Enhancing Player Experience in Asymmetric VR Games

Author:

Michael McCready

Supervisors:

Dr. Alexandra Covaci

Dr. Luma Tabbaa

A thesis submitted in fulfillment of the requirements for the degree of Masters of Science by Research

in the

School of Engineering and Digital Arts

University of Kent

March 18, 2023

Acknowledgements

I would like to thank my supervisors Dr. Alexandra Covaci and Dr. Luma Tabba for their dedication in helping me navigate the research and thesis process. Their insights, teaching moments, and review of my work have allowed me to develop an effective research project and data analysis methods. Their support helped transform what felt like a daunting endeavor into a rewarding process.

I am grateful for the opportunity to discuss my research with Dr. George Ghinea. His insights were helpful in the establishment of my research methodologies.

I am grateful for the support I have received from supervisors and colleagues at Lethbridge College. Additionally, without the financial support of provided through the Lethbridge College Faculty PD Committee, it would not have been possible to pursue a master's degree.

Finally, it is with the utmost gratitude that I acknowledge the support from my wife. Pursuing a master's degree while working full-time requires a significant time commitment. Without the tireless support and encouragement from my wife, it would not have been possible to develop my asymmetric VR prototype, conduct my research and analyse the results, and write this thesis.

Abstract

Interest in multiplayer games that allow players to connect and play together using different technologies, such as virtual or augmented reality (VR/AR) has increased. Research has shown that in cross-reality gaming experiences (eg. where there are differences in players' abilities, user interface (UI), and methods of interaction) it is possible to achieve an enhanced player experience (PX) through various interdependencies. However, most of the previous work focuses on co-located scenarios, where the space and proximity of the players are local and utilised. In this study, I present an asymmetric VR game prototype called *LabXscape*. Through the prototype, I researched how asymmetries of interface, methods of interaction, information access, and narrative impact the PX for players using different technologies (eg. VR, mobile, PC). In this asymmetric VR game prototype, players can use different devices. Their interactions, movements, and information influence and are shared with each other, creating a cross-reality experience. My observations reveal that there are factors that allow non-VR players to have as engaging an experience as VR players, despite using a less immersive device.

Contents

Acknowledgements **i**

Abstract **ii**

List of Acronyms **xi**

1 Introduction **1**

1.1 Background 1

1.2 Aim and Research Questions 3

1.3 Scope 5

1.4 Contribution 5

1.5 Thesis Overview 6

2 Literature Review **8**

2.1 Game Design and Player Experience 9

2.1.1 Mechanics, Dynamics, Aesthetics (MDA) Framework . . . 10

2.1.2 Player Interaction 12

2.1.3 Game Narrative 15

2.1.4 Multiplayer Cooperative Gaming 17

2.2 Embodiment, Presence, Engagement, Immersion 19

2.2.1 Embodiment 20

2.2.2 Presence 24

2.2.3 Engagement 27

2.2.4 Immersion 31

2.3 Asymmetric VR 32

2.3.1 The Importance of Asymmetric VR 33

2.3.2 Unique Challenges of Asymmetric VR 34

2.3.3 Asymmetric VR Frameworks 36

2.4 Research Gaps 40

2.5 Conclusion of Literature Review 42

3 System Design and Implementation **44**

3.1 Prototype Overview 45

3.2 Scenario Development 46

3.3 Avatars, Roles, Interactions, and Communication 49

3.3.1 PC Player 50

3.3.2 Mobile Player 52

3.3.3 VR Player 54

3.4 Tasks 56

3.4.1 Task 1: Exiting the Lab 56

3.4.2 Task 2: Disable Reactor Security Measures 57

3.4.3 Task 3: Replace the Power Crystal 58

3.5 Hardware Implementation 60

3.6 System Architecture Design 61

3.6.1 How the System Works 62

3.7 Chapter Summary 63

4 Methodology **66**

4.1 Ethics 67

4.2 Participant Screening Criteria 68

4.3 Participants 68

4.4 Experiment Design and Procedures 69

4.4.1 Research Software 71

4.4.2 Research Measures 71

4.5 Thematic Analysis 72

4.5.1 Phase One: Become Familiar with the Data 73

4.5.2 Phase Two: Generate Initial Codes 73

4.5.3 Phase Three: Search for Themes 74

4.5.4 Phase Four: Review Themes 74

4.5.5 Phase Five: Define Themes 74

4.5.6 Phase Six: Produce Report 75

4.6 Chapter Summary 75

5 Results **77**

5.1 Introduction 77

5.2 Narrative 78

5.2.1 Story Engages and Immerses Players 79

5.2.2 Roles Compensate for Device Immersion Limitations . . . 80

5.2.3 Quantitative Evaluation 82

5.3 Interactions 83

5.3.1 Physical Movement Creates Embodiment 83

5.3.2 Interaction Methods Affect Engagement and PX 86

5.3.3 Quantitative Evaluation 87

5.4 Engagement . . . 89
5.4.1 Team Dependencies Motivate Players to Complete Tasks . 90
5.4.2 Time Constraints Create Challenge and Enjoyment . . . 91
5.4.3 Visual Observation Sufficient for PC Players . . . 92
5.4.4 Lack of Preparation Reduces Engagement . . . 93
5.4.5 Quantitative Analysis . . . 95
5.5 Team Dynamics . . . 96
5.5.1 Verbal Communication Preferred for Team Collaboration . 97
5.5.2 Interdependence Creates a Positive PX Among Players . . 99
5.5.3 Quantitative Analysis . . . 100
5.6 Presence . . . 101
5.6.1 Humanoid Avatars Required Social Presence . . . 102
5.6.2 Focused Interactions Connect Players to Each Other . . . 104
5.6.3 Environment Responses to Non-VR Players Create Presence 105
5.6.4 Quantitative Analysis . . . 106
5.7 Summary of Findings . . . 107
5.8 Chapter Summary . . . 109

6 Discussion and Conclusion 111
6.1 PX of VR and non-VR Players . . . 112
6.2 Factors Affecting PX of Players in an Asymmetric VR Game . . . 113
6.2.1 Embodiment Factors . . . 113
6.2.2 Engagement Factors . . . 114
6.2.3 Social Presence Factors . . . 116
6.3 Best Practices for Designing an Asymmetric VR Game . . . 117
6.3.1 Design a Compelling Narrative and Device-specific Roles . 117

6.3.2 Tasks Should Include Interdependencies and Actively Involve All Players . . . 119
6.3.3 All Players Should Have a Humanoid Avatar . . . 120
6.3.4 Player Preparation Should be Considered . . . 121
6.3.5 Communication Protocols Need to be Established . . . 122
6.4 Limitations . . . 124
6.5 Future Work . . . 126
6.6 Conclusion . . . 127

References **128**

Appendices **149**
Appendix A Social Media Recruitment Post . . . 150
Appendix B Participant Recruitment Questionnaire . . . 151
Appendix C Participant Information Sheet . . . 155
Appendix D Informed Consent Form . . . 161
Appendix E Player Scenario Cards . . . 162
Appendix F GUESS-18 Survey Questions . . . 165
Appendix G Multimodal Presence Scale (MPS) . . . 169
Appendix H Semi-structured Interview Questions . . . 171

List of Figures

1.1 A simplified version of a virtuality continuum 2

2.1 Scaffolding of theories and concepts 8
2.2 MDA Framework order of influence 10
2.3 Swink's Model of Interactivity 12
2.4 Flow state model 14
2.5 Factors that affect game experience 16
2.6 Example of a Cooperative Game 18
2.7 Example of a game with a non-traditional avatar 20
2.8 An example of focused interaction between two players (GiantsVR) 26
2.9 The OA3 Framework 29
2.10 Player engagement with their character 30
2.11 Components of the Taxonomy of Asymmetric Interfaces 37
2.12 "Best fit" framework for asymmetric VR games 39

3.1 A birds-eye view of the virtual space in LabXscape 45
3.2 Scenario card provided to the PC player 48
3.3 UI for the PC player 51
3.4 Avatar for the PC player 51
3.5 UI for mobile player 53
3.6 Avatar for the mobile player 54

3.7 VR player directly interacts with the virtual environment 55
3.8 Avatar for the VR player 55
3.9 The directional dependencies in task 1 57
3.10 The directional dependencies in task 2 58
3.11 The directional dependencies in task 3 59
3.12 Equipment used by players in research study 61
3.13 LabXscape system architecture design 62
3.14 Normcore's MVC architecture 62
3.15 How the system works 63

4.1 Triangulation Design 66
4.2 Participant physical location relationship 70

5.1 Thematic map representing the dataset from all player types . . . 78
5.2 Visual representation of narrative total score from the GUESS-18 tool 82
5.3 Visual representation of usability total score from the GUESS-18 tool 88
5.4 Visual representation of enjoyment total score from the GUESS-18 tool 96
5.5 Visual representation of social connectivity score from the GUESS-18 tool 101
5.6 Visual representation of the MPS social presence totals 107
5.7 Visual representation of the overall GUESS-18 scores 108

List of Tables

1.1 Publications list arising directly from this thesis 6

2.1 Definition of types of mechanics of asymmetry 36

2.2 The Composite Framework for Asymmetric VR (CAVR) 38

4.1 Participant Gender and Age Range Percentages 69

List of Acronyms

6DoF Six Degrees of Freedom

API Application Programming Interface

AR Augmented Reality

AV Augmented Virtuality

CAVR Composite Framework for Asymmetric VR

FOV Field of View

GUESS Game User Experience Satisfaction Scale

HMD Head Mounted Display

HCI Human-Computer Interaction

IMU Inertial Measurement Unit

MDA Mechanics, Dynamics, Aesthetics

MPS Multimodal Presence Scale

MMO Massively Multiplayer Online

MR Mixed Reality

MUD Multi-User Dungeon

MVC Model, View, Controller Architecture

PX Player Experience

SoE Sense of Embodiment

UI User Interface

VR Virtual Reality

Chapter 1

Introduction

1.1 Background

While games in early arcades were single-player, visiting the arcade was a social activity, and it created enjoyment and fostered friendships (Egli & Meyers, 1984). As the popularity of arcades declined and gave way to the rise of home gaming due to consoles such as Atari and the Nintendo Entertainment System, the social aspect of video games did not dwindle; it was moved from the arcade to the basement. The shift in location gave rise to the "couch co-op" phenomenon where multiple people would gather to play video games, banter, socialise, and more (Consalvo, 2017). Over the next few decades, as technology increased and with the introduction of the Internet, social gaming rose to a new level. Video games evolved to allow players to meet new people, share experiences, and develop social relationships (Cade & Gates, 2017). As technology continued to improve, multiplayer games became popular in a variety of areas from esports (Palma-Ruiz et al., 2022) to serious games, where they target not only the entertainment of participants, but also their training or education by leveraging the principles of collaborative learning which allows multiple people to learn a concept together in various symmetric setups - from PC to Virtual Reality (VR) (Laamarti et al., 2014; Wendel & Konert, 2016).

The COVID-19 pandemic, which forced people to work, study, and entertain themselves from home, accelerated the emergence of technologies like augmented reality (AR) and VR as powerful tools for collaboration and connection, allowing people to interact in virtual environments as if they were in the same room, immersing themselves in various gaming experiences. VR is described as a technology that provides believable experiences in a virtual and immersive manner, while AR is a system that superimposes computer-generated content on top of the physical world (Shen & Shirmohammadi, 2008). In 1994, Milgram and Kishino developed the Virtuality Continuum in an attempt to create a taxonomy of mixed reality displays (as shown in Figure 1.1).

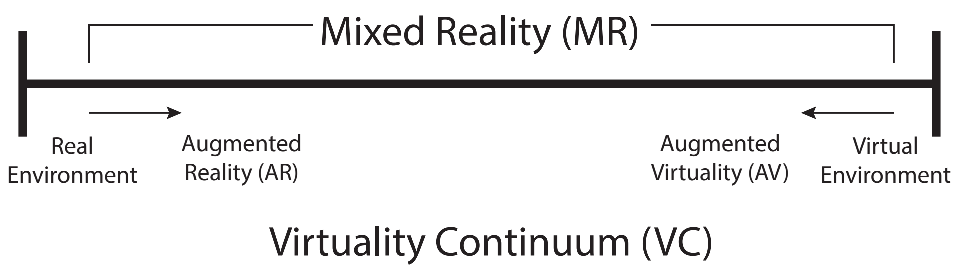


FIGURE 1.1: A simplified version of a virtuality continuum (Milgram et al., 1995)

According to Milgram and Kishino, Augmented Virtuality (AV) is on this continuum. While AR involves augmenting the physical world, AV involves augmenting the virtual world or connecting the virtual world to the physical world (Milgram et al., 1995). Despite their immersive qualities, VR head-mounted displays (HMDs) have received criticism for their isolating characteristics, both socially and technologically (Gugenheimer et al., 2019) and for the discomfort they sometimes induce (Kim, 2019). As a result of these limitations, VR research and design have started to look more and more into leveraging different systems to design novel interactions, which include bystanders and co-players.

In this context, various types of asymmetries were considered - from the asymmetry of player interfaces (rooted in cross-reality paradigms) to differences in how players interact with the game and the information they possess (Harris et al., 2016). Despite some previous work having looked into incorporating asymmetries in multiplayer VR games and understanding how this might impact the player experience (PX), this area is relatively novel, with the recent survey by Rogers et al. identifying only 25 relevant papers on this topic and several limitations and opportunities that need to be investigated further (Rogers et al., 2021). Some of these are multiplayer games with more than two players, remote play, or shared control within the game world and its impact on PX in asymmetric multiplayer VR games.

1.2 Aim and Research Questions

This thesis aims to research, investigate and further identify best practices for asymmetric multiplayer VR games. To assist in accomplishing these aims, I developed an asymmetric multiplayer VR game prototype that connects remote players to a shared virtual world using either a VR device, mobile device, or personal computer (PC). The game is developed based on principles from the literature related to game design. The exploratory research presented in this thesis aims to address specific literature gaps concerning asymmetric multiplayer VR game development.

Specifically, this thesis aims to address the following research questions:

- **RQ 1: Is it possible for VR and non-VR players to have an equally positive PX in a remote asymmetric VR game?** This research question is addressed in Chapter 5 through the presentation of qualitative data, which is based on interviews and video observations that have been grouped into themes. The qualitative data is supported by quantitative data, which is a combination of the Game User Experience Satisfaction Scale (Appendix F) and a subset of the MultiModal Presence Scale (Appendix G).
- **RQ 2: What factors affect the PX of VR and non-VR players in a remote asymmetric VR game?** Based on the findings presented in Chapter 5, this research question is addressed in Chapter 6 through an exploration of factors that affect the PX in VR and non-VR players which include device, social, and software factors.
- **RQ 3: What are the best practices for designing an asymmetric VR game that would provide an equal PX for all players?** This research question is also addressed in Chapter 6 and is based on the findings from Chapter 5 and the factors identified in response RQ 2.

1.3 Scope

This thesis is concerned with extending knowledge on the development of asymmetric multiplayer VR games, specifically how to design for a good PX of all players. This thesis is limited to only three types of devices: a standalone VR HMD with controllers, a mobile device, and a PC (see Section 3.5 for specific device setups). Although the scenario presented in Section 3.2 and the devices used are limited, the intent is that the findings of the research could be applied to other asymmetric multiplayer VR games using a combination of devices.

1.4 Contribution

This thesis contributes to identifying factors that affect PX in asymmetric multiplayer VR games, and offers theoretical and practical examples of these factors. The overall contributions from this thesis could be summarised as follows:

- Identifying factors that contribute to an enjoyable PX for both VR and non-VR players in an asymmetric multiplayer VR game.
- Evaluating/Exploring the impact of these factors on PX in an asymmetric VR game
- Presenting best practices for developing an asymmetric VR game.

Preliminary findings from this research were presented at the academic peer-reviewed workshops listed below.

TABLE 1.1: Publications list arising directly from this thesis

Conference / Workshop	**Title**	**Citation**
AVI2022 / Enhancing Cross-Reality Applications and User Experiences	Enhancing Player Experience in Asymmetric Virtual Reality Gameplay	(McCready et al. 2022)
ISMAR2022 / 1st Workshop on Prototyping Cross-Reality Systems	LabXscape: A Prototype for Enhancing Player Experience in Cross-Reality Gameplay	(McCready et al. 2022)

1.5 Thesis Overview

The thesis is structured as follows:

- Chapter 2 presents a literature review centred on topics pertinent to this study. Topics were chosen and presented in a way to scaffold theories. First, traditional game design theories are presented. Second, theories that focus on engaging and immersing players are presented. Finally, theories and frameworks related to asymmetric VR experiences are presented.
- Chapter 3 presents system design information for the asymmetric VR prototype game and details how the prototype was implemented. This includes the game scenario, roles, tasks, hardware implementation, and system architecture design. This chapter includes the techniques employed to enhance the PX of VR and non-VR players.

- Chapter 4 outlines the research methodology, the tools used in the study, and information about the participants, including how they were recruited and selected.
- Chapter 5 showcases the results of the qualitative study, organized by themes that were identified through a thematic analysis. A presentation of quantitative data is included as support for the qualitative findings.
- Chapter 6 provides an analysis of the qualitative findings and recommendations to improve PX of non-VR players in asymmetric VR games. The limitations of the study and future work opportunities are also included in this chapter.

Chapter 2

Literature Review

This literature review chapter outlines topics that explain the system design decisions detailed in Chapter 3 and underpin the findings of this thesis. The theories and concepts progressively build upon one another, as depicted Figure 2.1.

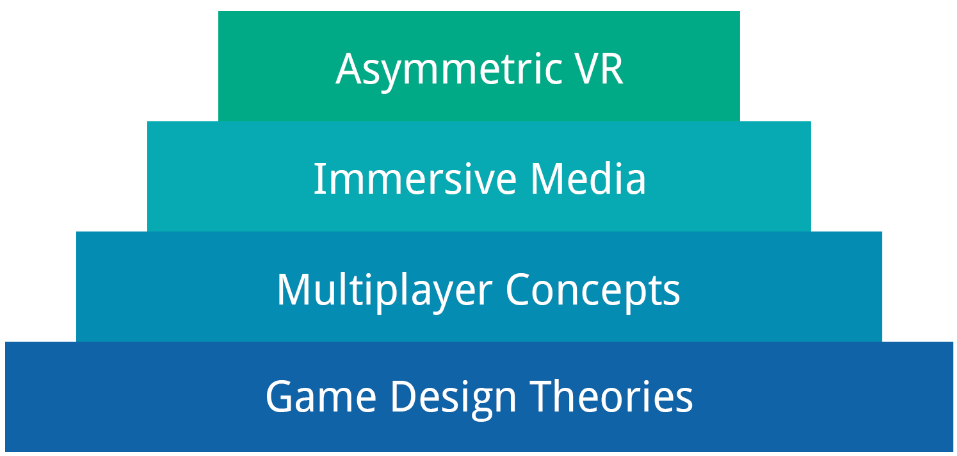


FIGURE 2.1: Scaffolding of theories and concepts

The chapter starts with literature that provides a theoretical understanding of PX and factors that contribute to a positive PX (Section 2.1); this includes exploring factors that contribute to a positive PX in a cooperative multiplayer setting. This section is not specific to immersive games, but rather generic game theory. Next, factors commonly associated with VR are explored and the affordances and limitations of VR, mobile, and PC devices, in relation to these factors, are discussed (Section 2.2). Understanding these factors may help to develop engaging and immersive games, including asymmetric VR games. The next section explores specific factors and theories that affect PX within asymmetric VR games (Section 2.3). At the conclusion of this chapter, a summary of the related work will be presented alongside the identified research gaps that this thesis attempts to address.

2.1 Game Design and Player Experience

Whether single-player, multiplayer, VR, or desktop computer, developing an engaging video game requires strategic decisions that are informed by game design theories. Game design has evolved significantly since the 1980s, when the creation of video games focused primarily on programming (Ulf, 2009). As various technologies improved over the past few decades, game design has become multi-faceted. To better understand the theory and application of game design principles, a number of frameworks have been developed.

In this section, I will research and explore related work on concepts that are required for successful video game design and a positive PX.

2.1.1 Mechanics, Dynamics, Aesthetics (MDA) Framework

Various game design theories and frameworks are in use today, each of them presenting its own set of benefits and drawbacks. The application of these theories and frameworks depends on the goals of the developer and which are deemed a "best fit" to those goals. According to O'Shea and Freeman, a game design framework is a set of concepts that provide insight into a set of design issues (O'Shea & Freeman, 2019).

One of the most popular game design frameworks is the Mechanics, Dynamics, Aesthetics (MDA) Framework (O'Shea & Freeman, 2019, p. 7). The MDA Framework was developed by Hunicke, Leblanc, and Zubek in 2004 and is intended to provide a formal approach to understanding games (Hunicke et al., 2004). The MDA Framework bridges the gap between game designers and players. Video games are created by designers and consumed by players. How the consumption occurs is unpredictable and may not be as the game designer intended, as demonstrated in Figure 2.2. Without the MDA Framework, game designers may make decisions that may not align with the player's perceptions or expectations.

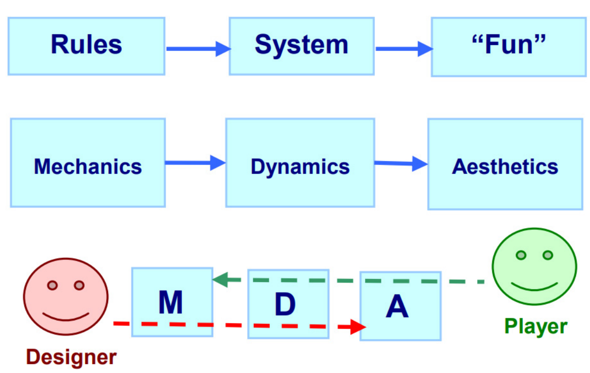


FIGURE 2.2: MDA Framework order of influence (Hunicke et al., 2004)

The MDA Framework approaches the game consumption challenges in a systematic manner by breaking down the consumption process into set components and the correlated design components, which are Mechanics, Dynamics and Aesthetics. Game designers focus on mechanics first and then move to aesthetics, whereas game players focus on aesthetics first and move to mechanics. Understanding this relationship is essential to develop a video game that is fun for players as it allows the perspectives of a game designer and game player to be considered at the same time (Deterding et al., 2011).

Mechanics represents the various actions, behaviors, and controls that are available to a player. **Dynamics** are the real-time responses of mechanics on player inputs. **Aesthetics** describes the emotional responses created in the player when interacting with the game.

Within MDA Framework there are taxonomies that are used to describe the aesthetics of the game:

- Sensation
- Fantasy
- Narrative
- Challenge
- Fellowship
- Discovery
- Expression
- Submission

The MDA Framework helps understand how decisions about gameplay affect the PX and can be applied across a gamut of video game genres and platforms.

2.1.2 Player Interaction

According to Hunicke et al., mechanics from the MDA Framework consists of the various actions and controls given to each player (Hunicke et al., 2004). This is partly dependent on how the player physically interacts with the game. Steve Swink describes this interaction as the Model of Interactivity. This model consists of the flow of information between the player and the computer, as depicted in Figure 2.3.

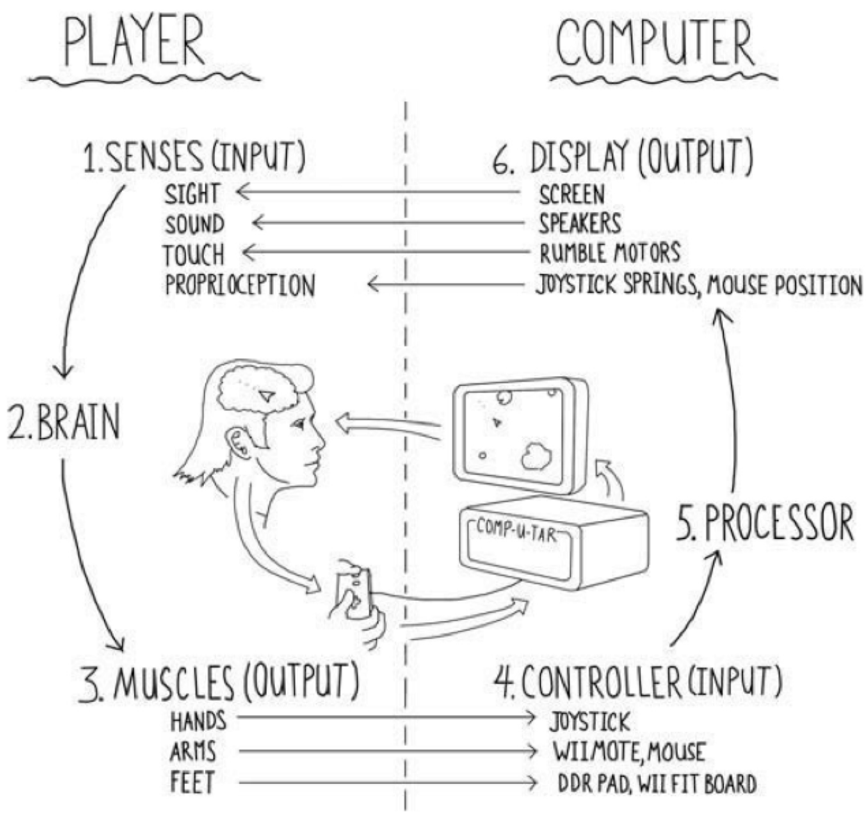


FIGURE 2.3: Swink's Model of Interactivity (Swink, 2009)

Swink indicates that the player receives input in the form of sight, sound, touch and proprioception. Proprioception is described by (Shinkle, 2008) as the feedback mechanism which determines the body's location and movement and is closely linked to the PX. Following the input the player receives, the output is performed through physical body parts such as hands, arms and feet using input devices such as a controller or mouse. These devices will have affordances and constraints, which will affect the PX.

The affordances and constraints of devices are often made manifest in how intuitive the controls seem. Intuitive controls are the extent to which the controls can be easily understood and do not interfere with the player's experience (Johnson et al., 2015). When input devices have naturally mapped control interfaces or authentic interaction, there is less abstraction between the task and the player action needed to perform the task, resulting in higher enjoyment of the game (McEwan et al., 2014). Despite best efforts by game designers, player interactions that are based on physical controllers, such as an Xbox controller or a Meta Quest controller, will often be abstracted. For example, if playing a racing game on the Xbox with a traditional controller, players will need to steer their car with a joystick on the controller. This is less intuitive and does not support the player's previous experience if they have driven a physical car before.

According to Swink, when a player receives input from one of their senses, their reaction time is based on the time it takes to perceive, think, and act (Swink, 2009). The more natural the interaction, the faster the reaction, resulting in a positive PX. The use of authentic input devices, which are devices with minimal abstraction, has been found to result in higher levels of player enjoyment and enhanced gaming experiences (Pietschmann et al., 2012). The impact of authentic input devices on PX is partly due to the reduced challenge and cognition required to translate the idea of the task into actually performing the task, which is understood by reviewing Flow Theory (Csikszentmihalyi, 1990).

Flow Theory is a mechanism used to analyse experiences in any setting to determine flow or "when attention is completely absorbed in the challenges at hand" (Nakamura & Csikszentmihalyi, 2009, p. 197). Components of Flow that contribute to this absorption of attention are a challenging activity requiring skill, a merging of action and awareness, clear goals, immediate feedback, concentration on the task, a sense of control, a loss of self-consciousness, and an altered sense of time (Chen, 2007).

The theory has been adapted to game design. In Flow Theory, the goal is to balance the external complexity of systems with the internal perspective that a player develops of the system. This balance creates a 'flow' that results in a positive player experience (Cowley et al., 2008). When games present complex or abstract controls, the player's concentration can be affected, resulting in a break in the flow experience (Peter, 2007), as depicted in Figure 2.4.

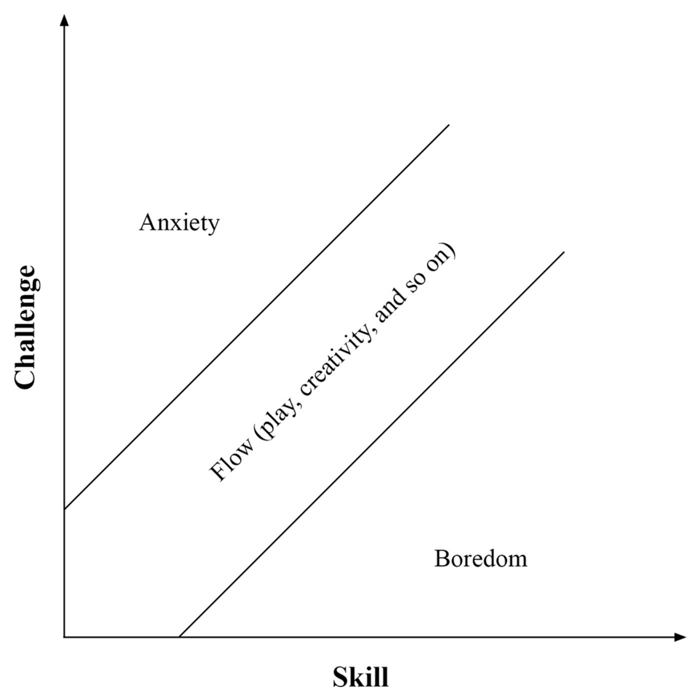


FIGURE 2.4: Flow state model (Csikszentmihalyi, 1990)

As mentioned above, one of the components of Flow is the loss of self-consciousness. Within games, it is not so much a loss of self-consciousness, but an expansion. This results in the player feeling a sense of union with the game (Peter, 2007) or an expansion of the player's concept of self (Järvinen et al., 2002) and the ability for a player temporarily forget who they are and take on a character's personality. This game-self personality (how a player views themselves in a game) is affected by the device used for player interaction. The game-self personality impacts player enjoyment and motivation (Birk & Mandryk, 2013).

2.1.3 Game Narrative

From as early as the mid-1970s, narrative has been included in video games to capture a player's attention (Ip, 2011), although the exact definition of narrative in game design has been the source of much debate (Koenitz, 2018). Narrative elements, as described as part of the structuralist theory, will be considered. These include story, events, actions, settings, and characters (Louchart & Aylett, 2004). Unlike the structuralist theory that indicates the story is unfolded in a chain of events, game narrative has the story discovered and shaped by the players using emergent narratives (Jenkins, 2004).

According to the MDA Framework, the narrative contributes to the framework's aesthetics component (Hunicke et al., 2004), because the narrative in video games can elicit an emotional response in players. In some cases, storytelling has been found to have more of an impact on PX than the challenge/skills balance in flow theory (Kolar & Čater, 2018). Unlike non-interactive media, this response is generated through the player's participation in the narrative.

Through their role in the narrative, players can shape the narrative by becoming an active participant in the story, which is especially true when narrative is combined with context and mechanics, as demonstrated in Figure 2.5.

