensional; a solid object or shape that has three dimensions – length, width, and height.

AR – Augmented Reality; an enhanced version of the actual world through the use of digital visual elements, sound or other sensory stimuli via technology.

C.A.V.E – Cave Automatic Virtual Environment; a projection-based immersive VR display which consists of a number of rear projection screens (typically 3 but can be more) or walls with a downward projection onto the floor.

CGI – Computer-Generated Imagery; digital graphics used in media, often as 3D animation.

DOF – Degree of Freedom; the limits to which physical movement or other physical processes are possible.

ESQ - Engagement Sample Questionnaire; a questionnaire used to evaluate continuation desire as an aspect of engagement in interactive narratives (Schoenau-Fog, 2011b).

FOMO – Fear of Missing Out [on something important]; fear of not being included in something or not experiencing something that others are experiencing.

FoV – Field of View; the open observable area a person can see through his or her eyes or via an optical device.

GEQ¹ - Game Engagement Questionnaire; a questionnaire developed by Brockmyer et al. (2009) which measures levels of engagement elicited while playing video games (Brockmyer et al., 2009).

GEQ² – Game Experience Questionnaire; a questionnaire developed by IJsselsteijn et al. (2013) which aims to comprehensively and reliably characterise the experience of playing digital games (IJsselsteijn et al., 2013).

GUESS - Game User Experience Satisfaction Scale; a game satisfaction questionnaire by Phan et al. (2016) which measures video game satisfaction based on key factors identified using an Exploratory Factor Analysis (Phan et al., 2016).

HCI – Human Computer Interaction; the interaction between humans and computers.

HMD – Head Mounted Display/Device; a headset used with VR systems.

IPQ – iGroup Presence Questionnaire; a tool to measure presence (igroup.org, 2016).

PEP - Player Engagement Process framework; a framework developed by Schoenau-Fog, (2011) (Schoenau-Fog, 2011a).

PI – Place Illusion; the illusion of being in a place when in a virtual environment (Slater and Sanchez-Vives, 2014).

Psi – Plausibility Illusion; experiencing/responding to events as if they were real when in a virtual environment (Slater and Sanchez-Vives, 2014).

SP – Spatial Presence; the relation between the VE as a space and the own body.

UES – User Engagement Scale; a tool used to measure User Engagement (O'Brien and Toms, 2010a)

UE – User Engagement; "the emotional, cognitive and behavioural connection that exists, at any point in time and possibly over time, between a user and a resource." (Attfield et al., 2011, p. 2).

UX – User Experience; a "user's perceptions and responses that result from the use and/or anticipated use of a system, product or service" (ISO DIS 9241-11, 2018).

VE – Virtual Environment; "interactive, virtual image displays enhanced by special processing and by non-visual display modalities, such as auditory and haptic, to convince users that they are immersed in a synthetic space." (Ellis, 1994, p. 17).

VR – Virtual Reality; “interactive, virtual image displays enhanced by special processing and by non-visual display modalities, such as auditory and haptic, to convince users that they are immersed in a synthetic space.” (Ellis, 1994, p. 17).

Appendix A: Publications

A.1. Effects of viewing condition on user experience of panoramic video

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A.2. User Experience of Panoramic Video in CAVE-like and Head Mounted Display Viewing Conditions

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A3. Effects of Camera Position on Perception of Self In 360 Degree Video and Virtual Environments

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A.4. 360 cinematic literacy: a case study

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Appendix B: User study one documents

B.1. Screening questionnaire

School of Science and Technology, Middlesex University,
The Burroughs, Hendon, London, NW4 4BT.

360 Degree Video Study - Screening Questions

Researchers: Mr. Adam Philpot, Dr. Peter Passmore and Dr. Bob Fields.

This study involves some use of Virtual Reality equipment. For some people, viewing using Virtual Reality equipment is not recommended. Therefore, if any of the below statements apply to you, we would have to ask you not to participate in this study. As a precaution use of Virtual reality viewing equipment may not be recommended where the participant:

- is or may be, pregnant
- has had a seizure
- has an epileptic condition
- is elderly
- suffers from psychiatric disorders
- suffers from a heart condition
- has pre-existing binocular vision abnormalities
- has had a loss of awareness
- suffers from a serious medical condition
- wears a pacemaker or other implanted medical device
- suffers from dizziness and/or sickness
- has a cold/flu at the moment
- has a stress or an anxiety related condition

1. Please tick if you can certify that none of the above applies to you. ☐

2. Please tick if you would be willing to be video recorded while viewing a 360 degree video during this study? ☐

If you have not been able to tick the above two boxes then you will not be able to participant in the study but we thank you very much for your interest, otherwise please continue to answer the questions below.