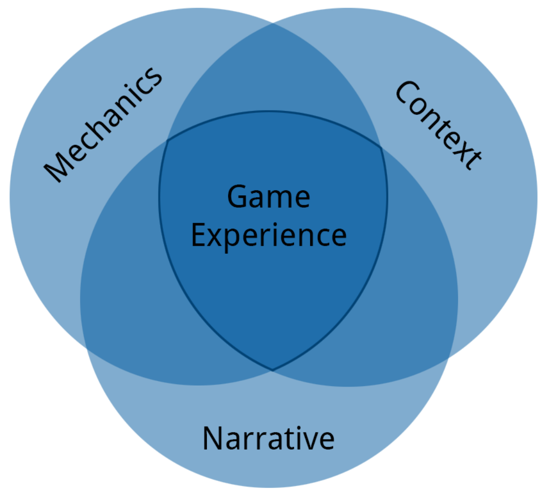


FIGURE 2.5: Factors that affect game experience (Elson et al., 2014)

As players can identify with their character role in the video game, the more the likelihood their enjoyment in the game increases. This enjoyment can increase when players interact with other players authentically, reinforcing their identification with the role (Hefner et al., 2007). Role identification and immersion in the narrative are increased when players have the ability to control their character in the video game (Qin et al., 2009). In fact, the higher the degree of perceived control a player has of their character in a video game, the higher the sense of presence (Moser & Fang, 2015). In addition to immersion increasing with increased character control, overall game enjoyment increases when players see the results of their interactions (Klimmt et al., 2007).

The importance of narrative in video games is not limited to the in-game narrative development. Pre-game stories or backstories can connect players to the virtual world and their role within the game. Pre-game stories have been found to have a positive effect on feelings of presence and game enjoyment (Park et al., 2010).

2.1.4 Multiplayer Cooperative Gaming

Multiplayer video games have different design patterns, including collaborative, competitive, and cooperative. In competitive games, the goals of the players are opposite each other. Collaborative and cooperative games are very similar but have a crucial difference. With cooperative games, players may work together to achieve a mutually beneficial outcome, but the results may not always be positive for all players. In fact, players often have different goals in cooperative games. An example of a cooperative game is League of Legends (pictured in Figure 2.6). In this game, players work together as a team to battle other teams online. The overarching goal is to win as a team, but individual players have personal goals such as gaining experience. Players in a collaborative game share a goal and share the outcomes (Zagal et al., 2006). Many of the factors discussed affect PX in multiplayer cooperative video games, with the added complexity of interplayer communications, relationships, and interactions. While multiplayer video games introduce some additional complexities, video games with multiple players can enhance PX and increase engagement (Ravaja et al., 2006).

According to Morschheuser et al., games with cooperative elements have three common features: (1) cooperative goals structures; (2) mechanics and rules that support and enable cooperation, and (3) communication features (Morschheuser, Riar, et al., 2017). How these features directly impact the PX is referred to as "group flow", which is an extension of the flow theory. Researchers have identified that effective group communication, knowledge of others' skills, and effective teamwork contribute to a positive group flow (Kaye, 2016).

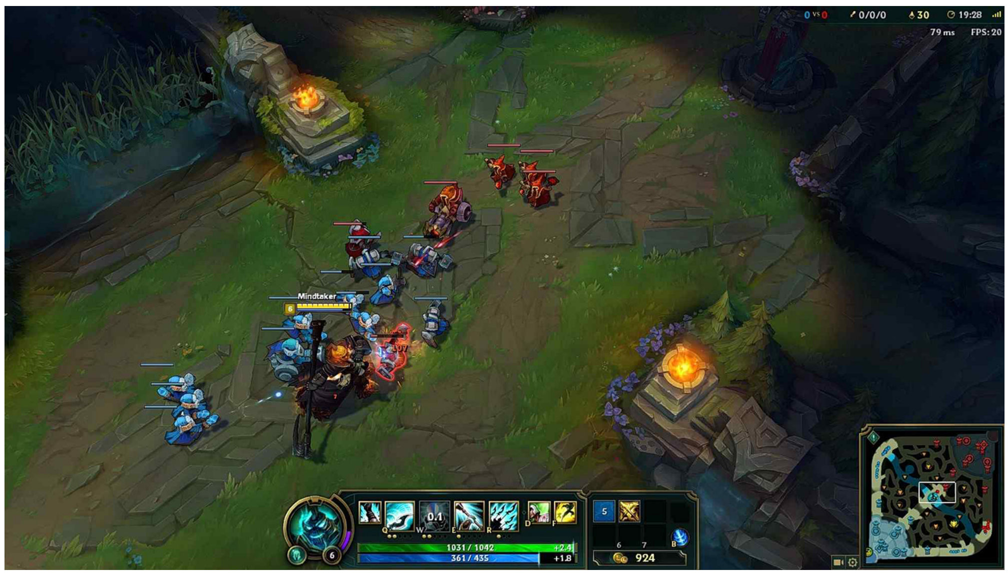


FIGURE 2.6: Example of a Cooperative Game (League of Legends) [1]

There are various design patterns for cooperative-style games. Two of the most common design patterns are complementary and shared goals. The complementary pattern has players control characters that support and complement each other. Shared goals is an approach where all players in a group share a common goal (Rocha et al., 2008), which has been found to positively affect enjoyment and cooperative behavior (Morschheuser, Maedche, et al., 2017). With this design pattern, **effective communication** is critical for positive PX; the lack thereof was shown to have a negative effect on PX (Kaye, 2016), which indicates

[1]https://leaguefeed.net/how-to-take-screenshots-in-lol/

that for the complementary design pattern to be successful, players need to be aware of the skills and abilities of each member of the team. The sharing of knowledge relies on the game's mechanisms for team communication.

The complementary pattern creates a feeling of interdependence, which has been found to positively affect enjoyment in multiplayer games (Kaye & Bryce, 2012). Interdependence is described as the "degree to which group members must rely on one another to perform their tasks effectively given the design of their jobs" (Saavedra et al., 1993, p. 61). This reliance on others in the game has been found to increase levels of social closeness and trust among players (Depping & Mandryk, 2017). Furthermore, researchers have compared games with asymmetric play and symmetric play and found that connectedness and social presence appeared to be higher in games with asymmetric play, especially when interdependence is high (Harris & Hancock, 2019). High interdependence occurs when player actions directly affect other players in the game, while the opposite is true for low interdependence (Emmerich & Masuch, 2017).

2.2 Embodiment, Presence, Engagement, Immersion

Whether playing a video game in VR, mobile, or on a PC there are factors that draw the player into the game and narrative. Immersion, engagement, presence, and embodiment are some of the main factors that draw a player into the game. The success of each device in achieving these factors will vary.

2.2.1 Embodiment

Embodiment is described as a sense that something is part of a player's body. For example, game controllers may become embodied as virtual hands (Lankoski, 2016). In video games, a primary vehicle for creating a sense of embodiment is through avatars or a player's character. A correlation has been identified between the visual representation of an avatar and embodiment and player behavior (Praetorius & Görlich, 2020). While the visual appearance of an avatar can have an influence on embodiment, it is the agency and control that a player has through their avatar and the effects of those actions in the virtual world that creates a stronger sense of embodiment (Klevjer, 2006). With that in mind, those playing the classic video game Pac-Man (pictured in Figure 2.7) may feel a sense of embodiment due to the simple and direct control of Pac-Man, despite the avatar being an abstract character.

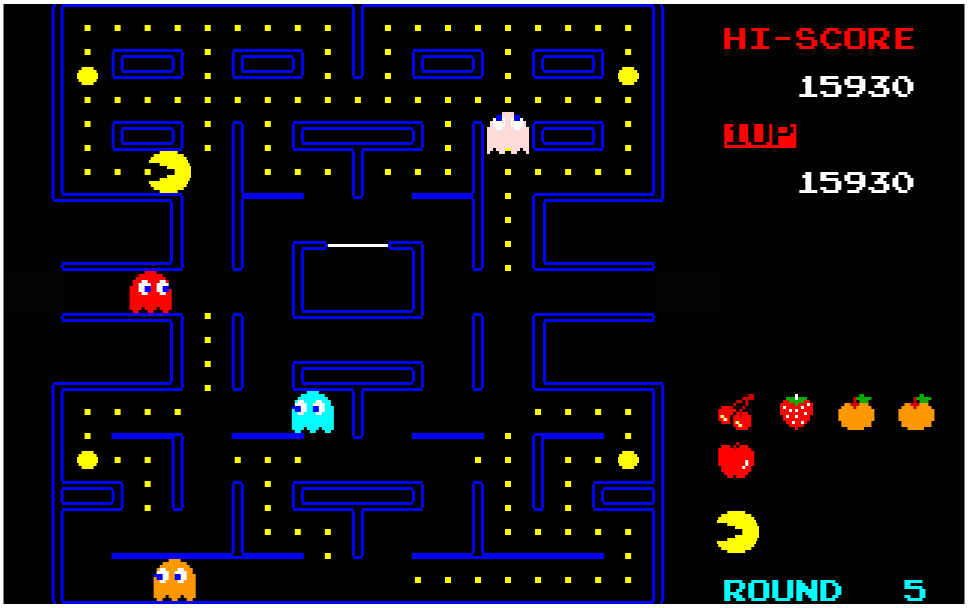


FIGURE 2.7: Example of a game with a non-traditional avatar (Pac-Man[2])

As the player-controlled camera is moved within the game, the assumption of an offscreen body is created, which produces a sense of diegetic embodiment (Rehak, 2003). This is explained through a theory called Game Ego (Wilhelmsson, 2006), which is described as creating a sense of being in a game through a "tactile motor / kinesthetic link". When a player moves their character, the exertion of control is an extension of their own sensory-motor system (Wilhelmsson, 2006). This extension allows a player to experience an awareness of the body in a game world, reinforcing a sense of being within the world (Wilhelmsson, 2001). The level of agency and control is so critical to embodiment that Wilhelmsson (2006) posits that even if a traditional visual character is not present, the ability to control objects within the game creates a manifestation of the player's presence in the game and provides the tactile/motor kinesthetic link between the player and the game.

Additionally, embodiment is achieved when a player assumes their character's goals, role, and mental state. This form of embodiment is called "The Projective Stance" or embodied thinking (Gee, 2008). The game narrative and character role directly impact the level of embodied thinking. As the player connects and understands their character's role and how they fit within the story, they attribute certain mental states to their character.

While the game story and character role can have a significant impact on the level of embodied thinking, the device a player uses to access the game world has a direct impact on the visual embodiment and interactive embodiment the player experiences. Devices that provide methods for natural interactions or

[2] https://www.mobygames.com/game/pc98/pac-man/screenshots/gameShotId,441927/

allow players to express themselves easily through physical movement can increase embodiment (Zavala-Ibarra & Favela, 2012).

Researchers have explored how embodiment is experienced in VR by defining a concept called Sense of Embodiment (SoE) (Kilteni et al., 2012) and three factors that contribute to SoE, which include:

- **Sense of Self-Location:** The feeling of one's self-being inside an avatar's body, which can be increased by having the first-person perspective aligned with the position of the artificial eyes.
- **Sense of Agency:** The sense of having motor control of the avatar is developed when there is a synchronicity of visuomotor correlations, or in other words, when the visual actions of the avatar match the player's intent. The Sense of Agency is increased when there is real-time avatar movement that correlates with physical action from the player.
- **Sense of Body Ownership:** Occurs when parts of the body appear to belong to one's self (Giummarra et al., 2008). The Sense of Body Ownership is influenced by bottom-up and top-down information. Bottom-up information includes synced multisensory inputs such as audio, visual, and haptics. In comparison, top-down information includes the cognitive processes that accept external objects based on pre-existing body representations (Tsakiris, 2010). The Sense of Body Ownership is increased when physical stimulation on the player's body matches seen stimulation on the virtual body. For example, if the VR avatar is holding a drill that is and the player feels physical vibrations or haptics, this reinforces the Sense of Body Ownership.

Mobile devices have limitations in influencing the 'Sense of Body Ownership' aspect of SoE. While mobile devices do not have the body tracking capabilities that VR devices have, they do have limited motion capabilities by combining the Inertial Measurement Unit (IMU) and the device's camera (Fang et al., 2016). This motion tracking enables the translation of a player's physical movement and rotation to the movement and rotation of their avatar in the game world, enhancing the Sense of Agency. Through this real-time mapping of player movement to their avatar, a sense of diegetic embodiment is created through the theory of prosthetic telepresence (Klevjer, 2006). In this sense, the mobile device becomes a window to the game world. The concept of prosthetic telepresence to engage non-VR players has been explored as part of the TeleSight project (Furukawa et al., 2019). In TeleSight, non-VR players can view the virtual world and interact with the VR player through an avatar robot that imitates the motion of a VR user.

While it is possible to create a SoE when playing a video game on a PC (Lankoski, 2016), there are limitations. For example, the Sense of Agency is limited as the interaction is mediated through an input device such as a mouse or keyboard. When the player's character moves in response to those inputs, there is minimal proprioception, and the player's avatar is described in this case as simply a "cursor that mediates the player's relationship to the story world" (Klevjer, 2006, p. 62).

2.2.2 Presence

The term presence is sometimes incorrectly used interchangeably with embodiment or the terms may be used to describe each other. Such as this statement, "presence in a game space means that the player must have some embodied presence, a sense of ‘being’ in the game space" (Taylor et al., 2002, p. 24). While there are some similarities, the two concepts have a main difference. Embodiment refers to the ability to perform bodily actions, and presence refers to the sense of existing in a particular setting (Schultze, 2010). There are three dimensions of presence, each having an impact on PX:

- Personal presence has been described as "a psychological state in which virtual objects are experienced as actual objects in either sensory or non-sensory ways" (K. M. Lee, 2004, p. 27). Another definition of personal presence is the "perpetual illusion of nonmediation" (Lombard & Ditton, 2006), meaning that a player forgets that their interaction is mediated and they believe they are interacting directly in the game world.
- Social presence is defined as the sense of other beings in the virtual world appearing to exist and respond to the player (Cuddihy & Walters, 2000). As other people in the virtual world appear real and react to the player; it is reinforced that the virtual world exists (Heeter, 1992).
- Environmental presence is defined as the extent to which the environment appears to be aware of a player’s existence and responds to their actions (K. M. Lee, 2004).

Personal presence is linked to a player’s ability to position themselves within their physical space (Riva et al., 2014). This concept also applies to virtual space, meaning if a player can move within virtual space, presence can be increased through physical movements. While this applies to VR devices, mobile devices can also allow a player to move within a virtual space through physical movements using an IMU (Fang et al., 2016). While PC devices are at a disadvantage when it comes to creating a sense of presence (when compared to VR devices), there are other factors besides the device that can be implemented on a PC experience to create presence, such as the ability to focus the player's attention (Tamborini & Skalski, 2006). This focus can be gained through the audiovisual senses or cognitively through the dramatic content or narrative (Tamborini & Skalski, 2006).

Social presence and social play have been found influence PX and enjoyment directly (Gajadhar et al., 2008). Several factors influence the degree of felt social presence: visual representation, interactivity, haptic feedback, depth cues, and audio quality (C. S. Oh et al., 2018). Researchers have found that people feel higher levels of social presence when a visual representation is available (C. S. Oh et al., 2018). Although there are mixed results in the requirement of avatars needing to be photorealistic or anthropomorphic (Nowak & Biocca, 2003). While real-time communication between players fosters social presence, communication combined with interaction between players creates a higher sense of social presence (C. S. Oh et al., 2018). When players are communicating and interacting together on a shared task, they share a common focus and become jointly engrossed, which is called focused interaction (Schultze & Brooks, 2019). The effect that focused interaction has on social presence is conveyed by the following definition of social presence: "the ability to recognize motor and proximal intentions which allows the Self to identify the Other whose intention is directed towards him" (Riva et al., 2014, p. 23). This is supported by other research which has identified that closely-coupled tasks (tasks requiring interaction by other players for completion) result in higher PX and player enjoyment (Beznosyk et al., 2012).

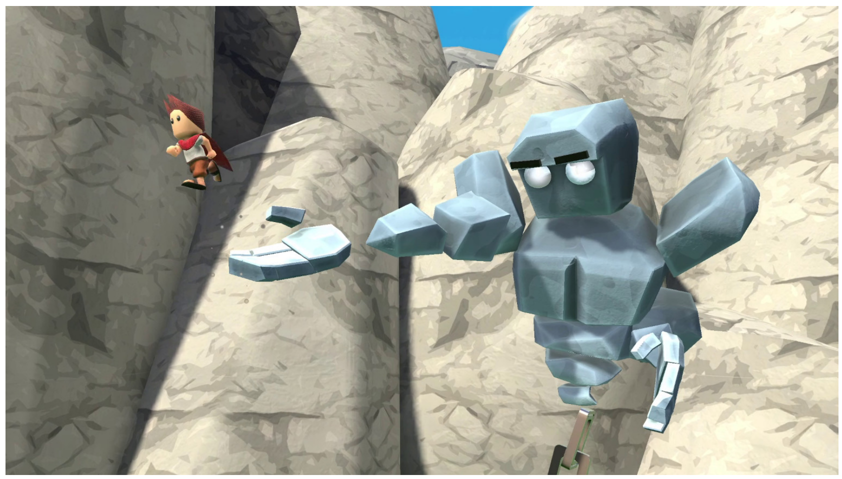


FIGURE 2.8: An example of focused interaction between two players (GiantsVR)[3]

Environmental presence is not just about the fidelity of the environment (Alexander et al., 2005), but rather is facilitated when the virtual world acknowledges the player's existence and responds to their presence (Heeter, 1992). For example, if a player entered an elevator and it took them to a new floor, this would increase the level of environmental presence as the elevator responded to the player's interaction (Heeter, 1992). The ability of a player to manipulate the virtual world directly affects environmental presence (Sheridan, 1992). It has been theorised that a virtual world that is highly responsive to a player can induce a higher degree of presence than a virtual world that provides responsiveness similar to the physical world (K. M. Lee, 2004).

[3]https://store.steampowered.com/app/1124160/VRGiants/

The ability to achieve personal, social, and environmental presence varies depending on the device used to access the game world. According to Slater and Wilbur, the glass of a computer screen creates a gap between the current reality and the reality appearing on the screen (Slater & Wilbur, 1997). This break has a negative effect on presence as the experience feels mediated and the player feels removed from the environment. With VR, that gap is significantly decreased, reducing the feeling of mediation.

Although the experience may feel less mediated because the virtual world is accessed through a VR HMD, there are still risks of mediation. A research study has found that when a control interface felt natural in VR, there was an increased sense of presence (Seibert & Shafer, 2018). The opposite holds true for control interfaces that do not feel natural. For example, if the VR experience involves using various buttons found on a typical VR controller and the interaction does not "fit" with the experience, a sense of mediation is created because the player is aware of the controller.

2.2.3 Engagement

Engagement has been described as the "simultaneous occurrence of elevated concentration, interest, and enjoyment encapsulating the experience of flow" (Hamari et al., 2016, p. 172). Additionally, it has been found that engagement is strongly dependent on game enjoyment (Allen et al., 2014). Similar to presence, there are three categories of dimensions of engagement: (1) behavioral engagement - the active participation in a given situation; (2) cognitive engagement - the mental investment in the activity, the application of critical thinking, and commitment, (3) and emotional engagement - the player’s affective response to others and the setting, demonstrated through interest, boredom, excitement, etc. (Annetta et al., 2009; Fredricks et al., 2004). Furthermore, in multiplayer games, engagement is a "result of a complex interplay of compensatory and reciprocal behaviors" (De Kort et al., 2007, p. 3), which are created through effective social play and a feeling of social presence.

Researchers have identified the Player Engagement Process as a framework used to identify how "engaging player experiences are sustained" (Schoenau-Fog et al., 2011, p. 13). The process has the following characteristics:

- players become motivated to play either through in-game motivations or through personal motivations
- when a player starts the game, either the objective is established through the game rules or the player establishes their own objective
- the objectives trigger activities the player performs to complete the objective
- an engaged player will desire to continue playing as long as the objective is not reached
- players can be emotionally affected as a result of performing a task to complete an objective or if the objective is not completed
- if the player is positively emotionally affected, player engagement can be sustained

The Player Engagement Process is represented by the Objectives, Activity, Accomplishments, Affect (OA3) Framework (as shown in Figure 2.9). Objectives are either extrinsic (goals within the game) or intrinsic (self-defined goals) that motivate the player. Some of the categories of activities that a player may undertake that encourage engagement include problem-solving, interfacing or how the player interacts with the game, exploration, experiencing characters, and socialising. When the objectives are accomplished, achievement rewards and the ability to progress increase engagement and motivation. Affect refers to the positive or negative emotions that are felt during the game (Schoenau-Fog et al., 2011).

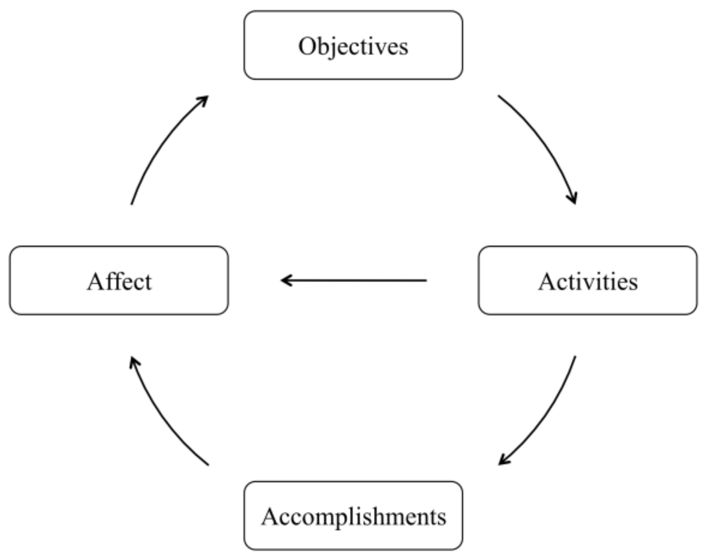


FIGURE 2.9: The Objectives, Activity, Accomplishments, Affect (OA3) Framework (Schoenau-Fog et al., 2011)

In developing engagement, the player character's role and the associated narrative is important. It has been theorised that engagement is created through goal-related engagement and empathetic engagement (as shown in Figure 2.10). Goal-related engagement is experienced when a player connects with their character and shares the character's goals. When the player shares their character's goals, empathy can be fostered, drawing the player into the game. Empathetic engagement is created as the player connects with the character through recognition (how the player constructs the character in their mind), alignment (how information is shared through playing the game), and allegiance (the loyalty a player has to the character based on personality and visual attributes) (Lankoski, 2011).

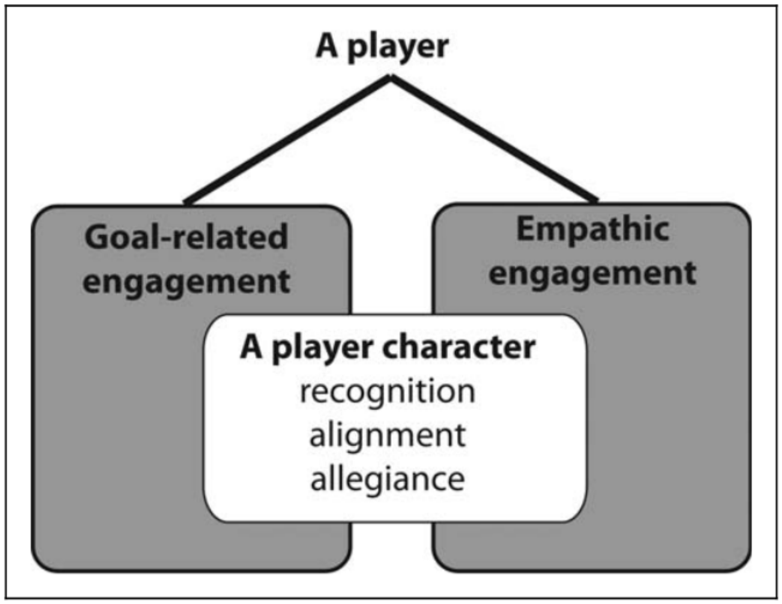


FIGURE 2.10: Player engagement with their character (Lankoski, 2011)

In addition to the cognitive and emotional factors mentioned above, the physical movement of the player's body affects engagement. Researchers have discovered that engagement can be increased by providing methods for players to interact with the game through body movement (Bianchi-Berthouze et al., 2007). Through body movement, VR and mobile devices may provide higher levels of engagement than PC devices. However, focusing on the cognitive and emotional engagement categories and flow theory allows players on PC devices to experience high levels of engagement.

2.2.4 Immersion

Discussion of the impact of immersion on PX goes as far back as the 1970s (Bender & Courtney Plante, 1972). Immersion is defined as the amount that the player is drawn into the world of the game's narrative (Mcmahan, 2003) of a suspension of disbelief that the player is inside a virtual environment (Dede, 2009). This is supported by later research that determined that immersion involves a loss of sense of time, disconnection from the physical world, and involvement in the task environment (Jennett et al., 2008). Attention has been identified as an essential factor of immersion. A correlation exists between the level of immersion a player feels and the number of attentional sources in the game (Brown & Cairns, 2004). How a player is drawn into the virtual world is attributed to three dimensions of immersion. The first, sensory immersion, is attributed to the audiovisual elements of a game. Challenge immersion is the second dimension, which is achieved when challenges and abilities are considered. These may be related to motor skills (physical interaction) or mental skills (problem-solving). The final dimension of immersion is imaginative immersion, which, when considered, encourages the player to use their imagination or connect with the character they are playing (Ermi & Mäyrä, 2007). With these definitions of immersion in mind, the elements of engagement, presence and, embodiment are closely connected to immersion and ultimately influence immersion.

2.3 Asymmetric VR

Asymmetry, as it pertains to Human-Computer Interaction (HCI) systems, describes "the capacity of individuals in a group to have different means to visualise and interact with virtual content" (Grandi et al., 2019, p. 1). This can be accomplished in one of two ways; through the device an individual uses to access the virtual content or through the role the individual is assigned. The concept of asymmetry has been researched in various disciplines, such as social psychology (Coffeng et al., 2021) and economics (Ausubel et al., 2002), but there is little research on asymmetry as it pertains to HCI (Ouverson & Gilbert, 2021), despite growing success with asymmetric VR games such as Keep Talking and Nobody Explodes. The research on asymmetric VR previously conducted has focused primarily on co-located users (Ouverson & Gilbert, 2021; Rogers et al., 2021). Co-located users share the same physical space while accessing a shared virtual space. For the purpose of this research, the definition of asymmetry will expand beyond visualising and interacting with virtual content and include asymmetry of information (also known as the Hidden Profile Paradigm) and asymmetry of space (players in different spaces). The asymmetries created through the different modes of accessing the shared virtual space can create interdependencies between users. As indicated in Section 2.1.4, interdependency creates an elevated sense of social presence, connectedness, and trust among participants.

In this section, I will explore the importance of asymmetric VR, its effect on player behavior, the complexities of developing asymmetric VR games, and the limitations of current asymmetric VR games. I will also share information from researchers who have developed frameworks for asymmetric VR applications.

2.3.1 The Importance of Asymmetric VR

Due to advances in HMD hardware, such as eye and hand tracking, VR experiences for training and entertainment have become more engaging and immersive. Despite the improvements to VR experiences, there are challenges with the use of HMDs. These devices isolate the user from their physical surroundings and those around them (Gugenheimer et al., 2019). This isolation can also affect others in the physical space, reducing them to bystanders and creating a feeling of exclusion (Gugenheimer et al., 2017). A large portion of the population experiences some form of motion sickness when in VR. In fact, 40% to 70% of those who have tried VR have reported feeling motion sickness (Kim, 2019). Cost is another challenge that has slowed the adoption of VR (Abulrub et al., 2011), both from a consumer and enterprise perspective. This challenge has begun to be addressed with the release of the Oculus Quest (now referred to as Meta Quest). Even though the cost issue has begun to be addressed, privacy and security concerns are other challenges to VR adoption (Adams et al., 2018). As a result of these challenges, only 26 million VR headsets are owned globally (Osterland, n.d.). That is less than 0.5% of the global population.

While VR devices provide highly immersive experiences, the challenges listed above may prevent some from participating. As a result, researchers have begun to investigate approaches to bring non-VR users into the shared virtual world using novel interactions. Asymmetric VR experiences can overcome some of the challenges listed above by reducing isolation and providing opportunities to participate in the shared virtual world using devices other than a VR HMD. Additionally, asymmetric VR experiences can create a sense of immersion and experiences that are different from those focused solely on VR users (Jeong et al., 2019) and, in some cases result in higher performances than an experience focused on a single-device interaction modality (Grandi et al., 2019).

2.3.2 Unique Challenges of Asymmetric VR

At its core, asymmetric VR is a multiplayer concept, and many of the factors identified in Section 2.1.4 should be considered. However, some additional complexities and nuances are unique to asymmetric VR. It is insufficient to just port a VR game into a mobile, AR, or PC game. The differences in interaction modalities and visual capabilities are substantial and would result in a negative video game experience. When the developers of Skyrim decided to release the game with a VR mode, the feedback was mixed, but highlight a number of problems with the initial release of the VR version of the game (Smith et al., 2019).

The affordances and limitations of each device used to access an asymmetric VR game will influence various elements of gameplay, creating multiple types of asymmetry. These types of asymmetries have been grouped under the category of Mechanics of Asymmetric, referring to the MDA Framework (Harris & Hancock, 2019). The types of asymmetries available are listed in Table 2.1.

Karaosmanoglu et al. (2021) found that the deliberate implementation of these asymmetries enhances PX and social connectedness by creating interdependence. Depending on the asymmetries and mechanics of the game, there may be different directionalities of interdependence. Mirrored dependence is the most common and implies that the players rely on each other similarly. Unidirectional dependence occurs when a player's progress depends on support from another player, but the dependence is not reciprocal. Bidirectional dependence has players relying on each other, but in different ways (Harris et al., 2016). The different directionalities of interdependence can create a power imbalance between players, resulting in interesting gameplay mechanics and social interactions. One of the challenges of implementing interdependence is the potential negative impact on the PX. If players' roles do not facilitate an equal sharing of responsibility or task involvement, those players less involved may feel disengaged from the game. Indeed, it has been found that when players shifted from a passive role to an active role, a more positive player experience was had by all players (Maurer et al., 2015).

While the asymmetries described in Table 2.1 may provide opportunities for creating interesting gameplay mechanics, they may also pose challenges for non-VR players' PX. Non-VR devices will have inherent differences from VR devices, creating natural asymmetries. For example, the Asymmetry of Interface naturally occurs between PC, VR, and mobile devices. Failure to deliberately address these differences and strategically implement asymmetries, in combination with factors highlighted earlier such as narrative and roles, may negatively affect PX. In the prototype designed by Karaosmanoglu et al. (2021), a number of asymmetries were included to enhance gameplay, but the non-VR player interface was not grounded in a narrative and they did not require active interaction.

Another asymmetric VR game, BirdQuestVR (Smilovitch & Lachman, 2019) anchored the asymmetries in a narrative, but the experience is limited to two players and two types of devices. Each type of device that is part of a game increases the complexity by introducing the potential for multiple forms of asymmetries. While the complex asymmetries created by multiple types of devices can be challenging, the resulting gameplay can be engaging and layered.

TABLE 2.1: Definition of types of mechanics of asymmetry (Harris & Hancock, 2019)

Type of Asymmetry	**Definition**
Asymmetry of Ability	Players have different abilities
Asymmetry of Challenge	Players face different challenges
Asymmetry of Interface	Input / Output different for players
Asymmetry of Information	Players have different information
Asymmetry of Investment	Players invest a different amount of time
Asymmetry of Goals / Responsibility	Players seek different outcomes

2.3.3 Asymmetric VR Frameworks

The complexity of designing asymmetric VR experiences necessitates robust guidelines or frameworks for developers. Albaek Thomsen et al. (2019), Ouverson & Gilbert (2021), Rogers et al. (2021) provide substantial underpinnings, but a deeper critical discourse is warranted, challenging and furthering their ideas to foster more nuanced and comprehensive frameworks.

Albæk Thomsen et al.'s (2019) taxonomy elucidates the roles of VR and non-VR participants as 'actors' and 'assistants', respectively. However, these delineations may oversimplify the complex dynamic that characterises asymmetric VR experiences. The degree of asymmetry—low, medium, and high—delineated based on the assistant's interaction level further propagates this oversimplification. Does the complexity of interaction in an asymmetric context merely boil down to object manipulation and viewing privileges? The game Keep Talking and Nobody Explodes, cited as an instance of high asymmetry, prompts reconsideration of such a binary role division. It's worth questioning if it's the asymmetry in interaction, role, or perceived responsibility that substantiates the experience.

The taxonomy propounded by Albæk Thomsen et al. integrates four primary components (as shown in Figure 2.11), each compelling in their own right, yet collectively they beg the question: Do these components holistically capture the essence of an asymmetric VR experience?

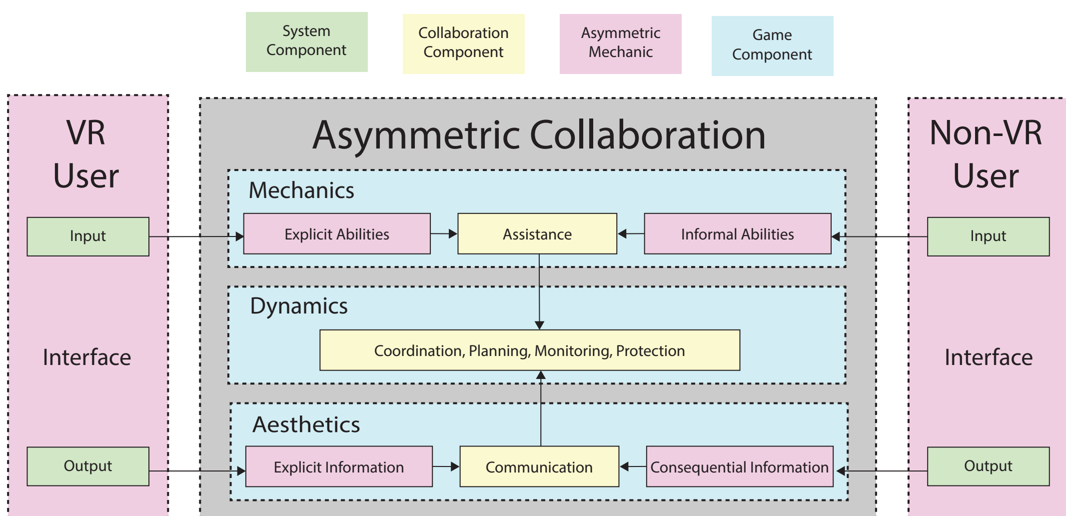


FIGURE 2.11: How the components of the taxonomy interact with each other (Albæk Thomsen et al., 2019)

They largely emphasise the hardware and mechanical constituents, with collaboration mechanics viewed from (Gutwin & Greenberg, 2000) perspective of traditional co-located collaboration. In doing so, they potentially miss the psychological and interpersonal dynamics unique to the immersive VR context.

The Composite Framework for Asymmetric VR (CAVR) put forth by (Ouverson & Gilbert, 2021) has intriguing insights and implications. The identified themes reflect a multidisciplinary approach, embracing everything from VR usage to organisational psychology. However, these themes predominantly pertain to co-located VR, and it's imperative to question whether these findings are readily transferable to remote VR experiences. The five dimensions of asymmetry in CAVR (as shown in Table 2.2) open up exciting perspectives.

TABLE 2.2: The Composite Framework for Asymmetric VR (CAVR) (Ouverson & Gilbert, 2021)

Asymmetry Dimensions	**Definition**
Spatial Co-presence	Group members access each other through different levels of mediated access
Transportation	Each group member accesses the virtual space through different interaction paradigms supported by the device
Informational Richness	The scope of information that is captured and delivered about the virtual space through devices
Team Interdependence	Group members have different goals that may overlap
Balance of Power	Group members have varying degrees of control over information, which is influenced by their role

The concept of spatial co-presence, as defined by Youngblut (2003) resonates with the VR context. However, does a conventional understanding of co-presence translate seamlessly into the asymmetric VR milieu, with varying levels of immersive engagement? And, in light of the positive PX associated with natural and physical movement correlation, does the transportation dimension capture the essence of movement within VR beyond physicality, encapsulating its psychological, emotional, and social aspects?

Rogers et al. (2021) contribute a "best fit" framework (as shown in Figure 2.12) rooted in a systematic review of asymmetric multiplayer VR games. A critique is warranted here as the inclusivity of this framework is contested by its reliance on a relatively narrow range of research sources. The resultant emphasis on embodied physical interaction and the presence of a human co-player as key influencers of positive PX suggests potential for elaboration. What about the cognitive and emotional aspects? Are they adequately represented in this framework?

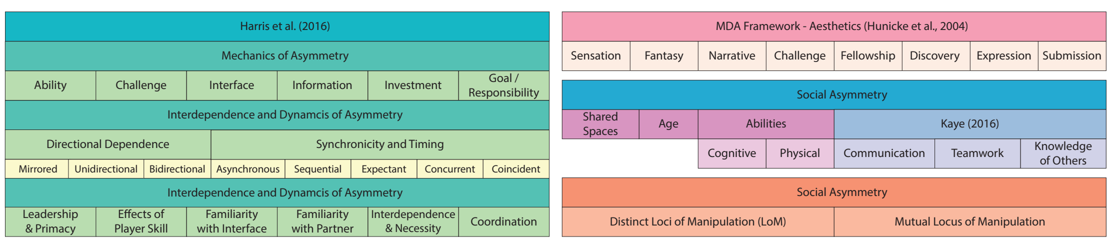


FIGURE 2.12: "Best fit" framework for asymmetric VR games (Rogers et al., 2021)

Moreover, the research gaps identified by Rogers et al., such as the focus on two-player research, lack of exploration of narrative impact, unexplored remote physical locations, and under-addressed "group flow" (Kaye, 2016), further challenge the comprehensiveness of the current literature on asymmetric VR.

In summation, these referenced works offer considerable insights into asymmetric VR experiences. Yet, a critical discussion exposes potential blind spots and suggests a need for more holistic, context-sensitive approaches that expand beyond the mechanical to encompass psychological and socio-emotional dimensions of the VR experience. Comprehensive exploration of such dimensions, focusing on aspects like role interplay, narrative immersion, group dynamics, and emotional engagement, could further enrich the existing frameworks and our understanding of asymmetric VR experiences.

2.4 Research Gaps

Despite an increase in demand for multiplayer VR games and an increase in academic research, there are a number of gaps. In existing studies, players are often co-located, which means that players are physically present in the same room. While co-located asymmetric multiplayer VR games tend to have a higher degree of social presence because of the physical proximity of the players, these types of games are only sometimes practical and can significantly reduce the number of people who can play the game. Understanding how remote setups influence different aspects of PX is highlighted as an important direction as it creates new possibilities for increasing access by allowing people from around the world to connect and play together, despite physical distance. Another challenge with many existing asymmetric VR games is the limitation of two people or two types of devices. An asymmetric VR game that supports multiple device types may increase reach and adoption as the potential user base increases dramatically with each device that is supported.

PX in asymmetric multiplayer VR games is greatly influenced by the social asymmetry factors of communication, teamwork and task-relevant knowledge of others (eg. roles and abilities). While these factors affect the PX in asymmetric multiplayer VR games, few studies have addressed these factors. These factors have been found to affect the "group flow" or shared experiences in cooperative gameplay (Kaye, 2016). Another aspect of the game that influences PX is the game narrative. According to Elson et al., PX is shaped by mechanics (the "rules of the game" and interaction options), context (the device that is used, the physical setting, presence of others), and narrative (the story, plot, events, and characters) (Elson et al., 2014). Unfortunately, the impact of narrative on PX has not been the focus of previous research studies.

Furthermore, authentic input devices have been found to contribute to higher immersion in video games (Pietschmann et al., 2012). VR, mobile, and PC devices have unique limitations and affordances. When these limitations and affordances are considered in the interaction methods, the result may be a more authentic experience with increased engagement, embodiment, presence, and immersion. Previous research is limited on the impact that authentic device interaction has PX. In addition to the impact of device interaction on PX, researching the impact of embodied interaction would be a worthwhile endeavor (Rogers et al., 2021). According to Dourish, embodied interaction is interaction with computer systems that exist in the physical and social reality (Dourish, 2001). It has been found that implementing embodied interaction can have a positive impact on personal, social, and environmental presence (Cuddihy & Walters, 2000).

2.5 Conclusion of Literature Review

Through the decades of game design research, many theories have been developed to identify types of players, develop formulas for engaging experiences, and improve PX. From the 8-bit adventures of Mario in Super Mario Bros. to the advanced and immersive games that span across devices in asymmetric VR games, the goals are similar, but approaches have become more complex. The complexity stems from the fact that theories scaffold together, as indicated in Figure 2.1. Researchers have identified factors that encourage a positive PX through game mechanics, interactions, and narrative. These have been referenced and extended, to understand multiplayer game design. Many of the traditional game design factors, such as embodiment, presence, engagement, and immersion, apply to immersive game design using VR and AV. Designers of asymmetric VR games look through the lenses of all the previously mentioned theories, with the added complexity of forced asymmetries resulting from players using different devices. The complex layering of theories required to understand the best design approaches for asymmetric VR games have been a challenge for the nascent video game category. As a result, frameworks and taxonomies have begun to be developed to address the unique challenges and opportunities of asymmetric VR games. These frameworks and taxonomies have built off existing research in traditional game design to present an approach for developing asymmetric VR games. While these studies have provided a great frame of reference, there are some gaps, as identified in the previous section. This thesis aims to address the research gaps and to develop a best practices guide for developing asymmetric VR games. As mentioned above, one of the components of Flow is the loss of self-consciousness. Within games, it is not so much a loss of self-consciousness, but an expansion. This results in the player feeling a sense of union with the game (Peter, 2007) or an expansion of the player's concept of self (Järvinen et al., 2002) and the ability for a player temporarily forget who they are and take on a character's personality. This game-self personality (how a player views themselves in a game) is affected by the device used for player interaction. The game-self personality impacts player enjoyment and motivation (Birk & Mandryk, 2013).

Chapter 3

System Design and Implementation

This chapter discusses the design and development of the multiplayer asymmetric VR prototype game, *LabXscape*. The scenario development process will be explained, including how the narrative was woven through the experience. The Avatars, Roles, Interactions, and Communications section is closely connected to the scenario. In this section, each of the player roles will be identified, and how the affordances and limitations of each device connected to the roles and interactions available. Additionally, this section will also outline the tasks each player is responsible for and the interdependencies created. The underlying architecture of the prototype and the methods by which the remote players are connected will be discussed in the System Architecture Design section. Finally, the Hardware Implementation section will discuss the devices used to experience the game. Throughout the sections in this chapter, references to theories and frameworks discussed in Chapter 2 will be made, and the influence they had on prototype design decisions.

3.1 Prototype Overview

LabXscape is a multiplayer asymmetric VR game prototype. It is a cross-reality escape room experience where remote players collaborate to prevent a catastrophic meltdown in a laboratory. A birds-eye of the game is shown in Figure 3.1. Each player accesses the shared virtual world using a different device, either through VR, mobile, or desktop PC. The use of narrative and player roles are tightly integrated into the game to elicit an emotional response and engage the user, as discussed in Section 2.1.3. The role each player is assigned depends on the device used. The assigned roles draw players into the experience as they identify with the avatar and re-frame the device limitations to be viewed as an expected way to interact. The use of device-specific roles, along with narrative, has been explored in the asymmetric VR game BirdQuestVR (Smilovitch & Lachman, 2019). Unlike BirdQuestVR, our prototype includes three players, each with a different device.

FIGURE 3.1: A birds-eye view of the virtual space in LabXscape

Existing researchers have developed a design approach for including social interaction in local multi-platform games (Liszio et al., 2017). The design methods are:

- **Unification:** a theme is identified and every aspect of the game is designed along this theme.
- **Storytelling:** this establishes a strong emotional bond with the virtual world and players, stimulates the imagination, and evokes cognitive immersion.
- **Stimulated communication:** should provoke communication and provide a common vocabulary to players.
- **Player roles and dependencies:** identifiable roles with specific information about the tasks and abilities will establish mutual dependencies.
- **Combination of multiple platforms:** diverse game controllers can help establish roles and abilities.

While this design approach was intended for local or co-located asymmetric VR games, the research reported in this thesis proposes that the approach can apply to remote asymmetric VR games as well and have followed this approach when developing *LabXscape*.

The goal of the prototype is to answer the research questions identified in Section 1.2.

3.2 Scenario Development

The scenario and tasks were developed with the affordances and limitations of each device in mind. The goal of the scenario is to deliver an engaging narrative that draws the players into the game and creates a sense of interdependence among the players. The setting for the game is a high-tech laboratory where experimental energy crystals are being researched. The facility has gone into lockdown as the energy crystal in the power reactor has failed. To prevent a catastrophic meltdown, the players need to work together to accomplish three tasks, culminating in replacing the depleted energy crystal with the correct energy crystal. This is a shared goal for each player and, as discussed in Section 2.1.4, is one of the multiplayer game design patterns to connect players and draw them into the experience. Another strategy discussed in Section 2.1.4 is interdependence, which can increase connectedness and social presence. One way to create interdependence is through complementary abilities (as discussed in Section 2.1.4). The complementary roles in *LabXscape* will be discussed in Section 3.3. Another way to create interdependence is through The Hidden Profile Paradigm or asymmetry of information (as discussed in Section 2.3). In *LabXscape*, players can access common information, such as the overall scenario and objectives. Other information is restricted to certain players, requiring those players to share the information with the rest of the group.

Players have a limited amount of time to solve the puzzles and prevent the meltdown and are constantly reminded of the impending doom through a countdown timer, which is visible to all players throughout the game. The timer imposes a temporal limit and creates time pressure. Researchers have found that introducing time pressures into games increases the physical and cognitive challenge (Cox et al., 2012). Challenge, as discussed in Section 2.1.2, directly impacts PX when examining flow theory. The challenge that time pressures create can also affect immersion through the challenge immersion dimension, as discussed in Section 2.2.4. A common approach with traditional escape rooms is to establish the scenario prior to entering the escape room (López-Pernas et al., 2019). This process can establish participant roles, explain the experience's goal, and draw the participants into the game. As indicated by Park et al., the value of backstories also applies to video games (Park et al., 2010). Before entering *LabXscape*, players are presented with a scenario card that provides an overview of the scenario, their role within the scenario, and team's goal. An example of the scenario card is shown below. The scenario cards for all the players can be found in Appendix E.

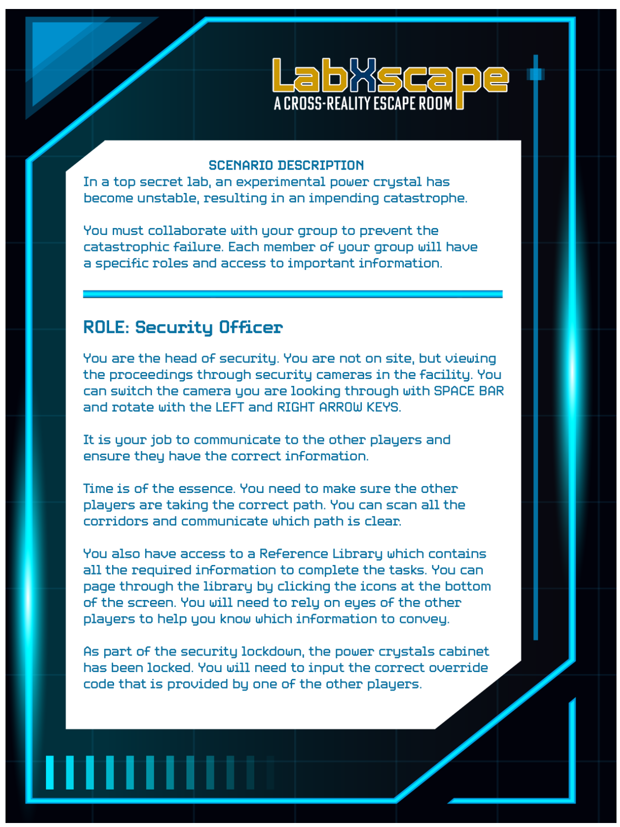


FIGURE 3.2: Scenario card provided to the PC player

3.3 Avatars, Roles, Interactions, and Communication

As highlighted in Chapter 2, the overall PX is directly influenced by avatars, roles, interactions, and players' communication methods. As demonstrated in the ShareVR research project, actively involving non-VR players is essential for a positive PX (Gugenheimer et al., 2017). ShareVR increased player engagement and social presence of VR and non-VR players through physical interaction. In my prototype, the focus was on enhancing engagement and social presence through interaction design, roles, and narrative.

In this section, I outline how the avatars, roles, interactions, and communication methods were chosen with the devices in mind and to connect the narrative and improve PX. Additionally, as identified by Lee et al., roles and the associated interactions have been found to be an effective way to have non-VR players feel as immersed as VR players in a virtual environment (J. Lee et al., 2020). A previous asymmetric VR research project, MagicTorch (Li et al., 2017), assigned roles and views to the virtual environment based on the type of device used. Unlike MagicTorch, my prototype focused on connecting the players together through a shared goal. As a result of the shared goal approach, I chose to focus on collaborative gameplay as the literature highlights improved PX and increased interdependence for VR and non-VR players (Karaosmanoglu et al., 2021). Following that, the game design choices were made to promote communication and increase interdependence between players.

3.3.1 PC Player

The PC player takes on the role of the security officer. Their responsibility is to act as a guide for the players in the lab and provide the information needed to complete tasks. The PC player can toggle between different cameras in the lab and rotate the cameras to explore parts of the lab. The cameras are strategically placed to restrict the PC player's view of key aspects of the game, creating interdependencies. While the PC player is not present in the virtual environment, the cameras and the camera output in the PC player's user interface (UI) (as shown in Figure 3.3) create a magic window to the virtual environment, anchoring the player in the virtual environment. Additionally, the PC player is able to navigate through a series of reference materials needed to help the VR and mobile players progress. While the PC player did not embody their character in the same way that the VR and mobile players did, the modes of interaction and narrative that were designed for the PC player facilitated embodied thinking. As the player engages in embodied thinking, their connection with the role of the security officer is strengthened, and the interactions they are afforded feel natural and support the role. For the PC player, their physical self becomes the character, and the PC itself becomes a part of the narrative and experience, not a tool to mediate access. A factor that contributes to the sense of embodiment is the UI. The interface was designed to enable embodiment and agency, despite not having an avatar in the virtual world (Jørgensen, 2012).

FIGURE 3.3: UI for the PC player

While the PC player is not represented in the virtual environment in the traditional sense, they are embodied through the security cameras placed throughout the lab and in the corridors (as shown in Figure 3.4). As the PC player rotates or adjusts zoom, a spatialised sound is heard by those near the camera, and movement of the camera is seen by those nearby, to create a sense of social presence among the other players. Additionally, a red light is illuminated when the camera is active, and the PC player is looking through it, potentially increasing social presence.

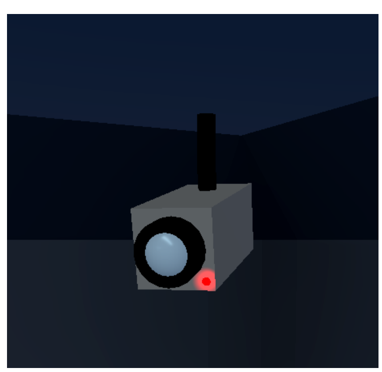


FIGURE 3.4: Avatar for the PC player

The primary way the PC player communicates with the other players is verbally. The VR and mobile players can communicate with other players non-verbally through gestures and avatar movement. Following the narrative, the PC player's voice is not spatialised to the other players, but is instead transmitted across an intercom. With the VR and mobile players acting as active anchors to the virtual environment, connection with them was paramount for the PC player to feel presence.

3.3.2 Mobile Player

The mobile player takes on the role of a droid, meant to provide assistance to the VR player. Unlike other studies (Rogers et al., 2021, p. 11), the mobile player has an active role and does not simply convey information. The mobile player's avatar can move around the virtual environment, either artificially using teleportation (as shown in Figure 3.5) or with the player physically moving. As the mobile player moves and rotates the mobile device, the avatar movements are matched one-to-one and in real-time. Similar to the PC player, the device becomes a window to the virtual world. The mobile player's physical movement augments the virtual world they are seeing through the mobile device by connecting some physical elements (the player) to the virtual world, creating a sense of augmented virtuality (AV) (Milgram et al., 1995).

The matching of the mobile player's avatar movement to their movement creates a strong sense of embodiment, as described in Section 2.2.1. Furthermore, Serubugo et al. suggested that further research could be conducted to explore how mobile devices could be used as controllers to give non-VR players new abilities (Serubugo et al., 2018). In addition to the movement interaction, the

FIGURE 3.5: UI for mobile player

mobile player needs to actively interact with objects in the scene to help the VR player progress, as discussed in Section 3.4. The physical movement and active interactions, often alongside the VR player, increase embodiment, engagement, presence, and immersion, ultimately enhancing the PX. This is supported by the previous research project Astaire (Zhou et al., 2019). In Astaire, the VR and non-VR players each have a VR controller and dance together. The mobile player's physical movement fostered a sense of embodiment and enjoyment. Similar to the PC player, the UI supports the mobile player's role as a droid and supports and enhances the PX.

Unlike the PC player, who also has a supportive role, the mobile player is in the virtual environment. Their avatar is a hovering droid (as shown in Figure 3.6). The avatar does not have any limbs and simply floats. This was a strategic decision to address the limited body-tracking capabilities of a mobile device.

The primary method of communicating for the mobile player is verbal. As the mobile player speaks, the black lens (as shown in Figure 3.6) blinks, providing

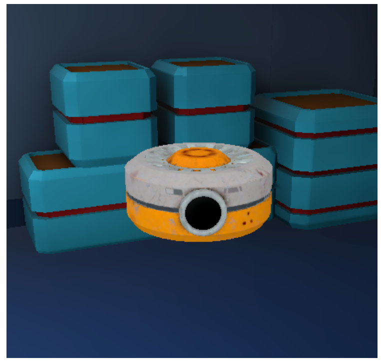


FIGURE 3.6: Avatar for the mobile player

visual confirmation that the mobile player is talking. As the mobile player's avatar is without limbs, non-verbal communication using gestures is limited to rotating their avatar's head to point to a direction or nodding and shaking head in response to questions.

3.3.3 VR Player

The VR player has the role of the scientist and is the protagonist of the narrative experience. Although they are the protagonist, they can only complete their tasks with the support and active involvement of the mobile and PC players. Unlike the PC and mobile players, the VR player's interaction is not mediated through a UI. They can interact directly with objects in the virtual environment (as shown in Figure 3.7). Although the feeling of mediation is limited, when compared to the VR and PC players, there is still a sense of mediation as the VR player is still interacting with motion controllers.

The VR player's avatar is a scientist in a containment suit (as shown in Figure 3.8). The movement of the player's hands and head is matched one-to-one to their avatar. This syncing of movement increases embodiment (as discussed in

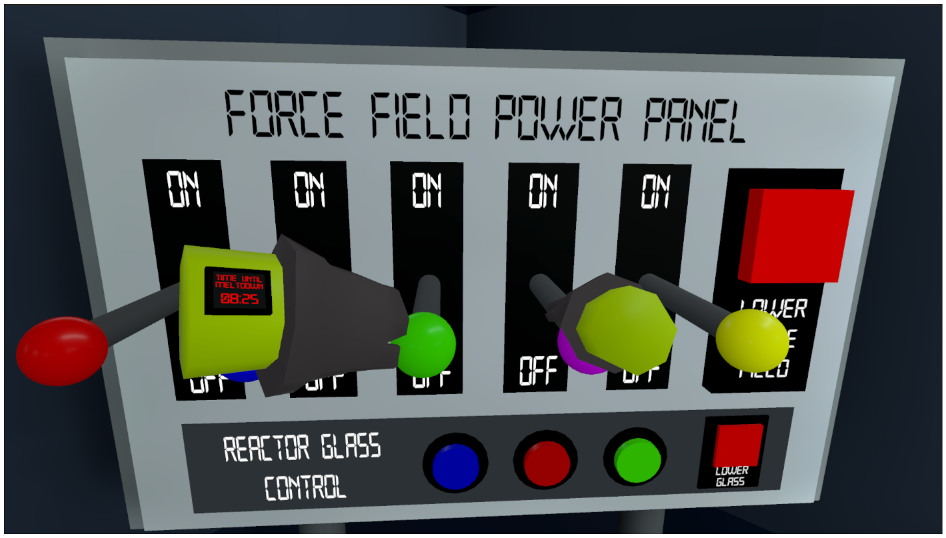


FIGURE 3.7: VR player directly interacts with the virtual environment

Section 2.2.1). As the VR player's avatar has motion-tracked hands, non-verbal communication using hand gestures is a form of communication afforded to the VR player, in addition to verbal communication.

FIGURE 3.8: Avatar for the VR player

3.4 Tasks

A vital component of a game-based narrative is the ability of players to discover and shape the story through their actions (as indicated in Section 2.1.3). Additionally, there needs to be a level of interdependency created with the tasks to foster social presence and connectedness (as indicated in Section 2.1.4 and Section 2.3). Each task in the prototype was designed to create interdependencies between players, support the narrative, and encourage communication and collaboration.

3.4.1 Task 1: Exiting the Lab

There are multiple doors the scientist (VR player) could leave through, but only one is correct. One door will lead to a dead end, resulting in wasted time. Another door will lead to a corridor with sentry robots, resulting in a failed attempt and sending the VR player back to the laboratory's centre, again wasting time. Exiting the lab quickly and efficiently will require communication and collaboration between all the players.

The directional interdependency created is unidirectional from the mobile player to the VR player and from the PC player to the VR player. The VR player requires support from both the mobile and the PC players to proceed, but the dependency is not mutual. The dependency between the VR and PC players is loosely-coupled or optional (indicated by the green arrow in Figure 3.9), which means that the VR player could proceed without the help of the PC player, but at a much slower pace, which could result in failure. However, the dependency between the VR and mobile players is tightly coupled or required (indicated by the red arrow in Figure 3.9). This means that with the coordinated actions of the mobile player, the VR player can proceed. The combination of optional and required dependencies creates an interesting team dynamic.

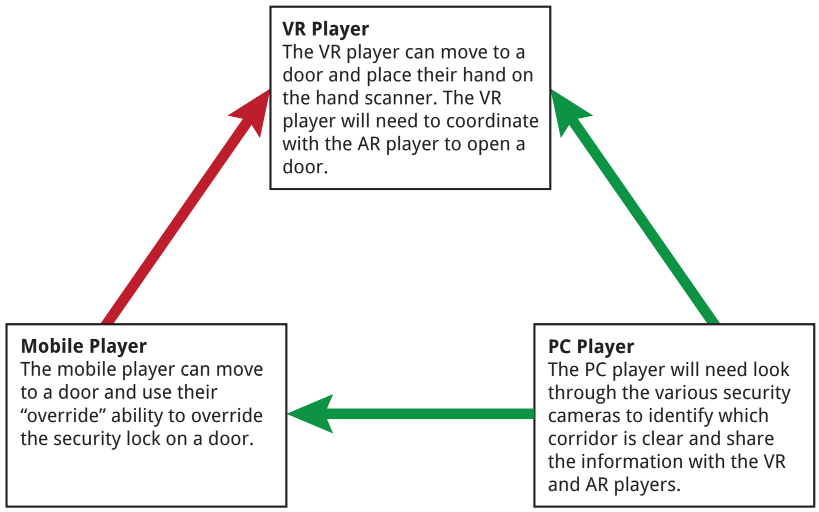


FIGURE 3.9: The directional dependencies in task 1

3.4.2 Task 2: Disable Reactor Security Measures

In order to replace the power crystal, the reactor will need to have the security measures disabled, namely lowering the force field and security glass on the reactor. Outside the lab, in one of the corridors, is a power panel with a series of levers and buttons that need to be used in the correct configuration to disable the security measures. The PC player has a reference document that indicates the possible configurations, but the correct configuration is based on the color of the reactor and force field, which the PC player cannot see.

Unlike Task 1, the interdependency between the mobile and VR players is optional. The VR player could return to the lab and confirm if the force field and reactor glass were lowered without the help of the mobile player, but this decision would require more time and possibly result in overall failure. The directional dependence between the VR and PC players is bidirectional and required. With five levers and three buttons, the number of combinations would make it nearly impossible for the VR player to select the correct combination before running out of time. Thus, the PC player must provide the correct lever and button combination. For the PC player to offer the correct information, the VR or mobile player must provide the PC player with the color of the reactor and force field.