3. Have you used any Virtual Reality Head Mounted Display in the past?

Yes ☐ No ☐

If yes, which?

4. Have you ever viewed 360 degree video?

Yes ☐ No ☐

5. If yes, which device/s did you use?

6. How frequently do you play video games?

Frequently ☐ Occasionally ☐ Seldom ☐ Never ☐

8. How frequently do you watch visual content such as TV series, news, movies etc.?

Frequently ☐ Occasionally ☐ Seldom ☐ Never

Participant Details

Name:
Age:
Gender:
Occupation:
Participant Number:

B.2. Consent form

Participant Identification Number:

CONSENT FORM

Title of Project: 360 Degree Video Study 2019

Name of Researcher: Mr. Adam Philpot

1. I confirm that I have read and understand the information sheet dated ....……………..…for the above study and have had the opportunity to ask questions.

2. I confirm that I am not affected by any of the conditions which are listed on the screening form which would preclude me participating in the study.

3. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason.

4. I agree that this form that bears my name and signature may be seen by a designated auditor.

5. I agree that my non-identifiable research data may be stored in National Archives and be used anonymously by others for future research. I am assured that the confidentiality of my data will be upheld through the removal of any personal identifiers.

6. I understand that my interview may be taped and subsequently transcribed.

7. I agree to take part in the above study.

Name of participant	Date	Signature
______________________________	________________	________________

Name of person taking consent (if different from researcher)	Date	Signature
______________________________	________________	________________

Researcher	Date	Signature
______________________________	________________	________________

1 copy for participant; 1 copy for researcher.

B.3. Participation information sheet

School of Science and Technology, Middlesex University,
The Burroughs, Hendon, London, NW4 4BT.

360 Degree Video Study Information For Participants

Researchers: Mr. Adam Philpot, Dr. Peter Passmore and Dr. Bob Fields.

Information

You are being invited to take part in a research study. Before you decide it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish. Ask us if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part.

What is the purpose of the study?

The aim of this study is to observe your behaviour while viewing various forms of video including immersive forms such as 360 degree video on various devices including computer monitors, phones, and VR headsets. The researchers may observe and record your behaviour and interview you about your experience. The information collected throughout the study is only for research purposes and participants will remain anonymous. The research is an investigation into how users experience various forms of video and VR experiences.

Why was I chosen?

You were chosen to take part in this study because you provided the desired responses to the questions in the screening questionnaire, i.e. you are willing to participate and are not adversely affected by issued identified in the screening questionnaire.

Do I have to take part?

It is up to you to decide whether or not to take part. If you do decide to take part you will be given this information sheet to keep and be asked to sign a consent form. If you decide to take part you are still free to withdraw at any time and without giving a reason.

Health and Safety Notice

You have already completed the screening questionnaire. The following is a brief summary of the Oculus health and safety guide which can be found at
http://static.oculus.com/documents/gear-vr-health-and-safety-warnings.pdf

The Rift/Gear VR will be set up according to the Oculus guidelines and used in a safe environment.

If you experience any abnormal or adverse effects while using the Rift or Gear VR, STOP using it immediately.

When you finish using the Rift or Gear VR, if you experience any abnormal or adverse effects e.g. dizziness, symptoms akin to motion sickness etc., take a few moments to rest and readjust. Do not drive, operate machinery or engage in visually or physically demanding activities that could be affected by the aforementioned symptoms. If such symptoms persist you are advised to consult a doctor.

Do not use the Rift or Gear VR if you have a pacemaker or other implanted medical device, without first consulting your doctor or the manufacturer of your medical device.

What Will Happen?

This research will be used as part of a research project and may be published in the future. You may be invited back at a later date to participate in a future study.

Please note that in order to ensure quality assurance and equity this project may be selected for audit by a designated member of the committee. This means that the designated member can request to see signed consent forms. However, if this is the case your signed consent form will only be accessed by the designated auditor or member of the audit team.