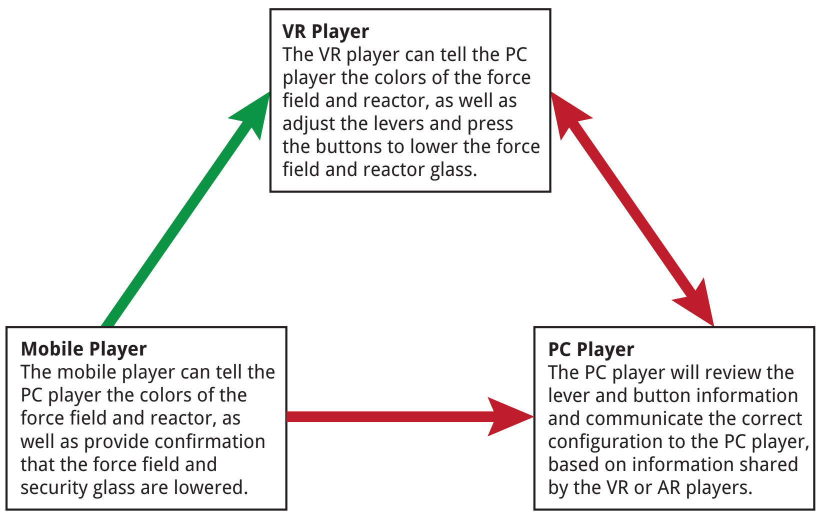


FIGURE 3.10: The directional dependencies in task 2

3.4.3 Task 3: Replace the Power Crystal

The final task for the team is to replace the faulty power crystal with the correct one. For the VR player to access the power crystals, they need help from the PC player who can unlock the cabinet by entering an unlock code in their console. This unlock code is only visible inside the lab by the VR and mobile players, which creates a bidirectional dependency between the PC and VR players. The mobile player could also provide the unlock code to the PC player. Once the cabinet is unlocked, the VR player can access the power crystals. The correct energised crystal must be used in the reactor. The wrong crystal or a depleted crystal would result in a catastrophic failure. There are four different colors of crystals, and the correct color correlates to the color of the reactor. Based on previously given information, the PC player can indicate which crystal to choose. The mobile player is then able to confirm which crystal from the correct colors is energised by performing a scan of the crystal.

Once the correct crystal is identified, the VR player can replace the faulty crystal with the correct one, thus avoiding a critical meltdown and completing the game.

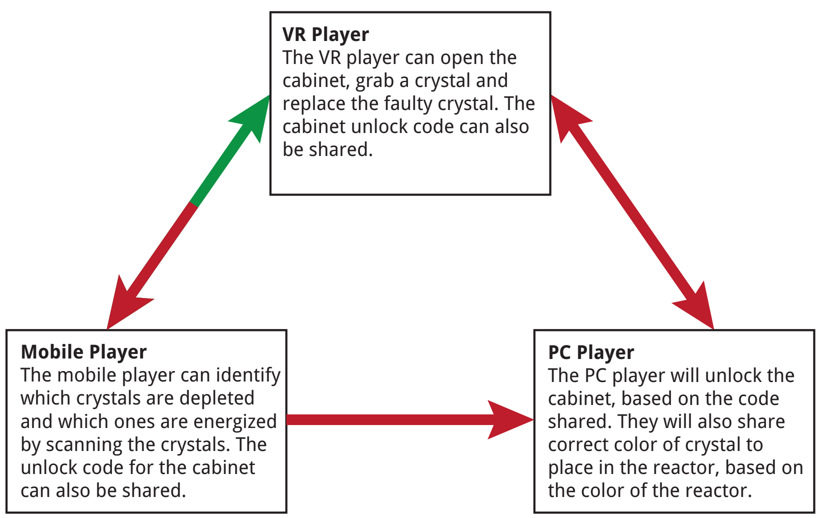


FIGURE 3.11: The directional dependencies in task 3

3.5 Hardware Implementation

The HMD chosen for the VR player is the Meta Quest 2. This device was chosen to provide the most physical freedom for players to move and explore as the device is standalone, meaning that it does not require a computer and has no cables. In addition to the standalone feature, the Quest 2 is a six degrees of freedom (6DoF) device, which means the rotation and translation (movement) can be tracked in three-dimensions. The 6DoF aspect of the Quest 2 is critical for the engagement and embodiment of the VR player. Finally, the Quest 2 has a similar development workflow and performance restrictions as the chosen tablet for the mobile player. Both devices are Android devices, have identical build processes, and require similar optimisation practices. The device chosen for the mobile player is the Lenovo P11 Plus 11" tablet. The Lenovo P11 Plus tablet has the following sensors; an accelerometer, gyroscope, and time-of-flight (TOF) sensor. The accelerometer is used to measure acceleration, which can be used to translate movement. The gyroscope is used to measure rotation. The TOF sensor is used to calculate depth information and is used for improved anchoring of digital content in the physical world. An Android device was chosen for the prototype to speed up development and testing workflows, as the workflows are similar for the Meta Quest 2. A tablet was chosen over a smartphone device to provide a larger field-of-view (FOV) in an attempt to improve immersion. The PC player used a Dell desktop computer with an NVIDIA 2070 Super GPU and a 27" monitor. All players used over-the-ear headphones to provide spatialised audio and isolation from their physical environment to improve immersion. Figure 3.12 shows some of the participants using the hardware.

FIGURE 3.12: Equipment used by players in research study; a) PC player, b) mobile player, c) VR player

3.6 System Architecture Design

The *LabXscape* prototype, developed using the Unity game engine (version 2020.3.9), incorporated additional Unity packages such as XR Interaction Toolkit (version 1.0.0-pre.6), AR Foundation (version 4.1.7), and Normcore (version 2.1). XR Interaction Toolkit was included to manage the interactions and locomotion of the VR player. AR Foundation was included to facilitate the anchoring of the digital content for the mobile player on to the physical ground. Normcore is the multiplayer framework responsible for handling data syncing and moving objects and players across all clients. XR Interaction Toolkit and AR Foundation work alongside Normcore to sync the VR and mobile players' movement across all clients (as shown in Figure 3.15).

Normcore uses a Model, View, Controller (MVC) architecture approach. This allows for a clean approach to networking and does not require a client to be the host in the game. When a change occurs on one client, such as movement or a change in a data element, the Controller identifies that change and communicates the change in data to the Model (which is stored in the Normcore datastore). When the particular Model is changed, the datastore notifies the

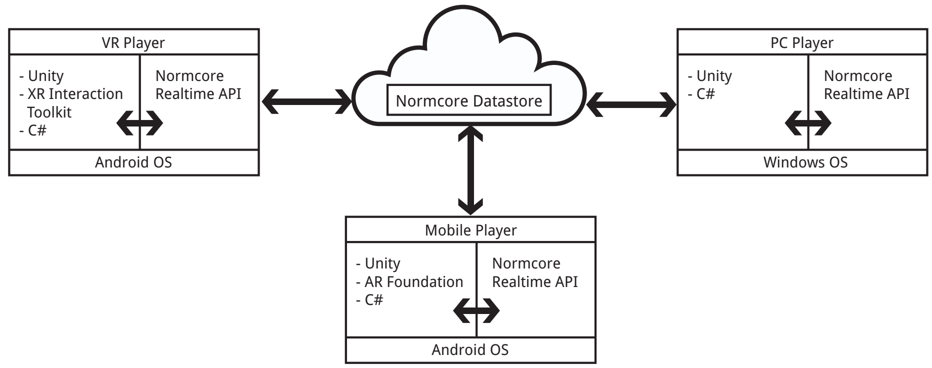


FIGURE 3.13: LabXscape system architecture design

Controllers in the other clients connected to the Normcore Room, which then updates the View (visual representation of the data change) in the other clients (as shown in Figure 3.14).

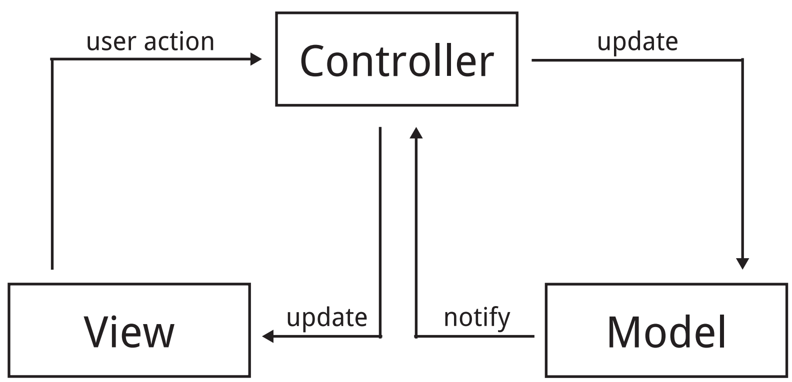


FIGURE 3.14: Normcore's MVC architecture

3.6.1 How the System Works

A build file is generated from Unity for both Windows and Android devices. Since the target devices for the VR and mobile players are Android devices, the same build file is used for both devices. When a player launches the game, the same scene used for each device is loaded and the player's device is detected.

Given the asymmetry in the interface, abilities, and avatars, it's essential to detect devices to ensure players receive content tailored to their specific device. Once the correct avatar is enabled in the scene, a request is initiated to connect to the Normcore Room ID stored in the application.

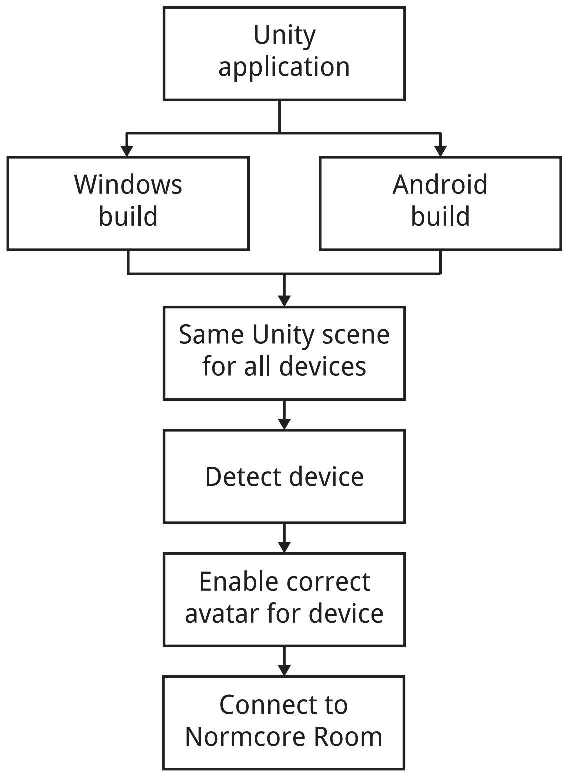


FIGURE 3.15: How the system works

3.7 Chapter Summary

This chapter, dedicated to system design, delves into the core technical aspects of the asymmetric VR game prototype, LabXscape. It provides an in-depth analysis of the role of asymmetry in shaping the gaming experience and the underlying mechanisms that bring this unique system to life.

Upon the game's initiation, the system loads a common scene regardless of the device in use. The system employs device detection mechanisms to identify the specific device on which the game has been launched. This recognition is paramount due to the existing asymmetry in the interfaces, information, abilities, and avatars between different devices.

In this context, 'asymmetry' denotes the unique variations and capabilities inherent to each device. Depending on the type of device (be it VR, mobile, or PC), the gaming interface, the level of interaction and control (abilities), and the player's virtual persona (avatar) can significantly differ. As such, the device detection process is crucial for the enabling of content and features that are tailored to suit the specifications of each unique device, thereby ensuring an optimal gaming experience.

Following this, the system activates the appropriate avatar within the gaming scene. The chosen avatar would be well-suited to the user's device, aligning with the device's input mechanisms and display capabilities. Once the avatar is integrated into the scene, the system initiates a connection request to the Normcore system. Normcore enables the data (eg. time, player movement, etc.) to be synced across all devices in real-time and allows the players to appear in a shared virtual space.

This system represents an advanced approach to asymmetric game design. The asymmetry fosters diversity in player experiences and interactions, enriching the overall gaming environment. The implementation of this asymmetric system involves intricate design considerations and strategic use of technological resources to achieve seamless cross-platform performance.

In essence, the LabXscape system is a manifestation of well-thought-out design choices and precise technical execution that underscore the potential of asymmetric games in offering unique, immersive experiences. It serves as a roadmap for further exploration and innovation in the domain of asymmetric VR gaming.

Chapter 4

Methodology

In designing the study, a mixed-methods approach was adopted, specifically *Triangulation Design*. The objective of the Triangulation Design approach is "to obtain different, but complementary data on the same topic" (Morse, 1991, p. 122). The data is gathered at the same time and then combined through interpretation (as shown in Figure 4.1) (Creswell & Plano Clark, 2007).

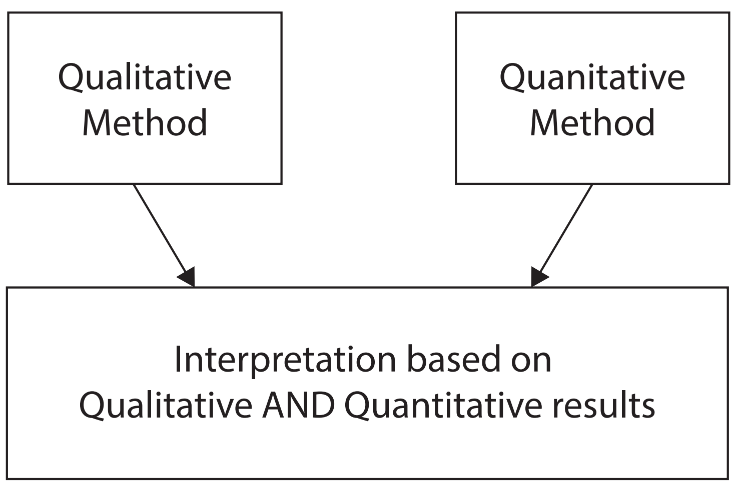


FIGURE 4.1: Triangulation Design

Using the recognised survey tools outlined in Section 4.4.2, quantitative data was collected that helped to identify opinions and views of the asymmetric VR game and to validate if the approaches used in the prototype game were successful in creating a positive PX for VR and non-VR players. While surveys can validate if the approaches were successful, it is more challenging to identify the factors, such as specific interaction options, opinions on role and narrative, etc., that contribute to the game's success. Indeed, quantitative methods are effective for identifying if and when, whereas qualitative methods identify the how and why (Budiu, 2017). The interviews and observations provided in-depth qualitative data and specific insights. Additionally, participant observation may uncover valuable information that may not be volunteered during other data collection methods (Kawulich, 2005). Furthermore, the goal of the quantitative data is to validate the findings from the qualitative research, which is one of the goals of triangulation (Golafshani, 2003), ideally resulting in a more credible study.

4.1 Ethics

Before the study began, selected participants completed and signed an informed consent form (as shown in Appendix D). The study was approved by both the University of Kent's Central Research Ethics Advisory Group and the Lethbridge College Research Ethics Board, as the study was conducted on Lethbridge College's premises.

4.2 Participant Screening Criteria

To identify whether measures built into the *LabXscape* asymmetric VR game prototype are effective, participants needed to be recruited to play the prototype game.

These participants were recruited through social media (as shown in Appendix A). Social media posts contained a brief synopsis of the research project, the requirements of participants, and a link to the research website, which contained a link to a Participant Recruitment Questionnaire (as shown in Appendix B). The questionnaire collected basic demographic questions such as gender and age range. Participants needed to be over the age of 18 to participate. In addition to age, questions related to an individual's health condition were included.

4.3 Participants

Twenty-four individuals participated in the research study. The gender and age range percentages are presented in Table 4.1.

Among those assigned to use the PC, 87% were familiar or very familiar with computers. Of those assigned to use the mobile device, 50% had used AR 10 or more times. Of those assigned to use the VR device, 50% had used VR 10 or more times.

TABLE 4.1: Participant Gender and Age Range Percentages

Gender	**Percentage**
Male	62.5%
Female	37.5%
Age Range	**Percentage**
18 - 24	4.2%
25 - 34	25%
35 - 44	41.7%
45 - 54	25%
55 - 64	4.2%

4.4 Experiment Design and Procedures

Participants were randomly assigned into groups of three. Additionally, group members were randomly assigned either a VR, mobile, or PC device. The randomisation used a simple random sampling approach (Taherdoost, 2016). Upon the arrival of each group, participants were given detailed information about the research study's nature, data usage, and their responsibilities (as shown in Appendix C). At this time, each player was provided the instructions and the scenario card for their assigned role (as shown in Appendix E). As shown in Figure 4.2, participants were escorted to physically separated rooms to begin the game.

As each member entered the *LabXscape* prototype, they were presented with a welcome screen with instructions that the game would begin when all players entered the virtual world. When all players had entered the game, controls were enabled, and the countdown timer began. Participants had twenty minutes to complete the three tasks and solve the puzzle. Participants were asked to complete a short survey after successful completion or when the time ran out. Following the survey (see Appendix F and Appendix G), a semi-structured interview (see Appendix H) was conducted with each participant, which was recorded. Interviews ranged between five and ten minutes in length.

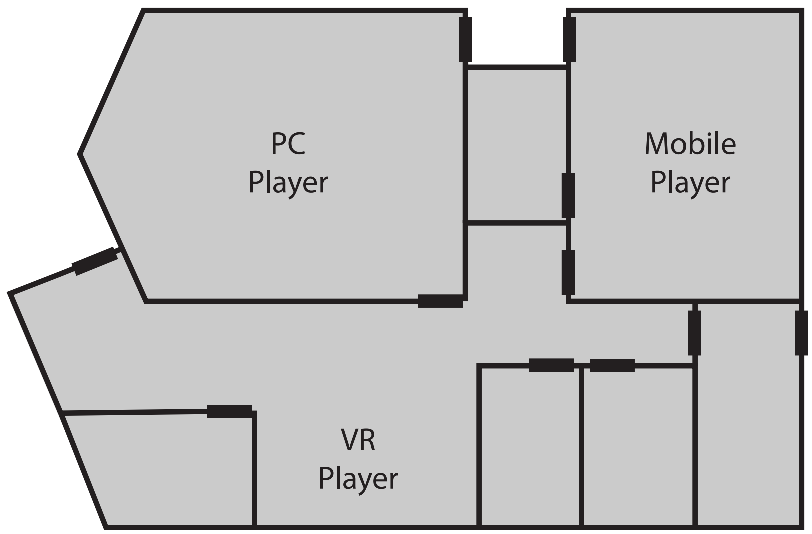


FIGURE 4.2: Participant physical location relationship

While in the asymmetric VR game, participant actions and verbal communications were recorded using a mobile device on a tripod. Where possible, the mobile device was positioned in such a way as to minimise participant faces being recorded. Following the game, each participant completed a short survey using a tablet. Finally, each participant was interviewed, and the interview audio was recorded using the Voice Memos app on an iPhone.

4.4.1 Research Software

The Transcribe feature of Microsoft Word was used for the transcription of the audio recording from participant interviews. The quantitative data collected from the participants were analysed using IBM SPSS Statistics (version 28.0.0.0). A thematic analysis was conducted on the qualitative data from the interviews and video recordings were analysed using NVIVO (release 1.6.1).

4.4.2 Research Measures

Participants were given a short survey that was a combination of a shortened version of the Game User Experience Satisfaction Scale (GUESS-18) and the social presence components of the Multimodal Presence Scale (MPS). The GUESS-18 research tool has been found to be a valid tool for measuring video game satisfaction (Keebler et al., 2020). The tool consists of 18 items that assess player satisfaction in the following areas:

- usability
- narratives
- play engrossment
- enjoyment
- creative freedom
- audio aesthetics
- personal gratification
- social connectivity
- visual aesthetics

Each item in the GUESS-18 tool is rated with a 7-point Likert scale (1 = Strongly Disagree to 7 = Strongly Agree). The creators of the GUESS-18 tool provided mechanisms for extracting an Overall Satisfaction value, which is included in Chapter 5. The total possible value for Overall Satisfaction is 63.

The MPS tool was developed as a standardised measure for presence (Makransky et al., 2017). The tool consists of items to measure physical, social, and self-presence. For this thesis, the focus was given to the five social presence items. Items in the MPS tool are rated with a 5-point Likert scale (1 = Completely Disagree to 5 = Strongly Agree). The items in the social presence dimension of the MPS assessed the following attributes:

- sense of coexistence
- human realism
- not aware of the artificiality of social interaction
- not aware of the social mediation

The total possible value of the social presence items from the MPS is 25.

4.5 Thematic Analysis

A detailed and validated thematic analysis process was established by (Braun & Clarke, 2006). This process includes six phases, listed below, and was the basis for my thematic analysis.

- Phase One: Become familiar with the data
- Phase Two: Generate initial codes
- Phase Three: Search for themes

- Phase Four: Review themes
- Phase Five: Define themes
- Phase Six: Produce a report

4.5.1 Phase One: Become Familiar with the Data

According to Braun and Clarke, this phase involved reading the data and jotting down initial thoughts (Braun & Clarke, 2006). During this phase, I used Microsoft Word's transcription service to transcribe the audio recordings from the interviews. As speech-to-text technology is not always accurate and can be affected by external factors such as non-speech noise ("Characteristics and limitations of Speech-to-Text", 2022), I went through the audio recordings after the transcription to validate the transcription. Following these steps, I read through each interview transcription, making notes along the way. In addition, I reviewed the video recordings of each participant, making observations and notes. The NVivo software was used for the notes collection.

4.5.2 Phase Two: Generate Initial Codes

In Phase Two, initial codes were formulated across the entire data set, encompassing both interviews and observations (Braun & Clarke, 2006). During this phase, I reviewed the interviews and video observations and created initial codes. As the focus of the thematic analysis process was to answer the research questions, the coding process followed a theoretical or deductive approach, rather than an inductive one. With this approach, elements of the interviews and observations are coded that pertain to existing literature (Skjott Linneberg & Korsgaard, 2019).

4.5.3 Phase Three: Search for Themes

In Phase Three, all codes were reviewed to identify themes, defined as patterns to organise data sets and describe the data in rich detail (Braun & Clarke, 2006). During this phase, I reviewed all the codes and identified groupings in which the codes could be included.

4.5.4 Phase Four: Review Themes

Phase Four is described by Braun and Clarke as reviewing and modifying the preliminary themes to see if the theme works with the coded extracts (level 1) and the whole data set (level 2). In this phase, I reviewed the themes in relation to the individually coded extracts and the entire data set to confirm if the data supports the theme and if the themes make sense (Braun & Clarke, 2006). Additionally, I determined if there are themes within the themes or in other words, sub-themes.

4.5.5 Phase Five: Define Themes

Phase Five represents the final stage of theme refinement. The purpose of this phase is to identify the essence of each theme and what aspect of the data and research questions the theme fits under. By the end of this phase, the themes, and any sub-themes, are finalised (Braun & Clarke, 2006). During this phase, I refined the themes and created the final themes as identified in Chapter 5.

4.5.6 Phase Six: Produce Report

This is the final opportunity for analysis and requires a selection of vivid extracts from the data that help tell the story of the data in a way that convinces the reader of the merit of the analysis (Braun & Clarke, 2006). The report of the findings are presented in Chapter 5.

4.6 Chapter Summary

In this chapter, I delved deep into the methodology adopted for evaluating the asymmetric VR game and the overall PX of VR and non-VR players. The research was underpinned by a mixed-methods approach, specifically the Triangulation Design, ensuring a comprehensive and multifaceted understanding of the game's user experience. Key takeaways of the chapter include:

- **Ethical Considerations:** Ensuring the ethical integrity of the research was paramount. Participants were informed about the study's nature, and their consent was obtained. The research also secured approvals from relevant ethics boards.
- **Participant Details:** A diverse group of 24 participants was recruited, with varying levels of familiarity with technology. Their experiences and feedback formed the basis of the research findings.
- **Experiment Design:** The study was meticulously designed, with participants being grouped and assigned different devices. The game tasks were structured to provide insights into the user experience across different platforms.

- **Data Analysis:** A rigorous thematic analysis process, based on Braun & Clarke's (2006) methodology, was employed. This involved multiple phases, from data familiarization to theme identification. Tools like Microsoft Word and NVivo played a crucial role in data transcription and analysis.
- **Research Tools:** The research utilized validated tools like the Game User Experience Satisfaction Scale (GUESS-18) and the Multimodal Presence Scale (MPS) to gather quantitative data. These tools helped in assessing various facets of the game experience, from usability to social presence.

In conclusion, the methodology chapter laid a robust foundation for the research, ensuring that the findings are both credible and insightful. The subsequent chapters will delve into the results and discussions based on this comprehensive methodology.

Chapter 5

Results

5.1 Introduction

This study aimed to determine how the limitations and affordances of non-VR devices affected PX and how to design an asymmetric VR game that engages non-VR players as effectively as VR players. As the study focuses on player perception, the primary research method was qualitative and included interviews and observations, which were analysed using a thematic analysis approach. Quantitative methods, using the defined GUESS-18 (Appendix F) and MPS (Appendix G) tools are presented to support the findings from the thematic analysis.

Five main themes were identified by applying the thematic analysis process outline in Section 4.5. Within each of the main themes are sub-themes of factors that affected PX for VR and non-VR players. The themes and sub-themes are highlighted in Figure 5.1.

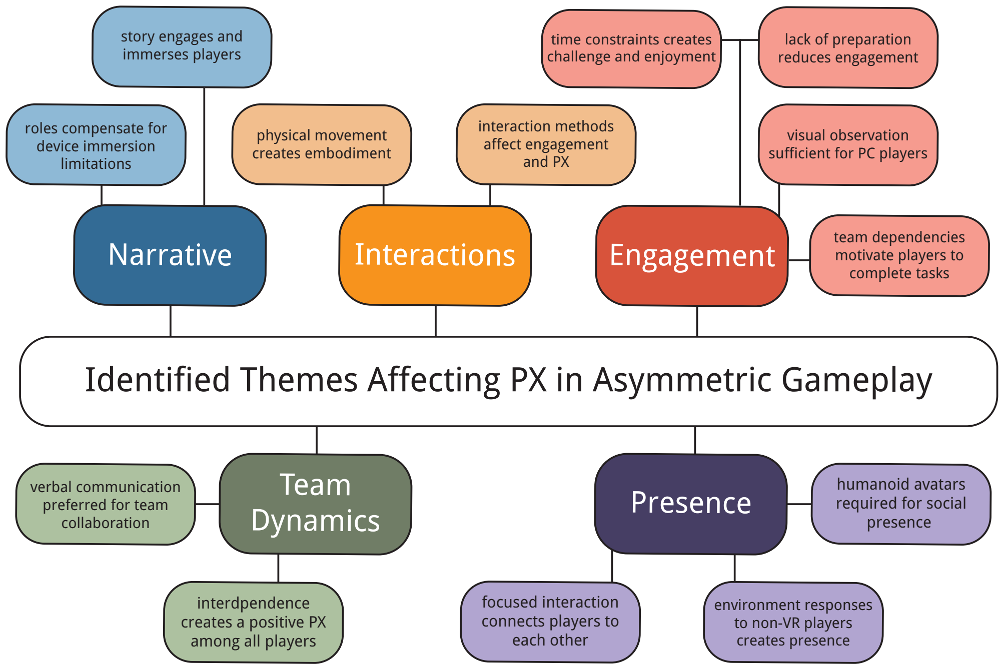


FIGURE 5.1: Thematic map representing the dataset from all player types

5.2 Narrative

It was observed that the narrative of the asymmetric VR game was a significant factor in enhancing the PX for VR and non-VR players. The following sub-themes were identified;

- **Story engages and immerses players**. This sub-theme focused on the design and structure of the story element of the asymmetric VR game, including the setting, plot, and objectives.
- **Roles compensate for device immersion limitations**. This sub-theme concerned how the role and responsibilities assigned to the player created a feeling of immersion.

5.2.1 Story Engages and Immerses Players

Non-VR players reported feeling emotionally and cognitively engaged in the game due to the story. In some cases, the narrative increased engagement as a result of the social aspects of the narrative, in other cases, the engagement was affected because of the challenge/goal aspects of the narrative.

> "*The narrative kept me focused on the broader story. I'm going to come out of this with my own narratives that I survived. It allowed me to play out what I what I ideally want to happen.*" [PC player, Session 5, Interview]

> *"It was a really good story because I know I'm a robot assistant and I need to help people. It was such a nice story. This made me feel more like I'm actually a robot assistant."* [Mobile Player, Session 8, Interview]

> "*I mean it helped me understand the objective. It helped me understand what we were trying to do as a team.*" [VR player, Session 6, Interview]

> "*It definitely was a good narrative. It gave a sense of purpose to it. Made me feel like I knew what I was trying to do and why I was there.*" [VR player, Session 7, Interview]

It has been determined that video games that include narrative are more likely to elicit a physiological response in players than video games with no narrative schneider$_{d}eath_{2}$004.

> "*I think it [narrative] does convey this level of urgency or intensity because you're in a reactor and there's going to be a meltdown. I think having a story like that really is effective. It makes it more gamified or more intense,*

> *like I could almost feel my heart rate rising a bit as we were getting close to that countdown.*" [PC player, Session 7, Interview]

In *LabXscape*, the narrative included elements of urgency, which helped create a physiological response in some players, despite accessing the game with a less immersive device. While the increase in heart rate is observed by the participant and not measured, there is a correlation between heart rate changes and engagement (Boyle et al., 2012).

5.2.2 Roles Compensate for Device Immersion Limitations

As discussed in Section 2.1, the player role can impact various elements of PX, including engagement and embodiment. The roles in the game were well-defined and provided a clear sense of purpose for the players. Observations show that establishing roles for VR and non-VR players, which were supported by the limitations and affordances of the device they are using, could immerse players in the game and create a positive PX.

The PC players' experience in the game was limited and, they had limited immersion and methods of interaction, but the role they assumed supported those limitations and facilitated their ability to embody their character.

> *"I don't think I needed that immersive of an experience to get the same sort of benefit from it. I was already in my mind thinking about this scenario of looking through screens as a security guard like a remote assistant. That set my expectations."* [PC player, Session 1, Interview]

> *"I felt like it [device limitations] added because I actually felt like I was behind a security camera."* [PC player, Session 4, Interview]

> *"You know I had my role, and you know, and I could kind of immerse myself in that scenario.*" [PC player, Session 6, Interview]

While the mobile player had slightly more interaction options, as discussed in Section 5.3, they are still using a potentially less engaging and immersive device than a VR headset. Similar to the PC player, the role assigned to the mobile player supported the device's limitations and affordances, which contributed to a positive PX. The mobile player was able to support the VR player through active participation.

> *"I had fun knowing that I was robot 3000 and tried to embody that role. I felt like R2D2 going up to the doors and sticking that little probe and twisting in different directions. So yeah, it was great."* [Mobile Player, Session 7, Interview]

As with the non-VR players, the role assigned to VR players provided purpose and connected them to the other players.