What Do I Have to Do?

You will be asked to watch and comment on a range of video and VR media which may include looking at monitors, phones and VR headsets.

Firstly, you will be informed of the health and safety guidelines for using the Oculus Rift and/or Samsung Gear VR (also referred to as a HMD (Head Mounted Device)), which are identical.

Following each viewing with each individual device, you will review your experience with the researcher. You will be asked some questions and encouraged to provide feedback in regard to your experience of the 360 degree video. This will also be video recorded, in order for us to adequately analyse all of your feedback and comments. Once this has been completed for each viewing, using each device, the study will be concluded with a short debriefing.

Will my taking part in this study be kept confidential?

All information that is collected about you during the course of the research will be kept strictly confidential. Any information about you which is used will have your name and email address removed so that you cannot be recognised from it. All data will be stored, analysed and reported in compliance with the Data Protection Act 1998 (which can be viewed here: http://www.legislation.gov.uk/ukpga/1998/29/contents).

You will be video recorded only while wearing the HMD and at an angle to obscure your face as much as possible. The recorded video will not be broadcast, viewed or given to any third party and will be kept securely on an encrypted computer. The original media used to record the film will be securely locked in a cabinet, separate to any other information about you, to which only the named researchers have access to.

Who has reviewed the study?

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Further Information

Further information can be obtained from:

Adam Philpot
Email: ap1002@live.mdx.ac.uk

Dr. Peter Passmore:
Email: p.passmore@mdx.ac.uk

Thank you for taking part in this study. A copy of this information sheet and a signed copy of the consent form will be provided to you.

B.4. Interview questions

<u>Questions</u>

How do/did you feel after/while watching the video?

Can you tell me more about X?

Did you find any differences to 'normal' videos that you watch on your phone, PC or TV?

What's good about watching videos this way? What's bad about watching videos this way?

I noticed that you looked around a lot, why?

Can you recall any moments that made you feel inclined to look around more?

You said "X" while viewing; can you tell me more about that?

How much did the video hold your attention or focus?

How much were you interested in this video?

When it finished, were you disappointed that it was over?

What kinds of programmes would you like to watch in 360, using this device?

Can you remember…

How many years has the beekeeper been keeping bees?

How many microphones were on the honeycomb?

How many fellow beekeepers were in the background?

B.5. Questionnaire

Please circle the number; from 1 (not at all) to 5 (very much), that best matches your response to each statement.

During my experience of the displayed environment...

I felt like I was there, in the scenes of the video

Not at all   Very much

1	2	3	4	5
1	2	3	4	5

I felt I could interact with the displayed environment

Not at all   Very much

1	2	3	4	5
1	2	3	4	5

I paid more attention to the displayed environment than I did to my own thoughts (e.g., personal preoccupations, daydreams etc.).

Not at all   Very much

1	2	3	4	5
1	2	3	4	5

I felt as though I was in the same space as the character and/or objects.

Not at all   Very much

1	2	3	4	5
1	2	3	4	5

And finally,

How much did you enjoy the content of the clip?

Not at all Very much

1	2	3	4	5
1	2	3	4	5

How much did you enjoy the way you viewed the clip?

Not at all Very much

1	2	3	4	5
1	2	3	4	5

B.6. Debriefing sheet

Middlesex University London

School of Science and Technology, Middlesex University,
The Burroughs, Hendon, London, NW4 4BT.

360 Degree Video Study Debriefing Information For Participants

Researchers: Mr. Adam Philpot, Dr. Peter Passmore and Dr. Bob Fields.

IMPORTANT: For Your Information

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If you have been adversely affected by any of the content viewed during the 360 degree videos, you may contact the Middlesex University support centre for support and assistance. An appointment can be booked via http://unihub.mdx.ac.uk/your-support-services/counselling-and-mental-health. Additionally, contact can be made via the following email address: counselling@mdx.ac.uk or telephone: 020 8411 6058 for more information.

The Counselling & Mental Health team
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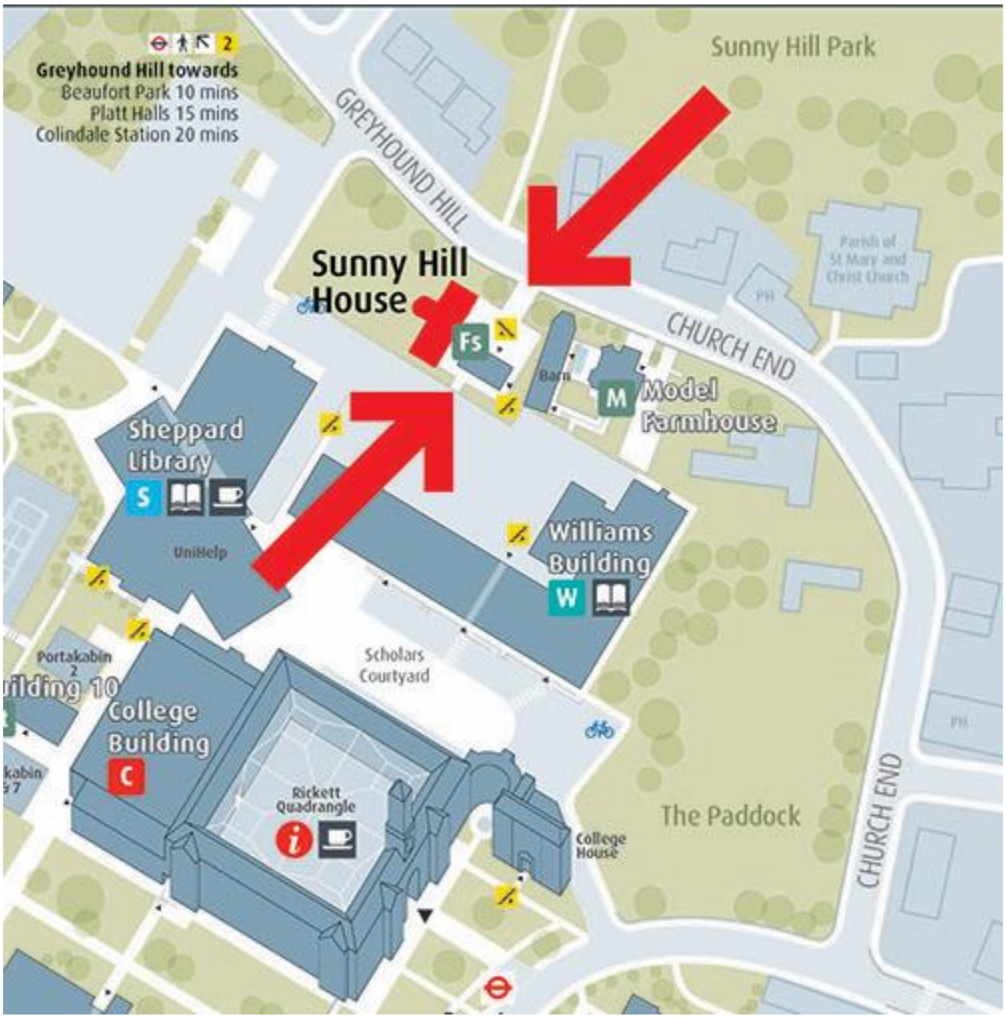

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Dr. Peter Passmore:
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Thank you for taking part in this study.

Appendix C: User study one documents

C.1. Screening questionnaire

School of Science and Technology, Middlesex University,
The Burroughs, Hendon, London, NW4 4BT.

360 Degree Video Study - Screening Questions

Researchers: Mr. Adam Philpot, Dr. Peter Passmore and Dr. Bob Fields.

This study involves some use of Virtual Reality equipment. For some people, viewing using Virtual Reality equipment is not recommended. Therefore, if any of the below statements apply to you, we would have to ask you not to participate in this study. As a precaution use of Virtual reality viewing equipment may not be recommended where the participant:

- is or may be, pregnant
- has had a seizure
- has an epileptic condition
- is elderly
- suffers from psychiatric disorders
- suffers from a heart condition
- has pre-existing binocular vision abnormalities
- has had a loss of awareness
- suffers from a serious medical condition
- wears a pacemaker or other implanted medical device
- suffers from dizziness and/or sickness
- has a cold/flu at the moment
- has a stress or an anxiety related condition

1. Please tick if you can certify that none of the above applies to you. ☐

2. Please tick if you would be willing to be video recorded while viewing a 360 degree video during this study? ☐

If you have not been able to tick the above two boxes then you will not be able to participant in the study but we thank you very much for your interest, otherwise please continue to answer the questions below.