> "*It [narrative] helped me understand the objective. It helped me understand what were trying to do as a team.*" [VR player, Session 6, Interview]

> "*It was a good narrative. It gave a sense of purpose, made me feel like I knew what I was trying to do.*" [VR player, Session 7, Interview]

While the implementation of roles in *LabXscape* is similar to (J. Lee et al., 2020), I chose to integrate the assigned roles as part of a larger narrative. Additionally, the interaction options support the device and role within the narrative. I also focused on remote, rather than co-located players, which has been proven to result in more effective communication and social presence (Born et al., 2019).

5.2.3 Quantitative Evaluation

As previously mentioned, the asymmetric VR game, BirdQuestVR (Smilovitch & Lachman, 2019), incorporated device-dependent roles within a narrative context to enhance player enjoyment. However, the research findings were not detailed in the article. The narrative elements of the story and role are essential to creating enjoyment for all players, including the non-VR players. This is supported by the quantitative data presented below.

A one-way ANOVA was conducted to determine if the satisfaction with the narrative was different for groups using different types of devices to access the cross-reality game. The ANOVA results showed no statistically significant difference between the three device groups, $F(2, 21) = .350$, $p = .708$. Data is presented as mean ± standard deviation. VR players' satisfaction with the narrative ($M = 5.56$, $SD = .82$) was very similar to PC players' satisfaction ($M = 5.53$, $SD = 1.19$), but mobile players' satisfaction ($M = 4.87$, $SD = 2.48$) was slightly lower.

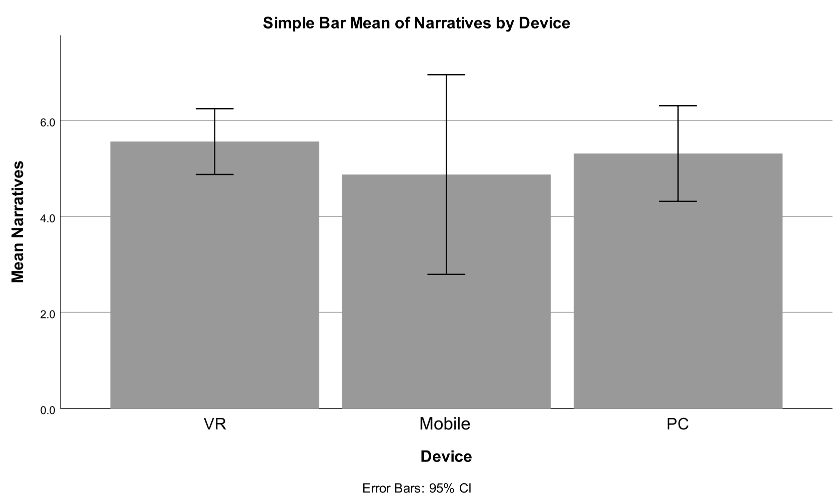


FIGURE 5.2: Visual representation of narrative total score from the GUESS-18 tool

The mobile players' lower satisfaction with the narrative may be attributed to a reduced ability to identify with their character in the game. As was indicated in Section 2.1.3, when players are able to control their character, role identification and immersion increases (Qin et al., 2009). The manner in which the mobile players controls their character is more abstracted than the VR and PC players, this abstraction can have a negative effect on player enjoyment (McEwan et al., 2014).

5.3 Interactions

As discussed in Section 2.1.2, how a player interacts with a video game contributes to their overall PX. The following sub-themes were identified;

- **Physical movement creates embodiment**. This sub-theme focused on the impact interactions performed through body movement had on PX for VR and mobile players.
- **Interactions Methods Affect Engagement and PX**. This sub-theme concerned how naturally recognised interactions that support the role and limitations of the PC device affected the PX for the PC player and how locomotion challenges experienced by VR and mobile players negatively affect PX.

5.3.1 Physical Movement Creates Embodiment

As described in Section 2.4, embodied interaction can have a positive impact on presence and PX. For the mobile player, leveraging the IMU to allow the player to navigate and explore the virtual environment through physical movements connected the player to the virtual environment, fostering presence and embodiment, which ultimately can result in improved PX.

> *"It's kind of like being in a VR environment. I just started walking around, so in a sense it felt like it was a VR except instead of having a device right on my face as I was just holding it up."* [Mobile Player, Session 5, Interview]
>
> *"It [the ability to control your character] definitely connected you to your player as far as being able to control their movements quite well."* [Mobile Player, Session 1, Interview]
>
> *"Moving around the space with the scientist and watching the scientist do things really connected me to this space."* [Mobile Player, Session 3, Interview]
>
> *"The tablet was really cool because it's like a mixed reality device. I'm actually walking and then the game actually moves and it's so fun."* [Mobile Player, Session 8, Interview]
>
> *"It's fun to do that and it really felt like wearing 3D goggles."* [Mobile Player, Session 7, Interview]

As was suggested by Serubugo et al. (2018), I explored how a non-VR player could use features of the mobile device to give them new abilities. In the case of *LabXscape*, the mobile players were able to move physically and have their movement reflected in the virtual world. The mobile players' movement allowed them to anchor themselves in the virtual environment and feel connected to the VR player. They could more effectively connect with their character and embody their role as a support droid as they control their character, resulting in a higher sense of presence. In addition to the mobile player's physical movement affecting engagement, the fact that the mobile device acted as a window to the virtual world increased immersion. Similar to the TeleSight research project (Furukawa et al., 2019), the mobile device enabled prosthetic telepresence, allowing the mobile player to access the virtual world. Furthermore, a study by Denisova and Cairn (2015) confirmed that the first-person viewpoint where the world is viewed through the eyes of a character increased immersion compared with the third-person viewpoint, regardless of the preferred viewpoint of the users.

Of all the players, VR players were afforded the most movement of body and limbs, which contributed to VR players feeling a sense of embodiment.

> "*I put my physical body there and then was able to peek around the corner to try not to be spotted. It felt pretty natural.*" [VR Player, Session 6, Interview]

> "*I could look around. I could see the full interaction of what I was touching.*" [VR Player, Session 3, Interview]

> "*I felt like I was there. I was interacting with the environment.*" [VR Player, Session 5, Interview]

As indicated by Zhou et al. (2019), physical movement is essential for creating a sense of embodiment for both VR and non-VR players. Unlike the Astaire asymmetric VR experience, the non-VR player that moves (the mobile player) does not look at a computer screen, which is potentially immersion-breaking, but rather looks through the mobile device,which acts as a window to the virtual world.

5.3.2 Interaction Methods Affect Engagement and PX

As described in Section 2.1.2, when interactions are more natural, there is less abstraction and reduced cognitive load, which can contribute to an improved PX. The interactions can appear natural through the method of interaction, device, or how the interaction is presented in the context of the narrative.

> *"I'm very used to the PC configuration so that actually worked really nicely for me because this is a format I'm used to."* [PC player, Session 6, Interview]

> *"The controls were clear and easy to figure out. I'm really good at skimming information or scanning and taking the essential information to piece together."* [PC player, Session 5, Interview]

While the PC players' interactions were limited, they were presented in a familiar paradigm. Using a mouse and keyboard to toggle through a series of information panels is something most people have experienced. This familiarity supported embodied thinking and reduced cognitive load, ultimately leading to a positive PX.

Providing methods for the mobile players to move around the virtual environment helped to anchor them to the environment. Since physical spaces are limited, artificial locomotion or teleportation was introduced. It was observed in some mobile players that the teleportation did not work as expected, potentially negatively affecting the PX.

> *"I found some of the teleporting to be a little bit frustrating because I would teleport and think I knew where I was going and then I would be like on the other side of the wall."* [Mobile Player, Session 4, Interview]

> *"The device took away from the experience a little bit because the movement wasn't constant."* [Mobile Player, Session 5, Interview]
>
> *"I was getting stuck with places like the reactor and for some reason, I would go out of the map."* [Mobile Player, Session 8, Interview]

Even though artificial movement such as smooth locomotion is a common practice in VR games, there are still challenges with this approach such as motion sickness and unfamiliarity, which can reduce engagement and PX.

> *"There were things that popped me out of it [the experience]. Whenever I tried to move forward and I was trying to turn, I was shifted 90 degrees and it shifted back."* [VR player, Session 4, Interview]
>
> *"Personally I do struggle from motion sickness. I found that I would just look in the direction I needed to go and close my eyes and move forward and then open them again."* [VR player, Session 6, Interview]

These experiences affected the VR and mobile players' cognitive load, as they needed to focus on accounting for the errors in locomotion or motion sickness. This shift in cognitive load potentially disengaged them from the game and negatively impacted PX.

5.3.3 Quantitative Evaluation

The PC players' interactions felt natural and connected to their assigned role and likely matched a familiar paradigm, resulting in a positive interaction experience. Whereas there were some challenges experienced by both the VR and mobile players regarding interaction and locomotion, some of which are identified in Section 5.4.4. The quantitative data below supports these observations.

A one-way ANOVA was conducted to determine if the satisfaction with the controls and interface was different for groups using different types of devices to access the cross-reality game. The ANOVA results showed no statistically significant difference between the three device groups, F (2, 21) = .542, p = .590. Data is presented as mean ± standard deviation. VR players' satisfaction of the controls (M = 5.12, SD = .954) was very similar to mobile players' satisfaction (M = 5.18, SD = 1.99), but PC players' satisfaction (M = 5.87, SD = 1.66) was slightly higher.

The VR and mobile players' slightly lower satisfaction with usability could be attributed to the locomotion challenges identified by VR and mobile players. Additionally, the higher usability satisfaction of the PC players could be a result of the interaction options provided to the PC players. As mentioned in Section 2.1.2, authentic and intuitive controls have a positive effect on PX.

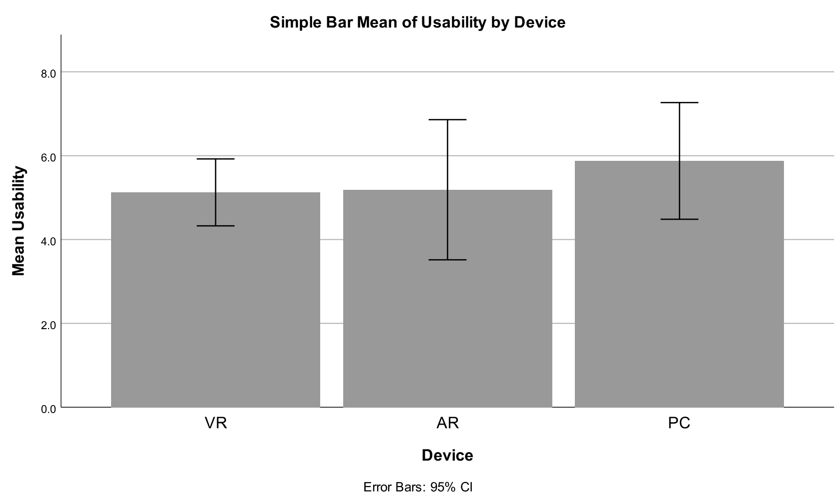


FIGURE 5.3: Visual representation of usability total score from the GUESS-18 tool

5.4 Engagement

The engagement that VR and non-VR players experience in an asymmetric VR game has a consequence on PX. The more engaged the players are, the more likely they will have a positive PX. The following sub-themes were identified:

- **Team dependencies motivate players to complete tasks.** This sub-theme focused on the desire players felt not to let team members down and, as discussed in Section 5.2.1, is correlated to the narrative.
- **Time constraints create challenge and enjoyment.** This sub-theme concerned the pressure to complete the tasks within a specific time frame and the impact on enjoyment, again correlated to the narrative.
- **Visual observation sufficient for PC players.** This sub-theme identified how the PC player felt satisfied with the limited ability to observe the other players in the game.
- **Lack of preparation reduces engagement.** This sub-theme concerned how the confusion caused by the lack of player preparation and affected player engagement and PX.

As discussed in Section 2.2.3, player engagement is created through goal-related and empathetic engagement. As a result of the engagement felt by players, including the non-VR players, it was observed that teams that failed to complete the challenge in time opted to continue the challenge to completion, despite the scenario being over. The cheers and smiles demonstrated a sense of pride and accomplishment for teams that completed the challenge in time.

5.4.1 Team Dependencies Motivate Players to Complete Tasks

As discussed in Section 2.1.4, interdependence has been found to have a positive effect on enjoyment and increase social closeness among players. Observations show that the feeling of dependence generated through an asymmetric multiplayer VR game can engage both VR and non-VR players. Players are drawn into the experience and motivated to complete the tasks and communicate with team members through these dependencies.

VR and non-VR players were drawn into the experience because they possessed critical information or abilities required for tasks to be completed. This dependency engaged players and helped them connect to the other players through a common goal, ultimately immersing them in the game.

> *"I had a sense of being there because I was very focused on the goal, which is to stop the meltdown. I wanted to help them get what they needed so we could mutually achieve that goal and I didn't want to let them down."* [PC player, Session 6, Interview]

> *"I felt I was there. I felt committed to trying to make sure that the reactor didn't blow up."* [PC Player, Session 8, Interview]

> "*I think having other people that you didn't want to let down helped me keep going.*" [VR player, Session 1, Interview]

As described in Section 2.2.3, these statements represent both cognitive and emotional engagement. These players were cognitively engaging as they were determined to assist in solving the puzzles and guiding the other players. The responsibility they felt not to let their team down emotionally engaged them in the game.

5.4.2 Time Constraints Create Challenge and Enjoyment

Flow theory, as described in Section 2.1.2, indicates that challenge directly impacts PX. Time constraints are often used to create challenges and increase player enjoyment (von Ahn & Dabbish, 2008). Observations show that the pressure and challenges created by time constraints engaged both VR and non-VR players, as they would often communicate to their team on various occasions the time remaining to complete the game. The influence of time constraints on PX is magnified when connected to the feeling of duty to other team members and the social connections they feel.

> "*I felt I could sense the urgency, the stress of that because of the time was going down. I felt like I was there, even though I wasn't there, it was awesome.*" [PC player, Session 2, Interview]

> "*I was very focused on this game. I was focused on this clock (pointing to the computer) and not that clock (pointing to the clock on the wall).*" [PC player, Session 6, Interview]

> "*Several times through the game, the mobile player shares with the team the current time remaining in the game. During one of the final time updates, the mobile player exclaims 'it's down, it's down, it's down' (referring to the force field).*" [Mobile Player, Session 7, Observation]

> "*The time-based pressure enhanced the experience because it gave us that sense of urgency.*" [VR player, Session 1, Interview]

The influence of time constraints on enjoyment and PX is magnified when players feel an increased social connection to the other players in the game and a sense of responsibility to the other players.

5.4.3 Visual Observation Sufficient for PC Players

As highlighted in Section 2.2.3, a direct correlation exists between engagement and players' actions. While the PC player's actions were limited to accessing and sharing information and observing the virtual environment and other players through security cameras, that was sufficient with the caveat of wanting to have more control of their camera. The camera is the embodied avatar of the PC player and as referenced in Section 2.1.3, the higher degree of control of the avatar, the higher the sense of presence and immersion.

> "*I wanted to be part of the action. I wanted to see what the other players were seeing. I wanted to be more engaged, but I was limited to what I could see.*" [PC player, Session 2, Interview]
>
> "*There were times I wanted to be in there and move around and see.*" [PC Player, Session 7, Interview]
>
> " *I do wish there was a little bit more movement on the camera to look up or pan up a bit, because if you zoom too far in it, you're just locked in on the ground, which was a little bit unfortunate.*" [PC Player, Session 3, Interview]
>
> "*I relied heavily on the instructions. How we cooperated more was by listening and I kept zooming. I was relying heavily on the cameras and I needed the cameras to have a tilt, but they didn't.*" [PC Player, Session 5, Interview]

In addition to the players desiring equal task responsibility, players desire tasks that involves more than simply sharing information.

> "*I felt restricted because I could only zoom in, zoom out and check the rooms. I felt like the bulk of the interaction was communicating. I feel like I was just relaying information.*" [PC Player, Session 4, Interview]

> "*A limitation was because I was in the resource library and really it was just the four buttons I was clicking through*" [PC Player, Session 7, Interview]

5.4.4 Lack of Preparation Reduces Engagement

Player preparation is vital with any game, especially asymmetric multiplayer VR games. As players use different devices with different abilities and roles, they are less able to support each other during the game.

It was observed that both VR and non-VR players needed help understanding the instructions, their role within the narrative, game mechanics, and how they fit into the team. The confusion may have contributed to a poor PX.

> "*I first felt like I had to figure out what to do, and so I had to read the instructions and then I felt like that took some time.*" [PC player, Session 4, Interview]

> "*Appears to be trying to use an incorrect button for grabbing objects.*" [VR Player, Session 4, Observation]

> "*I don't know, maybe the instructions weren't as super clear. I didn't know I could use my mouse and click buttons to open up all the information I needed to share.*" [PC player, Session 2, Interview]

> *"I just wasn't always sure when I needed to step up, so it took me a little bit to figure that out."* [Mobile Player, Session 6, Interview]

The confusion was wider than players' confusion with their own role and responsibilities. It was also observed that players needed help understanding the role of each member of the team and how they would work together to accomplish the tasks.

> *"I also felt that there was lots of misunderstanding of how to play the game, and so we spent probably the first ten minutes trying to orientate how to play the game and therefore I think that impeded my communication and moving the game forward."* [PC player, Session 8, Interview]

> *"It took a while to get them actually communicating. It did limit me because I was kind of walking around for the first minute or two trying to figure out what exactly it was that was supposed to be happening. But once I figured out they had some of the information I needed, then it made more sense."* [VR player, Session 4, Interview]

> *"It took a couple of minutes to kind of get everything figured out since we hadn't been able to do anything beforehand."* [PC player, Session 3, Interview]

> *"There was some uncertainty with who had control over what. Like who enters the code to unlock the cabinet or who activates the hand scanner."* [VR player, Session 6, Interview]

> *"It took me a good 3-4 minutes to just figure out who's doing what and where everybody is and what our roles were."* [Mobile Player, Session 6, Interview]

Due to this confusion, non-VR players frequently consulted the external scenario cards to understand their roles and game instructions.Referring to the external scenario cards may clarify their role, but it can also remove them from experience.

> "*Having a little more time with the explanation sheets scenario cards. I had to keep kind of going back to them.*" [Mobile Player, Session 3, Interview]

> "*I think a lot of it went back to the handout sheet with the scenarios. I would not have remembered what my steps were if I hadn't had that sheet to reference.*" [Mobile Player, Session 4, Interview]

> "*mobile player looks away from the mobile device and refers to the printed scenario cards a few times.*" [Mobile Player, Session 1, Observation]

Our findings on the importance of preparation time for coordination, strategy development, and team awareness are in line with findings from Karaosmanoglu et al. in which they determined that collaborative asymmetric VR experiences require time for adaptation (Karaosmanoglu et al., 2021). Furthermore, the importance of providing dedicated time for strategising in a collaborative asymmetric VR game is reinforced by previous research (Sajjadi et al., 2014).

5.4.5 Quantitative Analysis

Despite some of the issues with the prototype that created challenges, all players reported a high level of game enjoyment, which is a determining factor of engagement. This observation is supported by the quantitative data shown below.

A one-way ANOVA was conducted to determine if level of enjoyment was different for groups using different types of devices to access the cross-reality game. The ANOVA results showed no statistically significant difference between the three device groups, $F(2, 21) = .483$, $p = .623$. Data is presented as mean ± standard deviation. VR players' level of enjoyment ($M = 6.18$, $SD = .458$) was identical to PC players' enjoyment ($M = 6.18$, $SD = .883$), while mobile players' enjoyment was just slightly lower ($M = 5.87$, $SD = .79$).

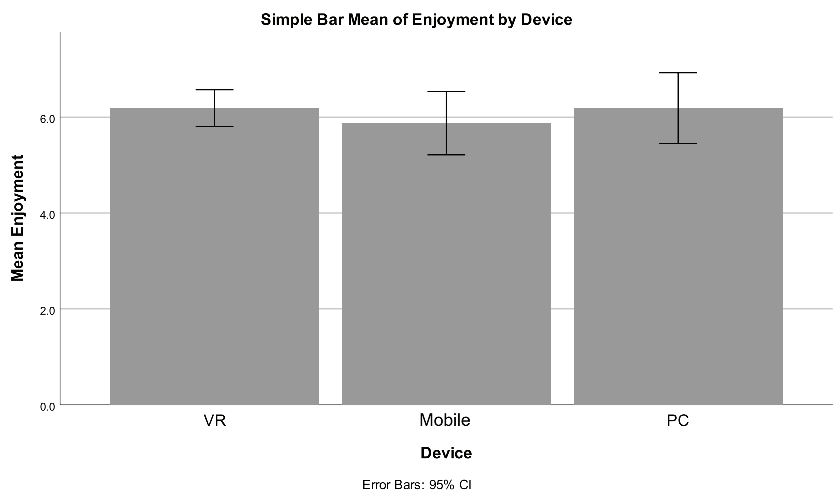


FIGURE 5.4: Visual representation of enjoyment total score from the GUESS-18 tool

5.5 Team Dynamics

How players communicate and work together is paramount, especially in asymmetric VR multiplayer games. As VR, mobile, and PC devices provide varying degrees of immersion, presence, and engagement, non-VR players' connection to other players in the game helps anchor them into the virtual world. The following sub-themes were identified:

- **Verbal communication preferred for team collaboration**. This sub-theme focused on the preferred use of verbal communication to communicate and coordinate their actions effectively.
- **Interdpendence creates a positive PX among all players**. The sub-theme concerned the requirements of team members needed to work together to complete tasks and the effect this had on social presence and PX.

5.5.1 Verbal Communication Preferred for Team Collaboration

While verbal communication is the primary method of communicating in asymmetric multiplayer VR games, non-verbal communication methods such as gestures and movement are possible. When players communicate with each other, particularly when there is visual feedback such as player movement or gestures, the feeling of social presence of those communicating may be increased.

> *"I was able to visibly see them physically moving around and you know they would emote through gesture. I don't think I felt detached from the experience."* [PC player, Session 1, Interview]

While the ability to perform gestures was available to the VR players, and to a point the mobile players, it was observed that the preferred form of communication was verbal.

The limitations players experienced in the game, through design or device, necessitated communication between players. The increased communication enhanced the player experience for VR and non-VR players and connected them.

> *“I found the communication to be pretty easy. It really enhanced the experience in the game because you do have to do so much by voice. Being in the role that I was in for security, I found that I had to be a lot more concise with my answers.”* [PC player, Session 3, Interview]

> *"Even though the scientist was down the hallway on the corner, I could still hear him. It was like he was right beside me. That was good.”* [PC player, Session 2, Interview]

> *"I could look at what I needed to see and then talk to the PC player. Without communication, it would be a two-dimensional video game. I found it quite immersive."* [VR player, Session 3, Interview]

> *"The communication part went really well. It was fun trying to problem-solve together. We were in it together trying to figure the puzzle out. I did very much like that."* [VR player, Session 1, Interview]

Some of the non-VR players found verbal communication challenging. This challenge was mainly due to the competing voices, which negatively affected some players’ ability to engage with the environment or other players.

> *“I found it hard to cognitively engage in the environment fully and still be listening to two other people with various types of responsibilities.”* [Mobile Player, Session 2, Interview]

> *"I said hi to them at the beginning and then the two of them got so engrossed in what they were doing. I wasn’t sure if they could hear me anymore or if I needed to communicate more with them, but then later in the process, they remembered that I was there.”* [Mobile Player, Session 7, Interview]

> *"The communication with the players was a little bit difficult because I felt that we were all talking above each other and that my instructions weren't being conveyed appropriately."* [PC player, Session 8, Interview]

5.5.2 Interdependence Creates a Positive PX Among Players

Collaboration is essential in asymmetric multiplayer VR games, especially for non-VR players. When VR and non-VR players are required to support each other through collaboration, it increases the engagement of all players.

> *"I thought that was fun. I wouldn't have liked it as much if one person could have just done this whole thing all by themselves. So, I liked that there was a team aspect to it and that I couldn't finish my part without somebody else doing their part."* [Mobile Player, Session 5, Interview]

> *"I think the device in the augmented reality helped with the assistance. I think having restrictive roles so that I couldn't go follow that guy was important because I would have totally gone."* [Mobile Player, Session 2, Interview]

> *"I thought the cooperation went well because we were able to say 'I need this bit of information' and someone was able to provide it. It felt very much like we were working together towards the goal."* [VR player, Session 1, Interview]

> *"I actually think the limitations added to the experience because it forced me to depend on the other players. The fact that I couldn't see the levers that the VR player had access to forced us to communicate back and forth. There were certain pieces that forced all three of us to engage. As a security*

> *officer, I was the only person who could input the code, so there was a need for everybody.*" [PC player, Session 7, Interview]

Despite the perceived limitations experienced by non-VR players, the required collaborations engaged non-VR players and worked towards creating a positive PX.

The asymmetrical nature of the interface, information, and abilities fostered interdependence among players and resulted in a positive PX for all players. These findings support the findings from previous research (Karaosmanoglu et al., 2021).

5.5.3 Quantitative Analysis

The communication features and collaboration opportunities facilitated a high feeling of social connectivity that was almost identical for all players. This observation is supported by the quantitative data shown below.

A one-way ANOVA was conducted to determine if the level of social connectivity was different for groups using different types of devices to access the cross-reality game. The ANOVA results showed no statistically significant difference between the three device groups, $F(2, 21) = .722$, $p = .497$. Data is presented as mean ± standard deviation. VR players' level of social connectivity ($M = 6.88$, $SD = .372$) was identical to mobile players' level of social connectivity ($M = 6.88$, $SD = .593$), while PC players' feeling of social connectivity was just slightly lower ($M = 6.31$, $SD = 1.03$). The lower feeling of social connectivity felt by the PC players may be attributed to the lack of a humanoid avatar for the PC player, an issue which is discussed in Section 5.6.1.

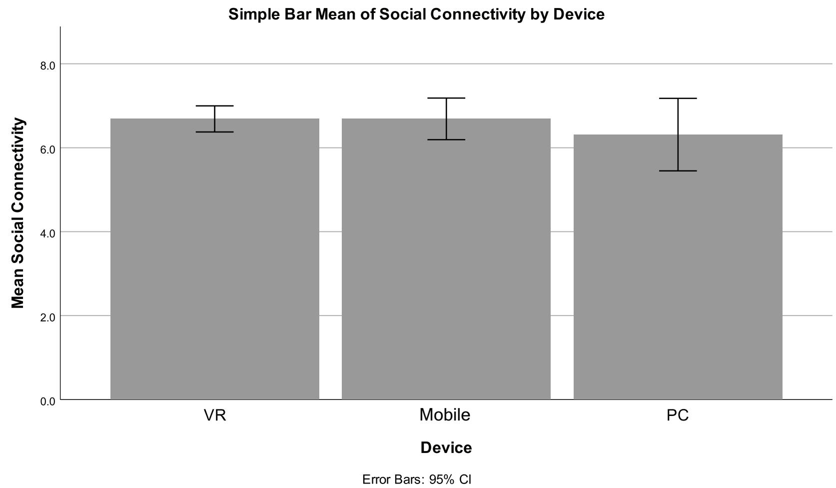


FIGURE 5.5: Visual representation of social connectivity score from the GUESS-18 tool

5.6 Presence

As indicated in Section 2.2.2, players feel various forms of presence, including social and environmental. The following sub-themes were identified;

- **Humanoid avatars required for social presence**. This sub-theme referred to the appearance and behavior of players' virtual representations within the game and the impact on both presence and social presence
- **Focused interaction connects players to each other**. This sub-theme concerned the interactions that required more than one player to complete through a synchronised effort.
- **Environmental responses to players' actions create presence**. This sub-theme focused on the environmental responses to player inputs and the impact on presence.

5.6.1 Humanoid Avatars Required Social Presence

As discussed in Section 2.2.1, embodiment is possible with non-traditional avatars as a result of Game Ego and embodied thinking. This is evident in the interview quotes in Section 3.3. While presence and embodiment are possible with non-traditional avatars for non-VR players, non-traditional avatars have the opposite effects on social presence. While previous research has identified the importance of avatars in creating social presence (Bulu, 2012), all players must have a humanoid visual avatar in the game to ensure equal focus. While this is important for PX and social presence, it becomes challenging to implement across all devices due to their limitations. It was observed that the PC player's non-traditional avatar, a security camera, may not have been sufficient to create a sense of social presence in the VR and mobile players. This may have contributed to a sense of imbalance in the team structure.

> "*At first it seemed like it was very like one-sided, because they both had avatars in the scene and I was not an avatar in the scene, I was just controlling the cameras.*" [PC player, Session 1, Interview]

> "*I think the security guard was a bit far away just because there wasn't really any physical representation of them. I think maybe it would be nice if maybe there's some sort of a screen that would pop up and just have like a 3D model of a security guard.*" [VR player, Session 5, Interview]

> "*The PC person was basically a voice that had some information.*" [Mobile Player, Session 3, Interview]

> "*The PC person, seemed the most disconnected unlike the mobile person who seemed to be right there.*" [VR player, Session 4, Interview]

A recognisable avatar that is controlled by the player not only positively affects the social presence felt by other players but also anchors the player to the virtual environment.

> "*When I was standing in front of the cabinet and I opened the door and she's 'like I'm moving.' I'm like 'oh, I need to be careful where I'm walking'.*" [VR player, Session 4, Interview]

> "*I felt like we were all in the same space. You know at one point in time I was kind of doing my task and I couldn't stand still, and the other guy was like 'oh sorry that's because I'm bumping into you, right?'*" [Mobile Player, Session 4, Interview]

> "*On a few occasions, the VR player smiles and waves to the mobile player.*" [VR player, Session 6, Observation]

Avatars are not only effective in creating a sense of social presence among players, but for connecting players to their character, which indirectly connects them to the environment.

> "*If there was a mirror somewhere in there I could see what I looked like. Maybe that would have helped the experience.*" [Mobile Player, Session 1, Interview]

As identified in Section 2.2.1, a player's own avatar and the ability to cognitively connect to their player through the visual representation of their avatar has an effect on embodiment.

5.6.2 Focused Interactions Connect Players to Each Other

Related to collaboration is the concept of focused interaction, which as described in Section 2.2.2, occurs when players are communicating and interacting together on a shared task. Not only does the concept of focused interaction increase social presence in all those participating, but it also anchors the players to the virtual world, increases engagement, and improves PX.

> *"I think I felt close to them because they could provide direction and they could see me."* [VR player, Session 8, Interview]

> *"We shared back and forth a lot of information. When I got out to the lever panel, I described everything I saw. Then the PC Player was able to go through and figure the levers and the button order."* [VR player, Session 2, Interview]

> *"I held the key to lowering the glass, but they worked with me, and we did it. I had to guide them like I was reading a set of instructions."* [PC player, Session 5, Interview]

> *"I could watch him do something and then he commented on what it was that he did, so it connected to him."* [Mobile Player, Session 3, Interview]

Players mentioned feeling like a community, and the focused interactions that players participated in were not the sole reason for the feeling of community. According to Oh and Lee, an attribute of a community is often a shared goal (K. Oh & Lee, 2005). As discussed in Section 2.1.4, a shared goal occurs when all players in the game share a common goal. Unlike the MagicTorch (Li et al.,

2017) game, my prototype focused on players working together to accomplish this shared goal, which resulted in a feeling of community.