3. Have you used any Virtual Reality Head Mounted Display in the past?

Yes ☐ No ☐

If yes, which?

4. Have you ever viewed 360 degree video?

Yes ☐ No ☐

5. If yes, which device/s did you use?

6. How frequently do you play video games?

Frequently ☐ Occasionally ☐ Seldom ☐ Never ☐

8. How frequently do you watch visual content such as TV series, news, movies etc.?

Frequently ☐ Occasionally ☐ Seldom ☐ Never

Participant Details

Name:
Age:
Gender:
Occupation:
Participant Number:

C.2. Consent form

Participant Identification Number:

CONSENT FORM

Title of Project: 360 Degree Video Study 2019

Name of Researcher: Mr. Adam Philpot

1. I confirm that I have read and understand the information sheet dated ....……………..…for the above study and have had the opportunity to ask questions.

2. I confirm that I am not affected by any of the conditions which are listed on the screening form which would preclude me participating in the study.

3. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason.

4. I agree that this form that bears my name and signature may be seen by a designated auditor.

5. I agree that my non-identifiable research data may be stored in National Archives and be used anonymously by others for future research. I am assured that the confidentiality of my data will be upheld through the removal of any personal identifiers.

6. I understand that my interview may be taped and subsequently transcribed.

7. I agree to take part in the above study.

Name of participant	Date	Signature
______________________________	________________	________________
Name of person taking consent (if different from researcher)	Date	Signature
______________________________	________________	________________
Researcher	Date	Signature
______________________________	________________	________________

1 copy for participant; 1 copy for researcher.

C.3. Participation information sheet

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The Burroughs, Hendon, London, NW4 4BT.

360 Degree Video Study Information For Participants

Researchers: Mr. Adam Philpot, Dr. Peter Passmore and Dr. Bob Fields.

Information

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What is the purpose of the study?

The aim of this study is to observe your behaviour while viewing various forms of video including immersive forms such as 360 degree video on various devices including computer monitors, phones, and VR headsets. The researchers may observe and record your behaviour and interview you about your experience. The information collected throughout the study is only for research purposes and participants will remain anonymous. The research is an investigation into how users experience various forms of video and VR experiences.

Why was I chosen?

You were chosen to take part in this study because you provided the desired responses to the questions in the screening questionnaire, i.e. you are willing to participate and are not adversely affected by issued identified in the screening questionnaire.

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Adam Philpot
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Dr. Peter Passmore:
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C.4. Interview questions

<u>Questions</u>

How do/did you feel after/while watching the video?

Can you tell me more about X?

Did you find any differences to 'normal' videos that you watch on your phone, PC or TV?

What's good about watching videos this way? What's bad about watching videos this way?

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Can you recall any moments that made you feel inclined to look around more?

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How much were you interested in this video?

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What kinds of programmes would you like to watch in 360, using this device?

Can you remember…

How many years has the beekeeper been keeping bees?

How many microphones were on the honeycomb?

How many fellow beekeepers were in the background?

C.5. Questionnaire

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I felt I could interact with the displayed environment

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I paid more attention to the displayed environment than I did to my own thoughts (e.g., personal preoccupations, daydreams etc.).

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1	2	3	4	5
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I felt as though I was in the same space as the character and/or objects.

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And finally,

How much did you enjoy the content of the clip?

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1	2	3	4	5
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How much did you enjoy the way you viewed the clip?

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C.6. Debriefing sheet

Middlesex University London

School of Science and Technology, Middlesex University,
The Burroughs, Hendon, London, NW4 4BT.

360 Degree Video Study Debriefing Information For Participants

Researchers: Mr. Adam Philpot, Dr. Peter Passmore and Dr. Bob Fields.

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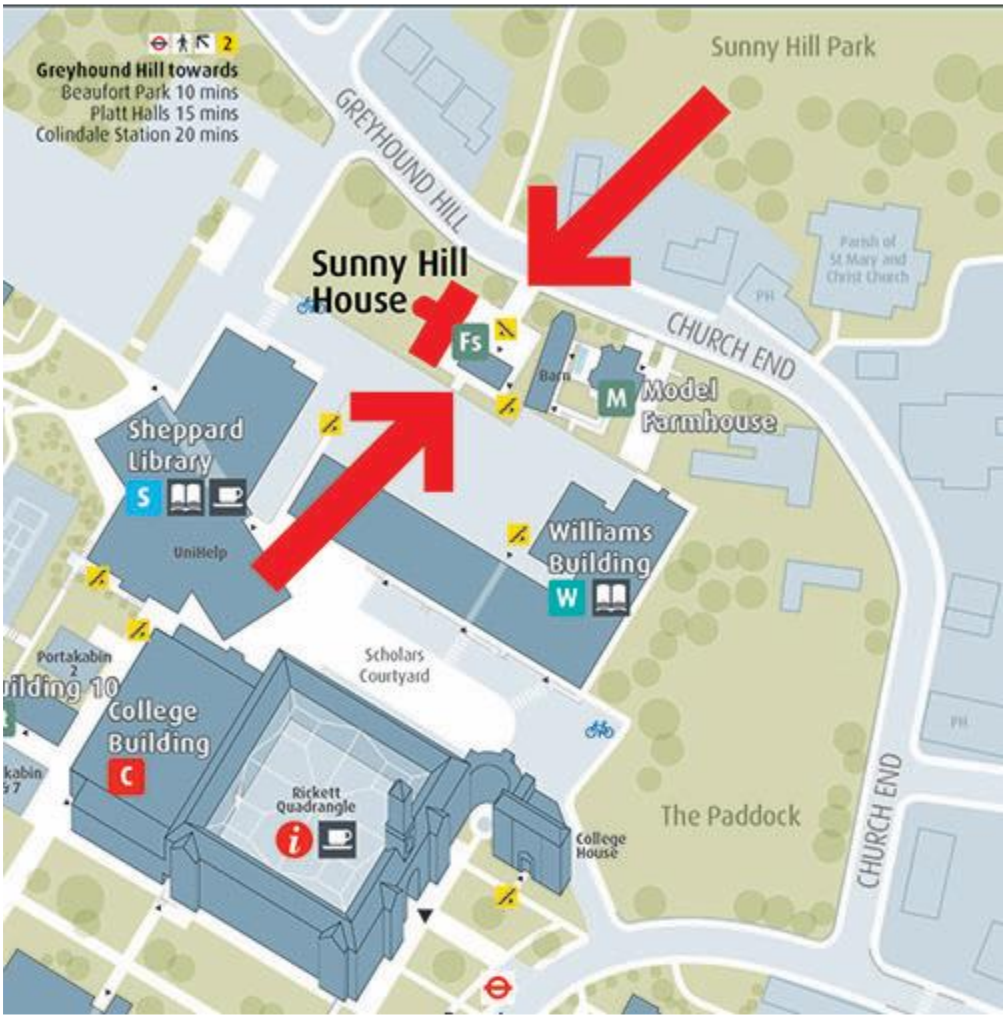

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Thank you for taking part in this study.

Appendix D: User study one documents

D.1. Screening questionnaire

School of Science and Technology, Middlesex University,
The Burroughs, Hendon, London, NW4 4BT.

360 Degree Video Study - Screening Questions

Researchers: Mr. Adam Philpot, Dr. Peter Passmore and Dr. Bob Fields.

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- has had a seizure
- has an epileptic condition
- is elderly
- suffers from psychiatric disorders
- suffers from a heart condition
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- has had a loss of awareness
- suffers from a serious medical condition
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- suffers from dizziness and/or sickness
- has a cold/flu at the moment
- has a stress or an anxiety related condition

1. Please tick if you can certify that none of the above applies to you. ☐

2. Please tick if you would be willing to be video recorded while viewing a 360 degree video during this study? ☐

If you have not been able to tick the above two boxes then you will not be able to participant in the study but we thank you very much for your interest, otherwise please continue to answer the questions below.

3. Have you used any Virtual Reality Head Mounted Display in the past?

Yes ☐ No ☐

If yes, which?