5.6.3 Environment Responses to Non-VR Players Create Presence

Environmental presence is most often experienced by those fully immersed in the virtual world, in this case, the VR player. It is however possible for the PC and mobile players to experience environmental presence as elements of the environment respond to their interactions. As the non-VR players experience environmental presence, it connects them to the virtual world.

> *"I think I cognitively shut off a lot of the subconscious surrounding of the actual physical and started thinking about things like that corner is where door two is, this corner is where door three is."* [Mobile Player, Session 2, Interview]
>
> *"When I moved, I moved within the room, so I assumed I had a presence."* [Mobile Player, Session 3, Interview]
>
> *"I could see the space and the three of us talking about something in this space said that the space was real."* [Mobile Player, Session 3, Interview]
>
> *"The PC player entered the crystal cabinet unlock code and then excitedly confirmed that the cabinet was unlocked."* [PC Player, Session 1, Observation]

As reflected by the comments, environmental presence was felt more by mobile players. This is likely a result of mobile players being able to interact with elements of the virtual world and appear to move around the environment, a feature not made available to PC players.

Despite the non-VR players being on less immersive devices, it was observed that sound effects that were triggered by others could connect non-VR players to the experience, allowing them to share in the feeling of accomplishment.

> "*I heard sound effects when they achieved something. I felt a sense of celebration.*" [PC player, Session 5, Interview]

> "*The PC player heard sounds triggered by the action of the VR player and began toggling through the various cameras to see where the sound came from.*" [PC player, Session 2, Observation]

> "*I just showed the droid, and he looked down and I could look at the droid and see what he was looking at the crystals that were in the cupboard.*" [VR player, Session 3, Interview]

5.6.4 Quantitative Analysis

While VR players experienced higher levels of social presence, non-VR players did feel social presence and also that they were recognised by other players in the game. This observation is supported by the quantitative data shown below.

A one-way ANOVA was conducted to determine if social presence was different for groups using different types of devices to access the cross-reality game. The ANOVA results showed no statistical significance between the three device groups, $F(3, 21) = .530$, $p = .596$. Data is presented as mean ± standard deviation. VR players experienced slightly higher social presence (M = 20, SD

= 2.4). PC players (M = 18.7, SD = 3.2) and mobile players (M = 18.7, SD = 2.8) experienced similar levels of social presence.

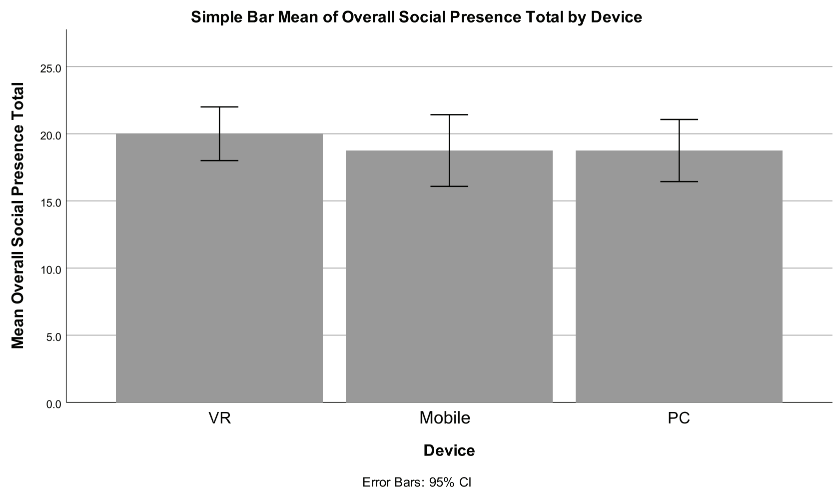


FIGURE 5.6: Visual representation of the MPS social presence totals

As mentioned in Section 2.2.4, one of the dimensions of immersion is sensory immersion. VR devices provide higher levels of sensory immersion than PC and mobile devices. Furthermore, the statements in the MPS use the verbiage, "virtual environment" (as shown in Appendix G). In could be concluded that VR players felt more connected to the "virtual environment", resulting in the higher values in social presence.

5.7 Summary of Findings

In this research study, I explored factors that would contribute to a positive PX for both VR and non-VR players in an asymmetric multiplayer VR game. Our findings suggest that VR and non-VR players can experience almost equal levels of game satisfaction. These findings are supported by the quantitative data presented below.

A one-way ANOVA was conducted to determine if player experience (overall GUESS-18 score) was different for groups using different types of devices to access the cross-reality game. The ANOVA results showed no statistically significant difference between the three device groups, $F (3, 21) = .762$, $p = .479$. Data is presented as mean ± standard deviation. VR players' satisfaction ($M = 51.2$, $SD = 4.6$) was very similar to PC players' satisfaction ($M = 50.0$, $SD = 10.4$), but mobile players' satisfaction ($M = 46.5$, $SD = 9.5$) was slightly lower.

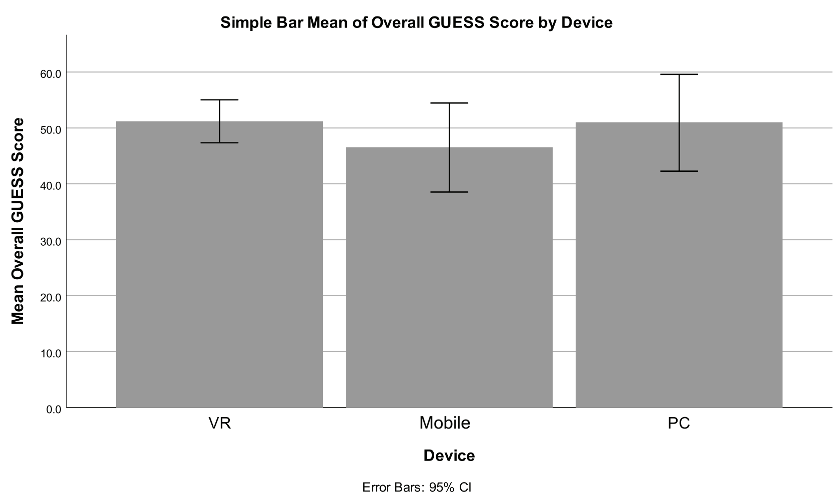


FIGURE 5.7: Visual representation of the overall GUESS-18 scores

5.8 Chapter Summary

The study delved into the exploration of PX in the context of asymmetric VR gaming, particularly focusing on the disparities between VR and non-VR device users. The primary objective was to identify how the inherent limitations and capabilities of non-VR devices influenced the PX and to devise strategies for designing an asymmetric VR game that could captivate non-VR players as effectively as VR players.

To achieve a comprehensive understanding, a mixed-method approach was used. The primary research method was qualitative, involving interviews and observations, analyzed using thematic analysis. Quantitative methods, such as the GUESS-18 and MPS tools, were used to support the findings. The analysis culminated in the identification of five pivotal themes:

- **Narrative Significance:** Beyond mere storytelling, the narrative emerges as a potent tool to bridge the experiential gap between VR and non-VR players, suggesting that game developers should prioritize narrative depth to foster inclusivity.
- **Compensation through Roles:** The study illuminates a novel approach to counterbalance device limitations. By strategically assigning roles, game designers can not only neutralize device constraints but also enrich the gaming dynamics, ensuring that non-VR players are not mere bystanders but active contributors to the game's progression.
- **Physical Movement & Interaction:** The correlation between physical movement, interaction methods, and PX underscores the need to design games that cater to diverse interaction preferences, ensuring that the physicality

of the game does not alienate any player segment.

- **The Social Fabric of Gaming:** The significance of team dynamics reaffirms that gaming is not just an individual pursuit but a social experience. The quality of interactions, collaborations, and even conflicts within a team can make or break the PX.
- **Avatar Realism and Immersion:** The emphasis on humanoid avatars suggests that the semblance of reality in virtual environments can amplify immersion, hinting at the psychological underpinnings of PX.

In conclusion, the chapter underscores the importance of understanding the nuances of PX in asymmetric VR gaming and offers insights into optimizing the experience for both VR and non-VR players.

Chapter 6

Discussion and Conclusion

Observations and recommendations are based on the established theories and frameworks identified in Chapter 2. The research questions addressed in this thesis are:

- **RQ 1: Is it possible for VR and non-VR players to have an equally positive PX in a remote asymmetric VR game?**

  This question is addressed in Section 6.1 and is based on the qualitative and quantitative findings in Chapter 5.
- **RQ 2: What factors affect the PX of VR and non-VR players in a remote asymmetric VR game?**

  This question is addressed in Section 6.2 and is supported by the previous research identified in Chapter 2.
- **RQ 3: What are the best practices for designing an asymmetric VR game that would provide an equal PX for all players?**

  This question is addressed in Section 6.3 and is also supported by the previous research identified in Chapter 2.

An asymmetric VR multiplayer game prototype called *LabXscape* was developed to answer these research questions. The intent of the prototype was to implement game elements that would support the device limitations of non-VR players and create experiences and interactions that would engage VR and non-VR players and result in a positive PX for everyone. The findings from the study have led to the development of recommendations for developers to consider when designing an asymmetric multiplayer VR game.

6.1 PX of VR and non-VR Players

Although players with all devices reported some challenges with the prototype asymmetric VR game, the result was a positive PX for all players. Through observations, interviews, and survey data, non-VR players can have almost as engaging an experience in an asymmetric VR game as VR players. While some elements were successful in engaging non-VR players, such as the narrative and roles (as shown in Section 5.2), others were less successful, such as the abstract avatar assigned to the PC player (as shown in Section 5.6.1) and providing narrative and role details on an information sheet. As was identified in Section 5.4.4, non-VR players often referred to the information sheet, which helped the player with gameplay, but likely took them out of the experience, potentially negatively affected their level of immersion. Additionally, including various types of asymmetries between players created a positive PX for VR and non-VR players.

6.2 Factors Affecting PX of Players in an Asymmetric VR Game

The PX of VR and non-VR players were affected by a number of factors. The factors can be categorised into the following areas:

- Embodiment Factors
- Engagement Factors
- Social Presence Factors

6.2.1 Embodiment Factors

While PC players did not have a traditional avatar, there did not seem to be problems with PC players embodying the character/role of the security guard. As indicated in Section 2.2.1, other aspects affect embodiment such as a player-controlled camera creating a diegetic embodiment and embodied thinking, resulting from a strong narrative and character connection. As identified in Section 5.2.2, PC players were able to put themselves in the role of the security guard easily, which made the interactions feel less abstract and more natural, resulting in PC players embodying their character.

For the most part, the mobile players were able to feel a sense of embodiment for similar reasons to PC players, with the addition of the ability of mobile players to control the movement of the character based on their physical movement, creating a sense of "tactile motor/kinesthetic link", as identified in Section 5.3.1. However, it was observed that the lack of an avatar visible by the mobile player may have created a disconnect between the player and the character. With the tracking limitations of mobile devices, creating an avatar that the mobile player can see in response to their movement, such as the VR player sees, is challenging. One option, as one of the participants suggested, would be to provide a mechanism such as a mirror to allow mobile players to see their avatar. Another option would be to provide a humanoid-type avatar that the mobile player could see "their body" if they looked down. A walk cycle animation would be triggered as the mobile player physically moved.

As a result of the direct correlation between player movement and their avatar movement, VR players also felt a sense of embodiment. VR players identified a high level of satisfaction with the narrative components of the game. The narrative and assigned role of the scientist or protagonist of the game further increased the feeling of embodiment through the "Projective Stance" theory identified in Section 2.2.1.

As discussed in Section 2.2.1, embodiment affects the PX. For non-VR devices, creating embodiment needs to be a priority and can be accomplished through narrative, roles, interactions, and avatars. VR players more easily experience embodiment because of their natural movement abilities. Still, it can be increased through a compelling narrative and role that draws VR players into the game and facilitates a connection with their character.

6.2.2 Engagement Factors

It was reported in Section 5.4 that PC players had as equally as high enjoyment as VR players. As described in Section 2.2.3, enjoyment and engagement are interconnected. One factor contributing to the high enjoyment of PC players is the cognitive engagement they experience. In Section 5.4, PC players reported feeling engaged or focused on the tasks to help the team complete the tasks in time. This focus on tasks or cognitive engagement created enjoyment for PC players, despite not being as immersed in the asymmetric VR game as the VR and mobile players.

While PC players demonstrated cognitive engagement, it was observed that many of the PC players desired to be more engaged in the game. While the narrative supported PC players' interaction limitations and methods of interaction, these limitations created an imbalance in active responsibility. With PC players being left to control cameras or access information to share with the other players, they often waited for other players to complete their tasks and then asked for more help. As indicated in Section 2.2.3, one of the dimensions of engagement is behaviour engagement, which is active participation in a situation. With PC players already feeling removed from the asymmetric VR game due to a reduced feeling of presence and social presence, maintaining engagement throughout the game is critical for a positive PX.

Mobile players were typically more engaged than PC players, as they had active tasks such as unlocking doors or scanning crystals. These tasks affected cognitive and behavioral engagement and contributed to the observations that mobile players were typically engaged in the game, despite the quantitative data showing slightly lower enjoyment than the VR and PC players. This lower engagement is likely a cause of mobile players' locomotion challenges (as described in Section 5.3.2), which increased their cognitive load. Cognitive load is often described as the mental energy required to process information or perform tasks (Feinberg & Murphy, 2000). The higher the cognitive load experienced by a player, the higher the likelihood for a reduction in player engagement (Alexiou & Schippers, 2018).

As identified in Section 5.4.4, all players equally expressed confusion about the game instructions, tasks, roles of each team member, and their responsibility within the game. This confusion may have led to frustration, potentially reducing immersion (Nylund & Landfors, 2015) and increasing cognitive load.

6.2.3 Social Presence Factors

As indicated in Section 5.6.1, humanoid avatars are critical for social presence in asymmetric VR games, especially when most of players have humanoid avatars. Failure to accommodate this requirement results in an imbalance because the player with a non-humanoid avatar may be overlooked, despite the ability for them to communicate verbally. Even though the PC player was the person that had all the information needed to accomplish tasks and could direct players to the correct corridors, they were often not consulted or their directions were ignored. The disembodied voice from the PC player was insufficient to create a strong feeling of social presence in the other players.

While the VR and mobile players felt a reduced social presence with regards to the PC player, social presence increased when players could see other players move and interact with the environment. The feeling of social presence increased when players spoke about the tasks they were performing and when players worked on tasks together.

6.3 Best Practices for Designing an Asymmetric VR Game

Designing an asymmetric multiplayer VR game that fosters equal involvement, engages all players, and addresses the limitations and affordances of non-VR devices requires a deliberate and strategic approach. The recommendations listed below are based on the findings from this research study listed in Chapter 5 and supported by existing theories and frameworks identified in Chapter 2.

Additionally, the design approach presented by Liszio et al. (2017) has been validated through my prototype. Every design element recommended was included in my prototype and directly impacted the PX for all players. For example, in the unification theme, the researchers recommended that rather than trying to explain away a particular mediated input system, its existence should be explained in the context of the game's theme. My prototype did this with the PC player. Rather than trying to pretend the player was not mediated through a computer, which could limit immersion, the computer itself became a part of the game theme through the player's role as a security guard monitoring the situation.

6.3.1 Design a Compelling Narrative and Device-specific Roles

Including a compelling narrative with equally compelling roles designed with device limitations in mind fosters engagement in both VR and non-VR players. It was observed that the narrative provided opportunities for players to feel present in the environment and support the development of social connections with the other players.

Developing roles that leverage each device's limitations and affordances help reduce cognitive load and increase immersion, embodiment, engagement, and presence. In *LabXscape*, the PC player is a security guard observing the game unfold through different security cameras. This role and how the player interacts with the computer have the potential to feel natural because this is a common trope found in film and television. With this role, the computer offers a natural interaction style rather than an abstract interaction style. The device limitations become strengths as they support immersion and draw the player into the virtual environment, encompassing the computer they are using (Conway, 2010).

Providing mechanisms for mobile players to move physically, and have those movements translate to their avatar in the virtual environment, has been found to increase presence and embodiment. It was noticed that some mobile players viewed the mobile device as a "window" to the virtual world. This is partly due to the physical movement opportunities provided to them. Mobile player movement using the mobile device's IMU is a relatively new concept. The mobile player's physical and artificial locomotion must match the physical world measurements. For example, if the mobile player walks one metre in the physical world, the correlated movement in the virtual environment should be appropriately represented.

The narrative should include a shared goal or objective. As indicated in Section 2.1.4, shared goals are likely to increase player enjoyment and cooperative behaviors. A component of a compelling narrative should also include a pressure element. This pressure element will encourage the players' bonding, enhance the effectiveness of the shared goal, and increase engagement. It was observed that both VR and non-VR players felt the tension caused by the time pressures in the game, which engaged them and increased enjoyment.

6.3.2 Tasks Should Include Interdependencies and Actively Involve All Players

With an asymmetric VR multiplayer game, as with many collaborative multiplayer games, players will interact to accomplish tasks. As discussed in Section 2.3.2, when collaborative tasks include a form of interdependence, PX and social connectedness are improved.

Observations indicated that non-VR players felt a sense of responsibility towards other players due to their interdependence. Not only did this feeling of responsibility connect the non-VR players to the other players, but it also increased engagement. As non-VR players collaborated with others, their sense of social presence heightened upon witnessing real-time results of their joint efforts, a phenomenon termed as 'focused interaction' (refer to Section 2.2.2).

In addition to tasks including interdependencies, tasks should actively involve all players. It was observed that when one or two players were performing actions, the non-VR players who were not involved in the task felt slightly disengaged. At this moment, they momentarily shifted from an active participant to a passive participant. Furthermore, it was observed that non-VR players, particularly the PC player, desired to take more of an active role in the game. Providing opportunities for all players to actively engage and interact with the game and the other players in ways that involve more than sharing information has a more significant opportunity of increasing engagement and immersion and, ultimately PX.

6.3.3 All Players Should Have a Humanoid Avatar

While research cited in Section 2.2.1 suggests that non-traditional avatars can still cause a player to feel a sense of embodiment, the effect that non-traditional avatars have on social presence is quite negative in an asymmetric VR game.

It was observed by many participants that the PC player, while visually represented by security cameras in the virtual environment, was often overlooked or felt distant or removed from the scenario. The VR and mobile players had recognisable visual avatars that responded to their physical movements, which helped create a sense of embodiment and social presence. The PC player was visually represented with a security camera, which other players only sometimes realised represented the PC player. This created an imbalance in representation and negatively affected the PX of the PC player and other players, as they often overlooked the PC player, which caused the team to perform tasks slower.

While it is recommended that all players have a humanoid avatar representing them, it is not suggested that the PC player be represented by a movable avatar that responds to keyboard input, similar to a first-person game. This approach will create more of an abstraction of input and negate the benefits of having the keyboard and mouse as natural input devices that fit the narrative and role assumed by the PC player. One possible recommendation would be to visually represent the PC player as an avatar on a computer screen within the virtual environment. This would fit with the paradigm that PC player is viewing the scenario through a computer, enhance the social presence felt by the other players towards the PC player, encourage the other players to keep the PC player top-of-mind and encourage frequent interactions with the PC player.

6.3.4 Player Preparation Should be Considered

Player preparation is essential in any game, but it is vital with an asymmetric VR game. With non-asymmetric VR games, players often have a similar view of the game. While they may have different abilities, there are commonalities such as input styles, UI, and tasks. Depending on the asymmetries implemented in an asymmetric VR game, players may have access to different roles, tasks, interfaces, information, and views. These differences make it challenging for the players to support each other.

It was observed that many participants needed help understanding what to do or what the other players' roles were, often rushing into the game without planning. Non-VR players were also observed frequently referring to a provided scenario card, potentially affecting their immersion in the game.

Asymmetric VR games should provide a dedicated space and time for players to interact, share information about each of their roles, and strategise. Additionally, rules and other pertinent information should be embedded directly into the gaming experience in an easily accessible manner in order to maintain immersion and attention.

6.3.5 Communication Protocols Need to be Established

As was identified in Section 5.5.1, some players experienced challenges with verbal communication. The overlapping communication that was experienced by some players occurs more frequently where conversations are not face-to-face (Johnová, 2004). The challenges with communication are partially due to the xlack of face-to-face communication and related factors such as facial expressions and gestures (Golden et al., 2008).

To address the verbal communication challenges that were experienced, it is recommended that communication protocols be set to compensate for the lack of face-to-face communication. The following is a list of metaphors identified by (Wadley et al., 2005) for voice communication in multiplayer games:

- **Two-way radio:** communication is equally available to all players
- **Mobile telephone:** communication is available anywhere in the game, but communication must be initiated
- **Land-line telephone:** communication is only available at particular locations in the game
- **Physical transmission of sound in air:** communication is only available between players who are in close proximity

The recommended communication metaphor depends on the nature of the asymmetric VR game. For a game similar to *LabXscape*, Wadley et al. (2005) recommends the two-way radio metaphor, but indicates that a voice protocol and radio discipline need to be implemented. The need for radio discipline is reinforced by further research (Wadley et al., 2015).

To address the recommendations from (Wadley et al., 2005), I propose a communication protocol similar to what physical radio operators would follow (Lees & Williamson, 2013). The **ClearComms Protocol** would ensure that players are familiar with communicating during the game and would potentially reduce confusion. The protocol consists of four elements:

- **Call Signs:** Each team member will be assigned a call sign that is unique (eg. Alpha 1, Bravo 2, etc.). When addressing a particular player, begin the transmission with the other player's call sign.
- **Procedural Words (pro-words:** These are common phrases such as "over", "out", "standby", and "roger". These pro-words will provide a common vocabulary that all players will be familiar with.
- **Clarity and Brevity:** When communicating, players will keep messages short and not use non-standard words or slang terms.
- **Radio Discipline:** Players will not interrupt current communication between players. If two players begin communicating at the same time, the player with the lower call sign (eg. Bravo 2 vs. Alpha 1) will yield the channel.

During the player preparation or tutorial stage of the game, players will have the opportunity to practice the ClearComms Protocol through scenario-based drills. While clear two-way radio communication protocols are essential in life-and-death situations, strict rigidity in a multiplayer game may have a negative impact. Further research would be ideal to identify the level of communication rigidness that can be implemented before negatively impacting the PX.

Another study (Gibbs et al., 2006) suggested that the two-way radio metaphor might pose challenges. They introduced a concept termed the Interactive Communication System (ICE), which essentially mirrors the physical transmission of sound in the air, with an option to activate a two-way radio as required.

the physical transmission of sound in air metaphor with the option to enable two-radio when needed. While ICE may appear to be restrictive at first, these restrictions allowed for more effective communication.

Furthermore, introducing enhanced visual cues to signify the speaking player could reduce confusion, prevent communication overlaps, and enhance activity coordination (Halloran et al., 2004).

6.4 Limitations

This study and thesis encompass certain limitations worth noting. Firstly, the sample size of this research study was small, with only 24 participants. In order to recruit and collect a large-scale dataset, considerable effort, time, and resources would be required. Recruiting more participants might have posed challenges, especially given the concerns related to the pandemic. Even with the small sample size, valuable information was uncovered through the thematic analysis of the interviews and observations. However, the small sample size did result in the quantitative data from the surveys yielding "not statistically relevant" results.

Secondly, the prototype required exactly three players using one of three devices; VR, PC, or mobile. The game needed to have each device to be included. The roles were also directly correlated to a specific device. For example, the PC player had to be the security guard, the VR player the scientist, and the mobile player the support drone. In addition, the research focused on a single specific asymmetric VR game prototype. While valuable insights were still generated, a study with a more generic game or a few different types of games could yield additional insights. Furthermore, the prototype was designed with a specific narrative, that of an escape room theme.

Thirdly, a "between subjects" design approach was used in the study. The research design did not include the use of a control group. For future studies, a control group could be implemented to establish a baseline to compare the impact of the experimental conditions, which are the different devices. The control group could consist of individuals observing the game, which can help establish the natural level of game enjoyment. This baseline provides a point of reference to measure how much each device augments the gaming experience (Braver et al., 2010). The goal of the research was not to determine player device preference, but rather to determine factors affecting the PX of VR and non-VR players and how to design asymmetric VR games to equally engage non-VR players, hence the decision to not use a "within subjects" design. A "within subjects" research study could provide some interesting advantages, including:

- **Reduced Variability:** In a within-subjects design, each participant serves as their own control, reducing the impact of individual differences on the dependent variable (Cohen, 2013). This can increase statistical power, reducing the sample size needed to detect a given effect (Charness et al., 2012).
- **Detecting Interaction Effects:** A within-subjects design can better detect

interaction effects between conditions or platforms and individual differences. For example, certain players may have different experiences across the VR, mobile, and PC platforms. A within-subjects design allows for the identification of such individual-level interactions (Kirk, 2013).

- **Consistency:** Participants' understanding of the game rules and mechanics remains consistent across platforms, controlling for potential confounding variables related to learning or understanding the game (Cohen, 2013).

Furthermore, all participants met in person during the onboarding session before being set up in separate rooms for the game session. This may have created preliminary social connections prior to the game, potentially skewing some of the feelings of social presence reported. The specific hardware and software requirements prevented an open call from being sent to recruit participants from around the world. Additionally, the lack of research assistants required the principal researcher to welcome and orient all participants at the same time.

6.5 Future Work

This thesis aimed to determine if VR and non-VR players could have an equally enjoyable experience in an asymmetric multiplayer VR game, identify factors affecting the PX, and develop best practices for designing an asymmetric VR game. These aims were accomplished, but with player roles being directly related to specific devices. Future work could explore the impact on PX of having roles not connected to device type. While this could reveal additional insights, an inherent challenge exists in the interaction limitations of non-VR devices that would need to be addressed. Additionally, future research could explore developing asymmetric VR games that were not designed for a specific number and type of devices. Asymmetric VR games that are designed to allow any combination of devices could introduce different group flow experiences.

Another research initiative worth exploring is expanding the asymmetric VR game beyond the escape room-style game to determine how the best practices identified in Section 6.3 would apply to different game styles. Furthermore, it would be worthwhile to determine if the research findings from this thesis could be applied to create positive user experiences in asymmetric serious games or asymmetric VR collaboration applications.

6.6 Conclusion

The impact of narrative, group flow, and authentic input devices on PX in an asymmetric VR game has yet to be widely researched. To address these games and determine if VR and non-VR players could be equally engaged, the prototype asymmetric VR game, *LabXscape* was developed. The prototype game was built following theories and frameworks identified in Chapter 2.

It was observed in the study that non-VR players can have almost as engaging a PX as VR players. Including a compelling narrative, player roles, and authentic interaction styles that supported the roles was highly effective at engaging non-VR players and immersing them into the asymmetric VR game.

When non-VR players can be actively involved in an asymmetric VR game and connected to the other players through shared goals and interactions, they can feel a sense of enjoyment and a positive PX.

References

Abulrub, A.-H. G., Attridge, A. N., & Williams, M. A. (2011). Virtual reality in engineering education: The future of creative learning. *2011 IEEE Global Engineering Education Conference (EDUCON)*, 751–757. https://doi.org/10.1109/EDUCON.2011.5773223

Adams, D., Bah, A., Barwulor, C., Musaby, N., Pitkin, K., & Redmiles, E. M. (2018). Ethics Emerging: The Story of Privacy and Security Perceptions in Virtual Reality. *Fourteenth Symposium on Usable Privacy and Security (SOUPS 2018)*, 427–442. https://www.usenix.org/conference/soups2018/presentation/adams

Albæk Thomsen, L., Nilsson, N. C., Nordahl, R., & Lohmann, B. (2019). Asymmetric collaboration in virtual reality: A taxonomy of asymmetric interfaces for collaborative immersive learning. *Tidsskriftet Læring og Medier (LOM)*, *12*(20). https://doi.org/10.7146/lom.v12i20.109391

Alexander, A. L., Brunyé, T., Sidman, J., Weil, S. A., et al. (2005). From gaming to training: A review of studies on fidelity, immersion, presence, and buy-in and their effects on transfer in pc-based simulations and games [Publisher: Citeseer]. *DARWARS Training Impact Group*, *5*, 1–14.

Alexiou, A., & Schippers, M. C. (2018). Digital game elements, user experience and learning: A conceptual framework. *Education and Information Technologies*, *23*(6), 2545–2567. https://doi.org/10.1007/s10639-018-9730-6

Allen, L. K., Crossley, S. A., Snow, E. L., & McNamara, D. S. (2014). L2 writing practice: Game enjoyment as a key to engagement [Publisher: University of Hawaii National Foreign Language Resource Center]. *Language Learning & Technology*, *18*(2), 124–150.

Annetta, L. A., Minogue, J., Holmes, S. Y., & Cheng, M.-T. (2009). Investigating the impact of video games on high school students' engagement and learning about genetics [Publisher: Elsevier]. *Computers & Education*, *53*(1), 74–85.

Ausubel, L. M., Cramton, P., & Deneckere, R. J. (2002). Chapter 50 Bargaining with incomplete information. *Handbook of Game Theory with Economic Applications* (pp. 1897–1945). Elsevier. https://doi.org/10.1016/S1574-0005(02)03013-8

Bender, P. K., & Courtney Plante, D. A. (1972). The Effects of Violent Media Content on. *Am Psychol*, *27*, 253–263.