4. Have you ever viewed 360 degree video?

Yes ☐ No ☐

5. If yes, which device/s did you use?

6. How frequently do you play video games?

Frequently ☐ Occasionally ☐ Seldom ☐ Never ☐

8. How frequently do you watch visual content such as TV series, news, movies etc.?

Frequently ☐ Occasionally ☐ Seldom ☐ Never

Participant Details

Name:
Age:
Gender:
Occupation:
Participant Number:

D.2. Consent form

Participant Identification Number:

CONSENT FORM

Title of Project: 360 Degree Video Study 2019

Name of Researcher: Mr. Adam Philpot

1. I confirm that I have read and understand the information sheet dated ....……………..…for the above study and have had the opportunity to ask questions.

2. I confirm that I am not affected by any of the conditions which are listed on the screening form which would preclude me participating in the study.

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6. I understand that my interview may be taped and subsequently transcribed.

7. I agree to take part in the above study.

Name of participant	Date	Signature
____________________	____________	____________
Name of person taking consent (if different from researcher)	Date	Signature
____________________	____________	____________
Researcher	Date	Signature
____________________	____________	____________

1 copy for participant; 1 copy for researcher.

D.3. Participation information sheet

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The Burroughs, Hendon, London, NW4 4BT.

360 Degree Video Study Information For Participants

Researchers: Mr. Adam Philpot, Dr. Peter Passmore and Dr. Bob Fields.

Information

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Why was I chosen?

You were chosen to take part in this study because you provided the desired responses to the questions in the screening questionnaire, i.e. you are willing to participate and are not adversely affected by issues identified in the screening questionnaire.

Do I have to take part?

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What Do I Have to Do?

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Will my taking part in this study be kept confidential?

All information that is collected about you during the course of the research will be kept strictly confidential. Any information about you which is used will have your name and email address removed so that you cannot be recognised from it. All data will be stored, analysed and reported in compliance with the Data Protection Act 1998 (which can be viewed here: http://www.legislation.gov.uk/ukpga/1998/29/contents).

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Email: ap1002@live.mdx.ac.uk

Dr. Peter Passmore:
Email: p.passmore@mdx.ac.uk

Thank you for taking part in this study. A copy of this information sheet and a signed copy of the consent form will be provided to you.

D.4. Interview questions

Questions

How do/did you feel after/while watching the video?

Can you tell me more about X?

Did you find any differences to 'normal' videos that you watch on your phone, PC or TV?

What's good about watching videos this way? What's bad about watching videos this way?

I noticed that you looked around a lot, why?

Can you recall any moments that made you feel inclined to look around more?

You said "X" while viewing; can you tell me more about that?

How much did the video hold your attention or focus?

How much were you interested in this video?

When it finished, were you disappointed that it was over?

What kinds of programmes would you like to watch in 360, using this device?

Can you remember…

How many years has the beekeeper been keeping bees?

How many microphones were on the honeycomb?

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D.5. Debriefing sheet

School of Science and Technology, Middlesex University,
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360 Degree Video Study Debriefing Information For Participants

Researchers: Mr. Adam Philpot, Dr. Peter Passmore and Dr. Bob Fields.

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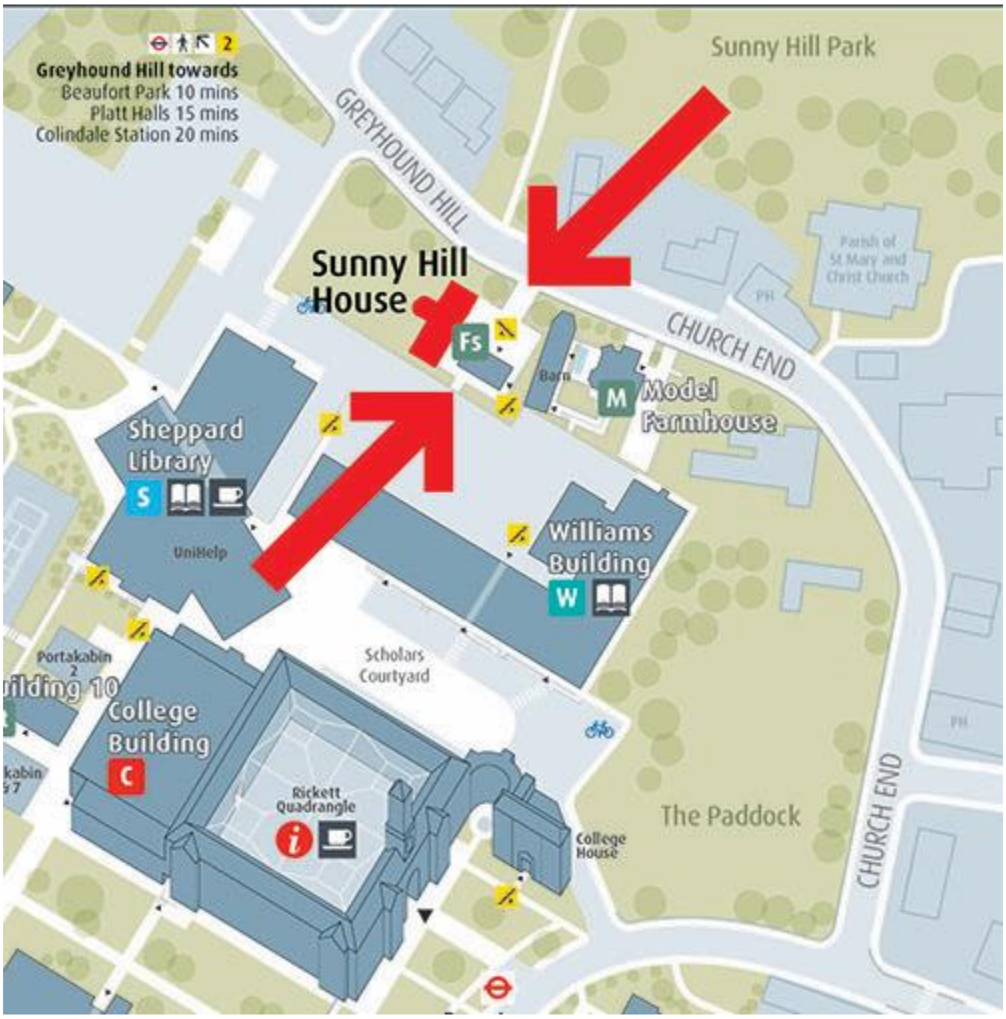

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Thank you for taking part in this study.

Appendix E: The IPQ

Igroup Presence Questionnaire (IPQ)

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 [1].

1. In the computer generated world I had a sense of "being there".

not at all ☐☐☐☐☐☐☐ very much

2. Somehow I felt that the virtual world surrounded me.

fully disagree ☐☐☐☐☐☐☐ fully agree

3. I felt like I was just perceiving pictures.

fully disagree ☐☐☐☐☐☐☐ fully agree

4. I did not feel present in the virtual space.

did not feel ☐☐☐☐☐☐☐ felt present

5. I had a sense of acting in the virtual space, rather than operating something from outside.

fully disagree ☐☐☐☐☐☐☐ fully agree

6. I felt present in the virtual space.

fully disagree ☐☐☐☐☐☐☐ fully agree

7. How aware were you of the real world surrounding while navigating in the virtual world? (i.e. sounds, room temperature, other people, etc.)?

extremely aware ☐☐☐☐☐☐☐ not aware at all

8. I was not aware of my real environment.

fully disagree | | | | | | | | fully agree

9. I still paid attention to the real environment.

fully disagree | | | | | | | | fully agree

10. I was completely captivated by the virtual world.

fully disagree | | | | | | | | fully agree

11. How real did the virtual world seem to you?

completely real | | | | | | | | not real at all

12. How much did your experience in the virtual environment seem consistent with your real world experience?

not consistent | | | | | | | | fully consistent

13. How real did the virtual world seem to you?

About as real as an imagined world | | | | | | | | indistinguishable from the real world

14. The virtual world seemed more realistic than the real world.

fully disagree | | | | | | | | fully agree

[1] Witmer, B.G. & Singer. M.J. (1998). Measuring presence in virtual environments: A presence questionnaire. Presence : Teleoperators and Virtual Environments, 7(3), 225-240.

Appendix F: The IPQ results

The means for each category of the IPQ in terms of viewing condition and ordering.

Viewing Condition / Ordering	IPQ Category			
	General Presence (G)	Spatial Presence (SP)	Involvement (INV)	Realism (REAL)
VR Overall	4.812	4.525	3.640	3.359
Phone Overall	2.577	2.621	1.578	2.125
VR First	4.625	4.225	2.718	3.343
VR Second	5	4.825	4.562	3.375
Phone First	3.375	3.2	1.625	2.5
Phone Second	1.5	2.043	1.531	1.75