Beznosyk, A., Quax, P., Lamotte, W., & Coninx, K. (2012). The Effect of Closely-Coupled Interaction on Player Experience in Casual Games [Series Title: Lecture Notes in Computer Science]. In M. Herrlich, R. Malaka, & M. Masuch (Eds.), *Entertainment Computing - ICEC 2012* (pp. 243–255). Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-642-33542-6_21

Bianchi-Berthouze, N., Kim, W. W., & Patel, D. (2007). Does Body Movement Engage You More in Digital Game Play? and Why? [ISSN: 0302-9743, 1611-3349 Series Title: Lecture Notes in Computer Science]. In A. C. R. Paiva, R. Prada, & R. W. Picard (Eds.), *Affective Computing and Intelligent Interaction* (pp. 102–113). Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-540-74889-2_10

Birk, M., & Mandryk, R. L. (2013). Control your game-self: Effects of controller type on enjoyment, motivation, and personality in game. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, 685–694. https://doi.org/10.1145/2470654.2470752

Born, F., Sykownik, P., & Masuch, M. (2019). Co-Located vs. Remote Gameplay: The Role of Physical Co-Presence in Multiplayer Room-Scale VR. *2019 IEEE Conference on Games (CoG)*, 1–8. https://doi.org/10.1109/CIG.2019.8848001

Boyle, E. A., Connolly, T. M., Hainey, T., & Boyle, J. M. (2012). Engagement in digital entertainment games: A systematic review. *Computers in Human Behavior*, *28*(3), 771–780. https://doi.org/10.1016/j.chb.2011.11.020

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, *3*(2), 77–101. https://doi.org/10.1191/1478088706qp063oa

Braver, T. S., Cole, M. W., & Yarkoni, T. (2010). Vive les differences! Individual variation in neural mechanisms of executive control. *Current Opinion in Neurobiology*, *20*(2), 242–250. https://doi.org/10.1016/j.conb.2010.03.002

Brown, E., & Cairns, P. (2004). A grounded investigation of game immersion. *Extended abstracts of the 2004 conference on Human factors and computing systems - CHI '04*, 1297. https://doi.org/10.1145/985921.986048

Budiu, R. (2017). Quantitative vs. Qualitative Usability Testing. https://www.nngroup.com/articles/quant-vs-qual/

Bulu, S. T. (2012). Place presence, social presence, co-presence, and satisfaction in virtual worlds. *Computers & Education*, *58*(1), 154–161. https://doi.org/10.1016/j.compedu.2011.08.024

Cade, R., & Gates, J. (2017). Gamers and Video Game Culture: An Introduction for Counselors. *The Family Journal*, *25*(1), 70–75. https://doi.org/10.1177/1066480716679809

Characteristics and limitations of Speech-to-Text. (2022). https://learn.microsoft.com/en-us/legal/cognitive-services/speech-service/speech-to-text/characteristics-and-limitations

Charness, G., Gneezy, U., & Kuhn, M. A. (2012). Experimental methods: Between-subject and within-subject design. *Journal of Economic Behavior & Organization*, *81*(1), 1–8. https://doi.org/10.1016/j.jebo.2011.08.009

Chen, J. (2007). Flow in games (and everything else) [Publisher: ACM New York, NY, USA]. *Communications of the ACM*, *50*(4), 31–34.

Coffeng, T., Van Steenbergen, E. F., De Vries, F., & Ellemers, N. (2021). Quality of group decisions by board members: A hidden-profile experiment. *Management Decision*, *59*(13), 38–55. https://doi.org/10.1108/MD-07-2020-0893

Cohen. (2013). *Applied Multiple Regression/Correlation Analysis for the Behavioral Sciences* (3rd ed.). Routledge. https://doi.org/10.4324/9780203774441

Consalvo, M. (2017). Player one, playing with others virtually: What's next in game and player studies. *Critical Studies in Media Communication*, *34*(1), 84–87. https://doi.org/10.1080/15295036.2016.1266682

Conway, S. (2010). A circular wall? Reformulating the fourth wall for videogames. *Journal of Gaming & Virtual Worlds*, *2*(2), 145–155. https://doi.org/10.1386/jgvw.2.2.145_1

Cowley, B., Charles, D., Black, M., & Hickey, R. (2008). Toward an understanding of flow in video games. *Computers in Entertainment*, *6*(2), 1–27. https://doi.org/10.1145/1371216.1371223

Cox, A., Cairns, P., Shah, P., & Carroll, M. (2012). Not doing but thinking: The role of challenge in the gaming experience. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, 79–88. https://doi.org/10.1145/2207676.2207689

Creswell, J. W., & Plano Clark, V. L. (2007). *Designing and conducting mixed methods research* [OCLC: ocm65399935]. SAGE Publications.

Csikszentmihalyi, M. (1990). Flow: The Psychology of Optimal Experience.

Cuddihy, E., & Walters, D. (2000). Embodied interaction in social virtual environments. *Proceedings of the third international conference on Collaborative virtual environments - CVE '00*, 181–188. https://doi.org/10.1145/351006.351039

De Kort, Y., Ijsselsteijn, W., & Poels, K. (2007). Digital Games as Social Presence Technology: Development of the Social Presence in Gaming Questionnaire (SPGQ). *Journal of Applied Mechanics-transactions of The Asme - J APPL MECH*.

Dede, C. (2009). Immersive Interfaces for Engagement and Learning. *Science*, *323*(5910), 66–69. https://doi.org/10.1126/science.1167311

Depping, A. E., & Mandryk, R. L. (2017). Cooperation and Interdependence: How Multiplayer Games Increase Social Closeness. *Proceedings of the Annual Symposium on Computer-Human Interaction in Play*, 449–461. https://doi.org/10.1145/3116595.3116639

Deterding, S., Dixon, D., Khaled, R., & Nacke, L. (2011). From game design elements to gamefulness: Defining "gamification". *Proceedings of the 15th International Academic MindTrek Conference: Envisioning Future Media Environments*, 9–15. https://doi.org/10.1145/2181037.2181040

Dourish, P. (2001). *Where the action is: The foundations of embodied interaction*. MIT press.

Egli, E. A., & Meyers, L. S. (1984). The role of video game playing in adolescent life: Is there reason to be concerned? *Bulletin of the Psychonomic Society*, *22*(4), 309–312. https://doi.org/10.3758/BF03333828

Elson, M., Breuer, J., Ivory, J. D., & Quandt, T. (2014). More Than Stories With Buttons: Narrative, Mechanics, and Context as Determinants of Player Experience in Digital Games: Narrative, Mechanics, and Context in Digital Games. *Journal of Communication*, *64*(3), 521–542. https://doi.org/10.1111/jcom.12096

Emmerich, K., & Masuch, M. (2017). The Impact of Game Patterns on Player Experience and Social Interaction in Co-Located Multiplayer Games. *Proceedings of the Annual Symposium on Computer-Human Interaction in Play*, 411–422. https://doi.org/10.1145/3116595.3116606

Ermi, L., & Mäyrä, F. (2007). Analyzing Immersion [Publisher: Peter Lang]. *Worlds in play: International perspectives on digital games research*, *21*, 37.

Fang, W., Zheng, L., & Deng, H. (2016). A motion tracking method by combining the IMU and camera in mobile devices. *2016 10th International Conference on Sensing Technology (ICST)*, 1–6. https://doi.org/10.1109/ICSensT.2016.7796235

Feinberg, S., & Murphy, M. (2000). Applying cognitive load theory to the design of Web-based instruction. *18th Annual Conference on Computer Documentation. ipcc sigdoc 2000. Technology and Teamwork. Proceedings. IEEE Professional Communication Society International Professional Communication Conference an*, 353–360. https://doi.org/10.1109/IPCC.2000.887293

Fredricks, J. A., Blumenfeld, P. C., & Paris, A. H. (2004). School Engagement: Potential of the Concept, State of the Evidence. *Review of Educational Research*, *74*(1), 59–109. https://doi.org/10.3102/00346543074001059

Furukawa, T., Yamamoto, D., Sugawa, M., Peiris, R., & Minamizawa, K. (2019). TeleSight: Enabling asymmetric collaboration in VR between HMD user and Non-HMD users. *ACM SIGGRAPH 2019 Emerging Technologies*, 1–2. https://doi.org/10.1145/3305367.3335040

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 [Series Title: Lecture Notes in Computer Science]. In P. Markopoulos, B. de Ruyter, W. IJsselsteijn, & D. Rowland (Eds.), *Fun and Games* (pp. 106–117). Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-540-88322-7_11

Gee, J. P. (2008). Video Games and Embodiment. *Games and Culture*, *3*(3-4), 253–263. https://doi.org/10.1177/1555412008317309

Gibbs, M., Wadley, G., & Benda, P. (2006). Proximity-based chat in a first person shooter: Using a novel voice communication system for online play.

Proceedings of the 3rd Australasian conference on Interactive entertainment, 96–102.

Giummarra, M. J., Gibson, S. J., Georgiou-Karistianis, N., & Bradshaw, J. L. (2008). Mechanisms underlying embodiment, disembodiment and loss of embodiment [Publisher: Elsevier]. *Neuroscience & Biobehavioral Reviews*, *32*(1), 143–160.

Golafshani, N. (2003). Understanding reliability and validity in qualitative research [Publisher: Canadá]. *The qualitative report*, *8*(4), 597–607.

Golden, T. D., Veiga, J. F., & Dino, R. N. (2008). The impact of professional isolation on teleworker job performance and turnover intentions: Does time spent teleworking, interacting face-to-face, or having access to communication-enhancing technology matter? *Journal of Applied Psychology*, *93*(6), 1412–1421. https://doi.org/10.1037/a0012722

Grandi, J. G., Debarba, H. G., & Maciel, A. (2019). Characterizing Asymmetric Collaborative Interactions in Virtual and Augmented Realities. *2019 IEEE Conference on Virtual Reality and 3D User Interfaces (VR)*, 127–135. https://doi.org/10.1109/VR.2019.8798080

Gugenheimer, J., Mai, C., McGill, M., Williamson, J., Steinicke, F., & Perlin, K. (2019). Challenges Using Head-Mounted Displays in Shared and Social Spaces. *Extended Abstracts of the 2019 CHI Conference on Human Factors in Computing Systems*, 1–8. https://doi.org/10.1145/3290607.3299028

Gugenheimer, J., Stemasov, E., Frommel, J., & Rukzio, E. (2017). ShareVR: Enabling Co-Located Experiences for Virtual Reality between HMD and

Non-HMD Users. *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems*, 4021–4033. https://doi.org/10.1145/3025453.3025683

Gutwin, C., & Greenberg, S. (2000). The mechanics of collaboration: Developing low cost usability evaluation methods for shared workspaces. *Proceedings IEEE 9th International Workshops on Enabling Technologies: Infrastructure for Collaborative Enterprises (WET ICE 2000)*, 98–103. https://doi.org/10.1109/ENABL.2000.883711

Halloran, J., Fitzpatrick, G., Rogers, Y., & Marshall, P. (2004). Does it matter if you don't know who's talking?: Multiplayer gaming with voiceover IP. *CHI '04 Extended Abstracts on Human Factors in Computing Systems*, 1215–1218. https://doi.org/10.1145/985921.986027

Hamari, J., Shernoff, D. J., Rowe, E., Coller, B., Asbell-Clarke, J., & Edwards, T. (2016). Challenging games help students learn: An empirical study on engagement, flow and immersion in game-based learning. *Computers in Human Behavior*, *54*, 170–179. https://doi.org/10.1016/j.chb.2015.07.045

Harris, J., & Hancock, M. (2019). To Asymmetry and Beyond!: Improving Social Connectedness by Increasing Designed Interdependence in Cooperative Play. *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*, 1–12. https://doi.org/10.1145/3290605.3300239

Harris, J., Hancock, M., & Scott, S. D. (2016). Leveraging Asymmetries in Multiplayer Games: Investigating Design Elements of Interdependent Play. *Proceedings of the 2016 Annual Symposium on Computer-Human Interaction in Play*, 350–361. https://doi.org/10.1145/2967934.2968113

Heeter, C. (1992). *Being* There: The Subjective Experience of Presence. *Presence: Teleoperators and Virtual Environments*, *1*(2), 262–271. https://doi.org/10.1162/pres.1992.1.2.262

Hefner, D., Klimmt, C., & Vorderer, P. (2007). Identification with the Player Character as Determinant of Video Game Enjoyment [Series Title: Lecture Notes in Computer Science]. In L. Ma, M. Rauterberg, & R. Nakatsu (Eds.), *Entertainment Computing – ICEC 2007* (pp. 39–48). Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-540-74873-1_6

Hunicke, R., Leblanc, M., & Zubek, R. (2004). MDA: A Formal Approach to Game Design and Game Research. *AAAI Workshop - Technical Report*, *1*.

Ip, B. (2011). Narrative Structures in Computer and Video Games: Part 1: Context, Definitions, and Initial Findings. *Games and Culture*, *6*(2), 103–134. https://doi.org/10.1177/1555412010364982

Järvinen, A., Heliö, A., Mäyrä, S., & Mäyrä, F. (2002). Communication and Community in Digital Entertainment Services. Prestudy Research Report.

Jenkins, H. (2004). Game design as narrative architecture. *Computer*, *44*(3), 118–130.

Jennett, C., Cox, A. L., Cairns, P., Dhoparee, S., Epps, A., Tijs, T., & Walton, A. (2008). Measuring and defining the experience of immersion in games. *International Journal of Human-Computer Studies*, *66*(9), 641–661. https://doi.org/10.1016/j.ijhcs.2008.04.004

Jeong, K., Kim, J., Kim, M., Lee, J., & Kim, C. (2019). Asymmetric Interface: User Interface of Asymmetric Virtual Reality for New Presence and Experience. *Symmetry*, *12*(1), 53. https://doi.org/10.3390/sym12010053

Johnová, M. (2004). The language of chat [Publisher: The Vilém Mathesius Society]. *Philologica. net*.

Johnson, D., Nacke, L. E., & Wyeth, P. (2015). All about that Base: Differing Player Experiences in Video Game Genres and the Unique Case of MOBA Games. *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems*, 2265–2274. https://doi.org/10.1145/2702123.2702447

Jørgensen, K. (2012). Between the Game System and the Fictional World: A Study of Computer Game Interfaces. *Games and Culture*, *7*(2), 142–163. https://doi.org/10.1177/1555412012440315

Karaosmanoglu, S., Rogers, K., Wolf, D., Rukzio, E., Steinicke, F., & Nacke, L. E. (2021). Feels like Team Spirit: Biometric and Strategic Interdependence in Asymmetric Multiplayer VR Games. *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems*, 1–15. https://doi.org/10.1145/3411764.3445492

Kawulich, B. B. (2005). Participant Observation as a Data Collection Method [Publisher: Forum Qualitative Sozialforschung / Forum: Qualitative Social Research]. *Forum Qualitative Sozialforschung / Forum: Qualitative Social Research*, *Vol 6*, and Reuse. https://doi.org/10.17169/FQS-6.2.466

Kaye, L. K. (2016). Exploring flow experiences in cooperative digital gaming contexts. *Computers in Human Behavior*, *55*, 286–291. https://doi.org/10.1016/j.chb.2015.09.023

Kaye, L. K., & Bryce, J. (2012). Putting the fun factor into gaming: The influence of social contexts on the experiences of playing videogames [Publisher: University of Zurich]. *International Journal of Internet Science*, *7*(1), 24–38.

Keebler, J., Shelstad, W., Smith, D., Chaparro, B., & Phan, M. (2020). Validation of the GUESS-18: A Short Version of the Game User Experience Satisfaction Scale (GUESS). *Journal of Usability Studies*, *16*(1), 49–62.

Kilteni, K., Groten, R., & Slater, M. (2012). The Sense of Embodiment in Virtual Reality. *Presence: Teleoperators and Virtual Environments*, *21*(4), 373–387. https://doi.org/10.1162/PRES_a_00124

Kim, M. (2019). Why you feel motion sickness during virtual reality. Retrieved February 8, 2022, from https://abcnews.go.com/Technology/feel-motion-sickness-virtual-reality/story?id=65153805

Kirk, R. (2013). *Experimental Design: Procedures for the Behavioral Sciences*. SAGE Publications, Inc. https://doi.org/10.4135/9781483384733

Klevjer, R. (2006). What is the avatar? Fiction and embodiment in avatar-based singleplayer computer games [Publisher: The University of Bergen].

Klimmt, C., Hartmann, T., & Frey, A. (2007). Effectance and Control as Determinants of Video Game Enjoyment. *CyberPsychology & Behavior*, *10*(6), 845–848. https://doi.org/10.1089/cpb.2007.9942

Koenitz, H. (2018). Narrative in Video Games. In N. Lee (Ed.), *Encyclopedia of Computer Graphics and Games* (pp. 1–9). Springer International Publishing. https://doi.org/10.1007/978-3-319-08234-9_154-1

Kolar, T., & Čater, B. (2018). Managing group flow experiences in escape rooms. *International Journal of Contemporary Hospitality Management*, *30*(7), 2637–2661. https://doi.org/10.1108/IJCHM-03-2017-0152

Laamarti, F., Eid, M., & El Saddik, A. (2014). An Overview of Serious Games. *International Journal of Computer Games Technology*, *2014*, 1–15. https://doi.org/10.1155/2014/358152

Lankoski, P. (2011). Player Character Engagement in Computer Games. *Games and Culture*, *6*(4), 291–311. https://doi.org/10.1177/1555412010391088

Lankoski, P. (2016). Embodiment in character-based videogames. *Proceedings of the 20th International Academic Mindtrek Conference*, 358–365. https://doi.org/10.1145/2994310.2994320

Lee, J., Kim, M., & Kim, J. (2020). RoleVR: Multi-experience in immersive virtual reality between co-located HMD and non-HMD users. *Multimedia Tools and Applications*, *79*(1-2), 979–1005. https://doi.org/10.1007/s11042-019-08220-w

Lee, K. M. (2004). Presence, Explicated. *Communication Theory*, *14*(1), 27–50. https://doi.org/10.1111/j.1468-2885.2004.tb00302.x

Lees, G., & Williamson, W. (2013). *Handbook for Marine Radio Communication 5E*. Taylor & Francis.

Li, J., Deng, H., & Michalatos, P. (2017). MagicTorch: A Context-aware Projection System for Asymmetrical VR Games. *Extended Abstracts Publication of the Annual Symposium on Computer-Human Interaction in Play*, 431–436. https://doi.org/10.1145/3130859.3131341

Liszio, S., Emmerich, K., & Masuch, M. (2017). The influence of social entities in virtual reality games on player experience and immersion. *Proceedings of the 12th International Conference on the Foundations of Digital Games*, 1–10. https://doi.org/10.1145/3102071.3102086

Lombard, M., & Ditton, T. (2006). At the Heart of It All: The Concept of Presence. *Journal of Computer-Mediated Communication*, *3*(2), 0–0. https://doi.org/10.1111/j.1083-6101.1997.tb00072.x

López-Pernas, S., Gordillo, A., Barra, E., & Quemada, J. (2019). Examining the Use of an Educational Escape Room for Teaching Programming in a Higher Education Setting. *IEEE Access*, *7*, 31723–31737. https://doi.org/10.1109/ACCESS.2019.2902976

Louchart, S., & Aylett, R. (2004). Narrative theory and emergent interactive narrative. *International Journal of Continuing Engineering Education and Lifelong Learning*, *14*(6), 506. https://doi.org/10.1504/IJCEELL.2004.006017

Makransky, G., Lilleholt, L., & Aaby, A. (2017). Development and validation of the Multimodal Presence Scale for virtual reality environments: A confirmatory factor analysis and item response theory approach. *Computers in Human Behavior*, *72*, 276–285. https://doi.org/https://doi.org/10.1016/j.chb.2017.02.066

Maurer, B., Aslan, I., Wuchse, M., Neureiter, K., & Tscheligi, M. (2015). Gaze-Based Onlooker Integration: Exploring the In-Between of Active Player and Passive Spectator in Co-Located Gaming. *Proceedings of the 2015 Annual Symposium on Computer-Human Interaction in Play*, 163–173. https://doi.org/10.1145/2793107.2793126

McEwan, M. W., Blackler, A. L., Johnson, D. M., & Wyeth, P. A. (2014). Natural mapping and intuitive interaction in videogames. *Proceedings of the first ACM SIGCHI annual symposium on Computer-human interaction in play*, 191–200. https://doi.org/10.1145/2658537.2658541

Mcmahan, A. (2003). Immersion, engagement, and presence: A method for analyzing 3-D video games. *The Video Game Theory Reader*, 67–86.

Milgram, P., Takemura, H., Utsumi, A., & Kishino, F. (1995). Augmented reality: A class of displays on the reality-virtuality continuum. In H. Das (Ed.). https://doi.org/10.1117/12.197321

Morschheuser, B., Maedche, A., & Walter, D. (2017). Designing Cooperative Gamification: Conceptualization and Prototypical Implementation. *Proceedings of the 2017 ACM Conference on Computer Supported Cooperative Work and Social Computing*, 2410–2421. https://doi.org/10.1145/2998181.2998272

Morschheuser, B., Riar, M., Hamari, J., & Maedche, A. (2017). How games induce cooperation? A study on the relationship between game features and we-intentions in an augmented reality game. *Computers in Human Behavior*, *77*, 169–183. https://doi.org/10.1016/j.chb.2017.08.026

Morse, J. M. (1991). Approaches to Qualitative-Quantitative Methodological Triangulation: *Nursing Research*, *40*(2), 120–123. https://doi.org/https://doi.org/10.1097/00006199-199103000-00014

Moser, C., & Fang, X. (2015). Narrative Structure and Player Experience in Role-Playing Games. *International Journal of Human-Computer Interaction*, *31*(2), 146–156. https://doi.org/10.1080/10447318.2014.986639

Nakamura, J., & Csikszentmihalyi, M. (2009). Flow theory and research. *Handbook of positive psychology*, *195*, 206.

Nowak, K. L., & Biocca, F. (2003). The Effect of the Agency and Anthropomorphism on Users' Sense of Telepresence, Copresence, and Social Presence in Virtual Environments. *Presence: Teleoperators and Virtual Environments*, *12*(5), 481–494. https://doi.org/10.1162/105474603322761289

Nylund, A., & Landfors, O. (2015). *Frustration and its effect on immersion in games : A developer viewpoint on the good and bad aspects of frustration* (Master's thesis) [Backup Publisher: Umeå University, Department of Informatics Issue: 2015.09 Series: Informatik Student Paper Master (INFSPM)]. Umeå University, Department of Informatics.

Oh, C. S., Bailenson, J. N., & Welch, G. F. (2018). A Systematic Review of Social Presence: Definition, Antecedents, and Implications. *Frontiers in Robotics and AI*, *5*, 114. https://doi.org/10.3389/frobt.2018.00114

Oh, K., & Lee, K.-P. (2005). A Review of Frameworks for Online Community Design-with Emphasis on Developing Online Community Construct. *International Design Congress 2005*.

O'Shea, Z., & Freeman, J. (2019). Game design frameworks: Where do we start? *Proceedings of the 14th International Conference on the Foundations of Digital Games*, 1–10. https://doi.org/10.1145/3337722.3337753

Osterland, A. (n.d.). Coronavirus could be catalyst to reinvigorate virtual reality headsets. Retrieved September 25, 2022, from https://www.cnbc.com/2020/05/02/coronavirus-could-be-catalyst-to-reinvigorate-virtual-reality-headsets.html

Ouverson, K. M., & Gilbert, S. B. (2021). A Composite Framework of Co-located Asymmetric Virtual Reality. *Proceedings of the ACM on Human-Computer Interaction*, *5*(CSCW1), 1–20. https://doi.org/10.1145/3449079

Palma-Ruiz, J. M., Torres-Toukoumidis, A., González-Moreno, S. E., & Valles-Baca, H. G. (2022). An overview of the gaming industry across nations: Using analytics with power BI to forecast and identify key influencers. *Heliyon*, *8*(2), e08959. https://doi.org/10.1016/j.heliyon.2022.e08959

Park, N., Min Lee, K., Annie Jin, S.-A., & Kang, S. (2010). Effects of pre-game stories on feelings of presence and evaluation of computer games. *International Journal of Human-Computer Studies*, *68*(11), 822–833. https://doi.org/10.1016/j.ijhcs.2010.07.002

Peter, B. (2007). Notes Toward a Sense of Embodied Gameplay. *DiGRA &#3907 - Proceedings of the 2007 DiGRA International Conference: Situated Play*. http://www.digra.org/wp-content/uploads/digital-library/07312.19059.pdf

Pietschmann, D., Valtin, G., & Ohler, P. (2012). The Effect of Authentic Input Devices on Computer Game Immersion. In J. Fromme & A. Unger (Eds.), *Computer Games and New Media Cultures* (pp. 279–292). Springer Netherlands. https://doi.org/10.1007/978-94-007-2777-9_18

Praetorius, A. S., & Görlich, D. (2020). How Avatars Influence User Behavior: A Review on the Proteus Effect in Virtual Environments and Video Games. *International Conference on the Foundations of Digital Games*, 1–9. https://doi.org/10.1145/3402942.3403019

Qin, H., Patrick Rau, P.-L., & Salvendy, G. (2009). Measuring Player Immersion in the Computer Game Narrative. *International Journal of Human-Computer Interaction*, *25*(2), 107–133. https://doi.org/10.1080/10447310802546732

Ravaja, N., Saari, T., Turpeinen, M., Laarni, J., Salminen, M., & Kivikangas, M. (2006). Spatial Presence and Emotions during Video Game Playing: Does It Matter with Whom You Play? *Presence: Teleoperators and Virtual Environments*, *15*(4), 381–392. https://doi.org/10.1162/pres.15.4.381

Rehak, B. (2003). Playing at Being: Psychoanalysis and the Avatar. *The Video Game Theory Reader*.

Riva, G., Waterworth, J., & Murray, D. (2014). Extending the Self through the Tools and the Others: A General Framework for Presence and Social Presence in Mediated Interactions. *Interacting with Presence: HCI and the Sense of Presence in Computer-mediated Environments* (pp. 9–31). DE GRUYTER OPEN. https://doi.org/10.2478/9783110409697.1

Rocha, J., Mascarenhas, S., & Prada, R. (2008). Game Mechanics for Cooperative Games.

Rogers, K., Karaosmanoglu, S., Wolf, D., Steinicke, F., & Nacke, L. E. (2021). A Best-Fit Framework and Systematic Review of Asymmetric Gameplay in Multiplayer Virtual Reality Games. *Frontiers in Virtual Reality*, *2*, 694660. https://doi.org/10.3389/frvir.2021.694660

Saavedra, R., Earley, P. C., & Van Dyne, L. (1993). Complex interdependence in task-performing groups. *Journal of Applied Psychology*, *78*(1), 61–72. https://doi.org/10.1037/0021-9010.78.1.61

Sajjadi, P., Cebolledo Gutierrez, E. O., Trullemans, S., & De Troyer, O. (2014). Maze commander: A collaborative asynchronous game using the oculus rift & the sifteo cubes. *Proceedings of the first ACM SIGCHI annual symposium on Computer-human interaction in play*, 227–236. https://doi.org/10.1145/2658537.2658690

Schoenau-Fog, H. et al. (2011). The Player Engagement Process-An Exploration of Continuation Desire in Digital Games. *DiGRA Conference*.

Schultze, U. (2010). Embodiment and presence in virtual worlds: A review. *Journal of Information Technology*, *25*(4), 434–449. https://doi.org/10.1057/jit.2010.25

Schultze, U., & Brooks, J. A. M. (2019). An interactional view of social presence: Making the virtual other "real". *Information Systems Journal*, *29*(3), 707–737. https://doi.org/10.1111/isj.12230

Seibert, J., & Shafer, D. M. (2018). Control mapping in virtual reality: Effects on spatial presence and controller naturalness. *Virtual Reality*, *22*(1), 79–88. https://doi.org/10.1007/s10055-017-0316-1

Serubugo, S., Skantarova, D., Evers, N., & Kraus, M. (2018). Self-overlapping Maze and Map Design for Asymmetric Collaboration in Room-Scale Virtual Reality for Public Spaces [Series Title: Lecture Notes of the Institute for Computer Sciences, Social Informatics and Telecommunications Engineering]. In A. L. Brooks, E. Brooks, & N. Vidakis (Eds.), *Interactivity, Game Creation, Design, Learning, and Innovation* (pp. 194–203). Springer International Publishing. https://doi.org/10.1007/978-3-319-76908-0_19

Shen, X., & Shirmohammadi, S. (2008). Virtual and Augmented Reality. In B. Furht (Ed.), *Encyclopedia of Multimedia* (pp. 962–967). Springer US. https://doi.org/10.1007/978-0-387-78414-4_253

Sheridan, T. B. (1992). Musings on Telepresence and Virtual Presence. *Presence: Teleoperators and Virtual Environments*, *1*(1), 120–126. https://doi.org/10.1162/pres.1992.1.1.120

Shinkle, E. (2008). Video games, emotion and the six senses. *Media, Culture & Society*, *30*(6), 907–915. https://doi.org/10.1177/0163443708096810

Skjott Linneberg, M., & Korsgaard, S. (2019). Coding qualitative data: A synthesis guiding the novice. *Qualitative Research Journal*, *19*(3), 259–270. https://doi.org/10.1108/QRJ-12-2018-0012

Slater, M., & Wilbur, S. (1997). A Framework for Immersive Virtual Environments (FIVE): Speculations on the Role of Presence in Virtual Environments. *Presence: Teleoperators and Virtual Environments*, *6*(6), 603–616. https://doi.org/10.1162/pres.1997.6.6.603

Smilovitch, M., & Lachman, R. (2019). BirdQuestVR: A Cross-Platform Asymmetric Communication Game. *Extended Abstracts of the Annual Symposium on Computer-Human Interaction in Play Companion Extended Abstracts*, 307–313. https://doi.org/10.1145/3341215.3358246

Smith, D., Granados, J., & Suss, J. (2019). Evaluating the Comprehensiveness of VR PLAY Guidelines Using Elder Scrolls: Skyrim VR. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, *63*(1), 2287–2291. https://doi.org/10.1177/1071181319631164

Swink, S. (2009). *Game feel: A game designer's guide to virtual sensation*. Morgan Kaufmann Publishers/Elsevier.

Taherdoost, H. (2016). Sampling Methods in Research Methodology; How to Choose a Sampling Technique for Research. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.3205035

Tamborini, R., & Skalski, P. (2006). The role of presence in the experience of electronic games. *Playing video games: Motives, responses, and consequences*, 225–240.

Taylor, L. N., Taylor, L. N., & Acknowledgments, T. P. (2002). *Video Games: Perspective, Point-of-view, and Immersion* (tech. rep.). University of Florida.

Tsakiris, M. (2010). My body in the brain: A neurocognitive model of body-ownership. *Neuropsychologia*, *48*(3), 703–712. https://doi.org/10.1016/j.neuropsychologia.2009.09.034

Ulf, H. (2009). Where Do Game Design Ideas Come From? Invention and Recycling in Games Developed in Sweden. *DiGRA &#3909 - Proceedings of the 2009 DiGRA International Conference: Breaking New Ground: Innovation in Games, Play, Practice and Theory*. http://www.digra.org/wp-content/uploads/digital-library/09287.25072.pdf

von Ahn, L., & Dabbish, L. (2008). Designing games with a purpose. *Communications of the ACM*, *51*(8), 58–67. https://doi.org/10.1145/1378704.1378719

Wadley, G., Carter, M., & Gibbs, M. (2015). Voice in Virtual Worlds: The Design, Use, and Influence of Voice Chat in Online Play. *Human–Computer Interaction*, *30*(3-4), 336–365. https://doi.org/10.1080/07370024.2014.987346

Wadley, G., Gibbs, M. R., & Benda, P. (2005). Towards a framework for designing speech-based player interaction in multiplayer online games.

Wendel, V., & Konert, J. (2016). Multiplayer Serious Games. In R. Dörner, S. Göbel, W. Effelsberg, & J. Wiemeyer (Eds.), *Serious Games* (pp. 211–241). Springer International Publishing. https://doi.org/10.1007/978-3-319-40612-1_8

Wilhelmsson, U. (2001). Enacting the Point of Being-Computer games, interaction and film theory Affordances and constraints, metaphorical concepts and experientialist cognition observed through the environment in computer games Enacting the Point of Being-Computer games, interaction and film theory Affordances and constraints, metaphorical concepts and experientialist cognition observed through the environment in computer games Dissertation submitted in partial fulfillment of the requirements for the [Publisher: Unpublished]. https://doi.org/10.13140/RG.2.2.29509.70888

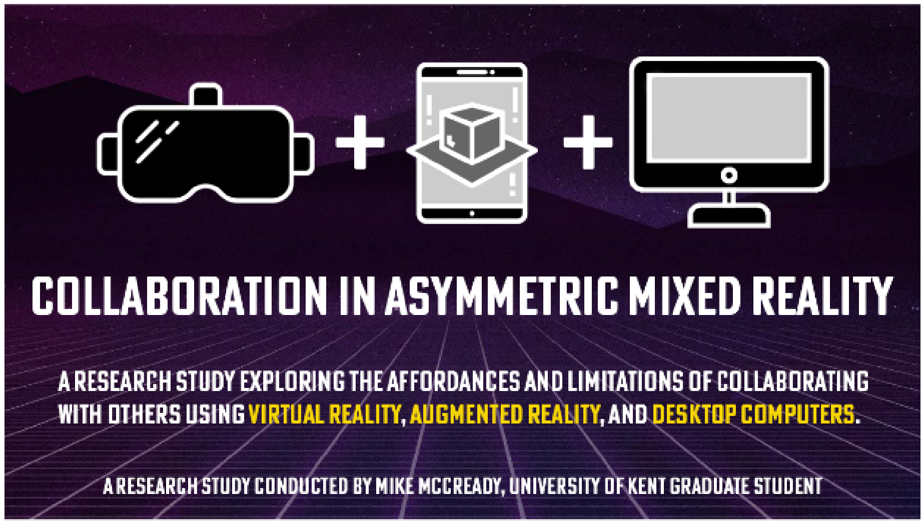
Wilhelmsson, U. (2006). Computer Games as Playground and Stage [eventplace: Perth, Australia]. *Proceedings of the 2006 International Conference on Game Research and Development*, 62–68.

Zagal, J. P., Rick, J., & Hsi, I. (2006). Collaborative games: Lessons learned from board games. *Simulation & Gaming*, *37*(1), 24–40. https://doi.org/10.1177/1046878105282279

Zavala-Ibarra, I., & Favela, J. (2012). Ambient Videogames for Health Monitoring in Older Adults. *2012 Eighth International Conference on Intelligent Environments*, 27–33. https://doi.org/10.1109/IE.2012.56

Zhou, Z., Márquez Segura, E., Duval, J., John, M., & Isbister, K. (2019). Astaire: A Collaborative Mixed Reality Dance Game for Collocated Players. *Proceedings of the Annual Symposium on Computer-Human Interaction in Play*, 5–18. https://doi.org/10.1145/3311350.3347152

Appendix A Social Media Recruitment Post



I am conducting a research study to understand how collaboration is affected in an asymmetric mixed reality experience, which means participants will be in the same shared virtual environment using different types of devices.

Participants sessions are 60 minutes in length. Participants must be over 18, be able to attend the session at Lethbridge College, have basic computer literacy, and English language proficiency.

If you are interested to learn more about the study and to express an interest in participating, visit www.mikemccready.ca, email mjm75@kent.ac.uk or send me a private message.

Appendix B Participant Recruitment Questionnaire

This questionnaire was completed on the participant's own time via computer, tablet, or smartphone. A link to this questionnaire was made available on the research study's website.

Some of the questions included in the questionnaire were used as potential exclusion criteria where health conditions may pose a risk to the potential participant.

Age Range (radio buttons)

- 18 - 24
- 25 - 34
- 35 - 44
- 45 - 54
- 55 - 64
- 65+

Gender (radio buttons)

- Male
- Female
- Non-binary
- Prefer to self-identify
- Other

How often do you play video games? (radio buttons)

- I don't play video games
- A few times a month

- A few times a week
- Daily
- Multiple times a day

What type of video games do you play on either mobile, console or computer (check all that apply) (checkboxes)

- First Person Shooter (eg. Call of Duty)
- Idle / Casual Games (eg. Candy Crush)
- Competitive Sports Games (eg. Rocket League)
- Puzzle Games (eg. Tetris)
- Racing Games (eg. Forza Motorsport 7)
- Role-playing Games (eg. Final Fantasy series)

Please select ALL activities you do on a mobile device (eg. smartphone, tablet). (checkboxes)

- Taking photos/videos
- Surfing the internet
- Online shopping
- Maps/directions
- Video calls
- Play games
- I don't have a mobile device
- Other

How many times have you used Virtual Reality (VR)? (radio buttons)

- 0 times
- 1 - 2 times

- 3 - 5 times
- 6 - 9 times
- 10+ times

How many times have you used Augmented Reality (AR)? (radio buttons)

- 0 times
- 1 - 2 times
- 3 - 5 times
- 6 - 9 times
- 10+ times

How easily do you get motion or car sick?

1	2	3	4	5	6	7
Never been sick before						Get motion sick very easy

I do not have a seizure disorder, epilepsy, or have ever had a seizure. (radio buttons)

- True
- False

I do not have a heart condition, heart arrhythmias, or suffer from hypertension. (radio buttons)

- True
- False

I do not have a vestibular (balance) disorder or medical conditions affecting balance. (radio buttons)

- True
- False

I haven't had a head injury or been diagnosed with a neurological disease in the past year. (radio buttons)

- True
- False

I am not pregnant or suspected of being pregnant. (radio buttons)

- True
- False

How do you assess your English proficiency? (radio buttons)

- Native or bilingual proficiency
- Full professional proficiency, or fluent
- Professional working proficiency, or intermediate
- Limited working proficiency, or lower intermediate
- Elementary proficiency, or beginner

Appendix C Participant Information Sheet

What is the purpose of the study?

Due to the current pandemic context, there has been a surge in interest in technology that allows people to connect, play, and collaborate, despite physical distance and restrictions. A technology area that has seen growth during the pandemic is multiplayer games. Immersive technologies such as virtual reality (VR1) and augmented reality (AR2) have also seen an increase in adoption, as people were looking for ways to connect during the lockdowns and beyond. Despite their immersive qualities, VR head mounted displays (HMDs) have also received criticism for their isolating characteristics, both socially and technologically and for the discomfort they sometimes induce. As a result of these limitations, VR research and design has started to look more and more into leveraging different systems for the design of novel interactions, which include bystanders and co-players. In this context, various types of asymmetries were considered from the asymmetry of player interfaces (rooted in cross-reality paradigms) to differences of how players interact with the game and the information they possess.

With this study, our aim is to address some of these existing gaps by developing an asymmetric VR game that connects remote VR, AR, and PC users in a shared virtual environment. This study may provide important insights and provide a foundation for developing a multi-user gaming experience that can scale and accommodate a variety of devices and number of participants.

Why have I been invited?

This research is looking for a minimum of 30 participants to take part in this study. You were invited because you are at least 18 years old and are able to travel to Lethbridge College.

Do I have to take part?

It is up to you to decide whether or not to take part. Your participation is entirely voluntary. If you do decide to take a part, you would be asked to sign a consent form prior to any further procedures.

You are free to withdraw from the research study at any time and without giving any reason. If you withdraw from the study prior to the anonymization of the data, your personal data will be destroyed. If you withdraw from the study after your data is anonymized, the anonymized data will remain part of the study, as it will not be possible to identify your data to remove it. In order to have your personal data removed from the study, you must withdraw prior to May 16, 2022.

Am I eligible to take part?

The following criteria need to be met in order to participate in the study:

- 18 years or older
- Fluent in English
- Have basic computer proficiency
- Have no condition or impairment that would affect your ability to participate
- Be able to attend a session at the Lethbridge College in Lethbridge, Alberta, Canada on either May 16 or May 17, 2022

What are the possible benefits of taking part?

We cannot promise that this study will provide any immediate benefits to you, however the information we get from this study will help to inform the research community on the effects of various devices on collaboration in a virtual environment. Many people enjoy participation in research, particularly expressing their views during in-depth interviews.

What are the possible disadvantages and risks of taking part?

For those participating with a VR or AR device, there may be some potential risks.

VR Risks

While participating in VR, you will be wearing a VR headset and headphones, which will totally block your view and understanding of position in the physical world. During this time, a facilitator will communicate to you through a microphone, which you'll be able to hear with your headphones. All obstructions such as cables and chairs will be cleared to minimize your physical risk. Additionally, a facilitator will monitor your physical movement and guide you if you're getting too close to an obstruction such as a wall or desk.

Although rare, some participants may experience VR sickness. This occurs when exposure to a virtual environment causes symptoms that are similar to motion sickness. The most common symptoms are general discomfort, headache, stomach awareness, nausea, vomiting, pallor, sweating, fatigue, drowsiness, disorientation, and apathy. If symptoms are severe, you will be instructed to remove the VR headset and will be removed from the study.

Prior to your session, your facilitator will provide you these two suggestions if you experience motion sickness:

- close your eyes for a few moments and then open them

- if the motion sickness is severe, take off your VR headset immediately and you will be removed from the study

AR Risks

While you will be able to see the physical world, you may lose track of your physical environment. This could result in walking into walls or other obstructions. All obstructions such as cables and chairs will be cleared to minimize your physical risk. Additionally, a facilitator will monitor your physical movement and guide you if you're getting too close to an obstruction such as a wall or desk.

What will happen to me if I take part?

You will be asked to attend one session at Lethbridge College. The session will last approximately 60 minutes.

The session will start with an Orientation Stage where instructions for the study and hardware usage will be provided. This stage will take 5 minutes.

Following the Orientation Stage you will be randomly assigned either a VR device, AR device, or desktop computer. You will then enter a shared virtual environment to collaborate and solve a series of challenges. This portion will take approximately 15 minutes. You will then be asked to complete a survey about the experience, which should take approximately 15 minutes.

At the conclusion of the survey, a short interview will be conducted about your overall experience. The interview will take approximately 15 minutes.

Will my taking part in this project be kept confidential?

All information obtained in this study will be handled in confidence by us.

As soon as the data is collected, the data will be stored in a secured university server. We will video record you while in the XR experience.. The camera will be placed in a position where non or minimum identifiable info can be gathered. From the collected video-recordings we will not be able to remove identifiable data, but these will be stored and anonymised so that no other personal identifiable info is connected to the video. The camera will not be left unattended or moved until the recordings have been transferred to a university server and removed from the camera. The interviews will be transcribed, coded and the results connected to a random ID and not personal identifiable information.. Screenshots from inside the virtual environment or quotes from interviews may be used, but these will also be anonymous. Once the video recordings are analyzed, they will be destroyed. All other anonymized data (observations, surveys, interviews) will remain with the research project.

To learn more about the University of Kent Privacy Notice, visit:
https://research.kent.ac.uk/ris-operations/privacy-notice

What will happen to the results of the study?

When the study is completed, we would analyse the data we collect and report the findings. It would be reported in an appropriate journal or presented at a conference. You will not be identified in any report or publication. If you wish to receive a copy of any reports resulting from the research, please ask us to include you in our mailing list.

Who are the researchers?

- Michael McCready (Chief Investigator) is a remote student in the MSc Digital Arts (by Research) program living in Lethbridge, Alberta, Canada.

- Dr. Alexandra Covaci (Supervisor) is a lecturer in Digital Arts and Technology and a researcher at the University of Kent.
- Dr. Luma Tabbaa (Supervisor) is a lecturer in Digital Arts and Technology and a researcher at the University of Kent.

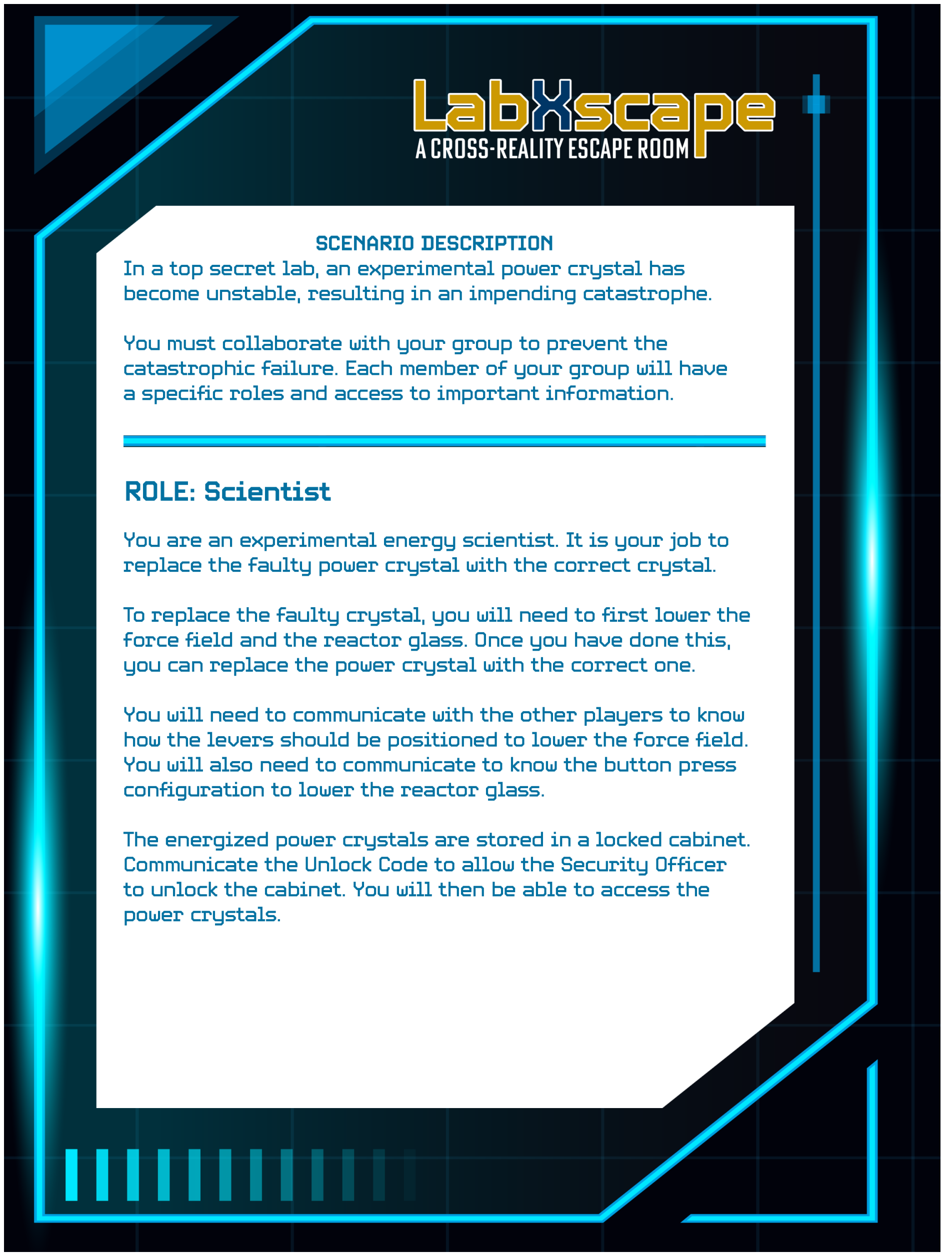
Appendix D Informed Consent Form

	Initial Boxes
I confirm I have read and understand the information for the above study which is stated in the Participant Information Sheet dated November 16, 2021. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily.	☐
I understand that the session will be video and audio recorded for analysis, and that as soon as this data is collected it will be stored on a secured server. No other identifiable information will be connected to this data. I understand that once the video recordings have been analyzed, they will be destroyed, but the anonymized observations will remain with the research study. I give permission for these recordings to occur.	☐
I understand that if I wish to receive the research results I will need to provide my email address. My email address will be stored separately from research data and will not identify my participation results. I give permission for my email address to be collected.	☐
I understand that my responses will be anonymised before analysis. I give permission for members of the research team to have access to my responses. I understand that the data could be used for publication.	☐
I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason. I understand that if I withdraw from the study after my data is anonymized, the anonymized data will remain part of the study, as it will not be possible to identify my data to remove it.	☐
I understand that my response will only be used for research purposes. I give permission for the research team to archive my anonymized responses for future research and make them available to other researchers in line with current data sharing practices.	☐
I agree to take part in the above research project.	☐

Participant: ________________ Signature: ________________ Date: __________

Lead Researcher ________________ Signature ________________ Date __________

Appendix E Player Scenario Cards



LabXscape
A CROSS-REALITY ESCAPE ROOM

SCENARIO DESCRIPTION

In a top secret lab, an experimental power crystal has become unstable, resulting in an impending catastrophe.

You must collaborate with your group to prevent the catastrophic failure. Each member of your group will have a specific roles and access to important information.

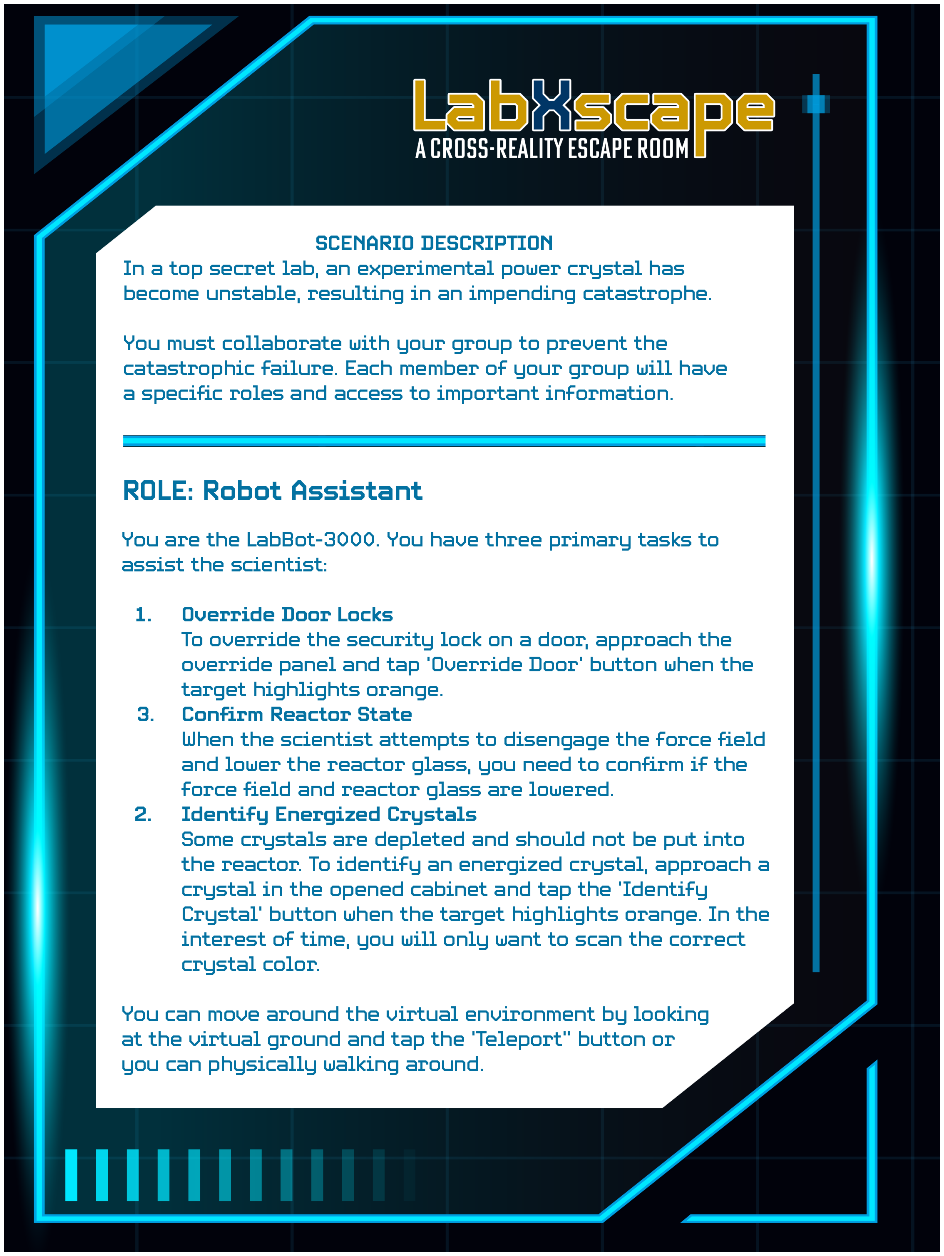
ROLE: Scientist

You are an experimental energy scientist. It is your job to replace the faulty power crystal with the correct crystal.

To replace the faulty crystal, you will need to first lower the force field and the reactor glass. Once you have done this, you can replace the power crystal with the correct one.

You will need to communicate with the other players to know how the levers should be positioned to lower the force field. You will also need to communicate to know the button press configuration to lower the reactor glass.

The energized power crystals are stored in a locked cabinet. Communicate the Unlock Code to allow the Security Officer to unlock the cabinet. You will then be able to access the power crystals.



LabXscape
A CROSS-REALITY ESCAPE ROOM

SCENARIO DESCRIPTION

In a top secret lab, an experimental power crystal has become unstable, resulting in an impending catastrophe.

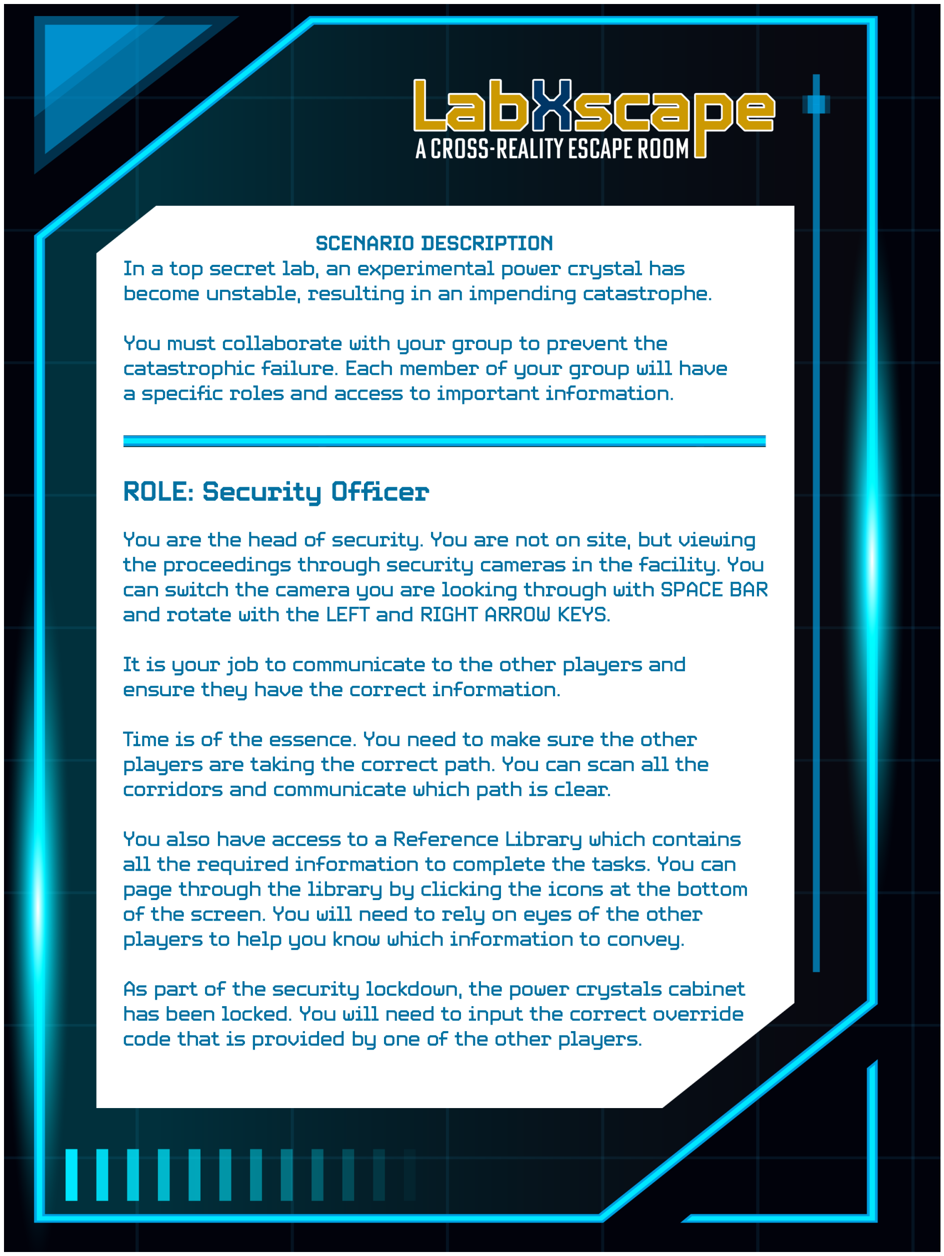
You must collaborate with your group to prevent the catastrophic failure. Each member of your group will have a specific roles and access to important information.

ROLE: Robot Assistant

You are the LabBot-3000. You have three primary tasks to assist the scientist:

1. **Override Door Locks**
   To override the security lock on a door, approach the override panel and tap 'Override Door' button when the target highlights orange.
3. **Confirm Reactor State**
   When the scientist attempts to disengage the force field and lower the reactor glass, you need to confirm if the force field and reactor glass are lowered.
2. **Identify Energized Crystals**
   Some crystals are depleted and should not be put into the reactor. To identify an energized crystal, approach a crystal in the opened cabinet and tap the 'Identify Crystal' button when the target highlights orange. In the interest of time, you will only want to scan the correct crystal color.

You can move around the virtual environment by looking at the virtual ground and tap the 'Teleport" button or you can physically walking around.



LabXscape
A CROSS-REALITY ESCAPE ROOM

SCENARIO DESCRIPTION

In a top secret lab, an experimental power crystal has become unstable, resulting in an impending catastrophe.

You must collaborate with your group to prevent the catastrophic failure. Each member of your group will have a specific roles and access to important information.

ROLE: Security Officer

You are the head of security. You are not on site, but viewing the proceedings through security cameras in the facility. You can switch the camera you are looking through with SPACE BAR and rotate with the LEFT and RIGHT ARROW KEYS.

It is your job to communicate to the other players and ensure they have the correct information.

Time is of the essence. You need to make sure the other players are taking the correct path. You can scan all the corridors and communicate which path is clear.

You also have access to a Reference Library which contains all the required information to complete the tasks. You can page through the library by clicking the icons at the bottom of the screen. You will need to rely on eyes of the other players to help you know which information to convey.

As part of the security lockdown, the power crystals cabinet has been locked. You will need to input the correct override code that is provided by one of the other players.

Appendix F GUESS-18 Survey Questions

The following items are from the shortened version of the Game User Experience Satisfaction Survey (Keebler et al., 2020).

I find the controls of the game to be straightforward.

1	2	3	4	5	6	7
Strongly Disagree						Strongly Agree

I find the game's interface to be easy to navigate.

1	2	3	4	5	6	7
Strongly Disagree						Strongly Agree

I am captivated by the game's story from the beginning.

1	2	3	4	5	6	7
Strongly Disagree						Strongly Agree

I enjoy the fantasy or story provided by the game.

1	2	3	4	5	6	7
Strongly Disagree						Strongly Agree

I feel detached from the outside world while playing the game.

1	2	3	4	5	6	7
Strongly Disagree						Strongly Agree

I do not care to check events that are happening in the real world during the game.

1	2	3	4	5	6	7
Strongly Disagree						Strongly Agree

I think the game is fun.

1	2	3	4	5	6	7
Strongly Disagree						Strongly Agree

I feel bored while playing the game.

1	2	3	4	5	6	7
Strongly Disagree						Strongly Agree

I feel the game allows me to be imaginative.

1	2	3	4	5	6	7
Strongly Disagree						Strongly Agree

I feel creative while playing the game.

1	2	3	4	5	6	7
Strongly Disagree						Strongly Agree

I enjoy the sound effects in the game.

1	2	3	4	5	6	7

Strongly Disagree ... Strongly Agree

I feel the game's audio (e.g., sound effects, music) enhances my gaming experience.

1	2	3	4	5	6	7

Strongly Disagree ... Strongly Agree

I am very focused on my own performance while playing the game.

1	2	3	4	5	6	7

Strongly Disagree ... Strongly Agree

I want to do as well as possible during the game.

1	2	3	4	5	6	7

Strongly Disagree ... Strongly Agree

I find the game supports social interaction (e.g., chat) between players.

1	2	3	4	5	6	7

Strongly Disagree ... Strongly Agree

I like to play this game with other players.

1	2	3	4	5	6	7
Strongly Disagree						Strongly Agree

I enjoy the game's graphics.

1	2	3	4	5	6	7
Strongly Disagree						Strongly Agree

I think the game is visually appealing.

1	2	3	4	5	6	7
Strongly Disagree						Strongly Agree

Appendix G Multimodal Presence Scale (MPS)

The following items are the social presence items of the Multimodal Presence Scale (Makransky et al., 2017).

I felt like I was in the presence of another person in the virtual environment.

1	2	3	4	5
Strongly Disagree				Strongly Agree

I felt that the people in the virtual environment were aware of my presence.

1	2	3	4	5
Strongly Disagree				Strongly Agree

The people in the virtual environment appeared to be sentient (conscious and alive) to me.

1	2	3	4	5
Strongly Disagree				Strongly Agree

During the simulation there were times where the computer interface seemed to disappear, and I felt like I was working directly with another person.

1	2	3	4	5
Strongly Disagree				Strongly Agree

I had a sense that I was interacting with other people in the virtual environment, rather than a computer simulation.

1	2	3	4	5
Strongly Disagree				Strongly Agree

Appendix H Semi-structured Interview Questions

Collaboration / Communication

- So how would you describe your communication with the other players as contributing to your overall experience and team performance?
- How did you cooperate with the other players in the game? How did the device limitations and affordances contribute to your ability to cooperate?
- Can you describe your communication experience with other players who were remotely located?

Embodiment / Interaction

- When in the virtual environment did you feel a sense of "being there"? Can you describe how you felt?
- Can you describe your ability to control your character and interactions with items in the environment and how they contributed to your experience?
- How did your "avatar" contribute to your game experience?

Usability

- How did you find the ability to move and interact with the virtual environment?
- Were the controls clear and easy to figure out?
- What challenges (if any) did you encounter in the experience?