

University of Nottingham
UK | CHINA | MALAYSIA

Physiological Adaptive VR Horror Experiences

Thesis submitted to the University of Nottingham for the degree of **Doctor of Philosophy, 30th September 2025.**

Callum Berger

20306440

Supervised by

Paul Tennent
Jocelyn Spence
Horia Maior

Signature _____

Date _____ / _____ / _____

Abstract

Fear appears in the art of virtually every culture, and more recently in the culture of virtual art. In many cultures, a specific type of fear, horror, has emerged as a genre of its own that evolves alongside media technologies, from Ancient Greek and Mesopotamian stories, to Gothic literature and early cinema, to video games and, more recently, virtual reality. Horror stories' emphasis on creating fear, immersion, and atmosphere makes them well-suited for experimentation in virtual reality, where presence and embodiment can heighten emotional intensity. Yet fear is profoundly subjective, and what terrifies one audience member may have little effect on another. This subjectivity presents both a challenge and an opportunity. Adaptive systems that respond to an individual's emotional state could address this subjectivity, offering more impactful horror experiences which better map to the intentions of the storyteller.

This thesis investigates the recognition and application of fear in adaptive virtual reality horror to understand how physiological measures, namely functional near-infrared spectroscopy, can be used to detect inferences of fear and how these measures can inform adaptive storytelling. In doing so, the thesis adopts a hybrid methodological approach that combines empirical experimentation, practice-based co-creation, and experimental design and deployment. First, an empirical study tested the use of functional

near-infrared spectroscopy for detecting fear in virtual reality, identifying activation in the left dorsolateral prefrontal cortex (the area established by neuroscientists to correspond with feelings of fear) during fearful conditions compared to calm conditions. Second, structured interviews with horror filmmakers supported the development of an adaptive toolkit, abstracting key factors and highlighting how audiovisual elements, such as lighting, sound, and atmosphere, could be manipulated to modulate fear while maintaining narrative coherence. Third, I applied these insights in the co-creation of an adaptive virtual reality horror experience, "A Place for Everyone", developed in collaboration with industry partner and film production company, AlbinoMosquito. Then that experience was evaluated with participants using mixed-methods, combining physiological measures (functional near-infrared spectroscopy and galvanic skin response), self-reports, and qualitative feedback to assess the effectiveness of adaptation. Overall, participants reported increased fear, immersion, and involvement in adaptive conditions. I then synthesise the results of all three studies to draw out key themes around adaptation, which are: Recognition of fear, application of fear in adaptive storytelling, implications for creative practitioners, ethical and governance considerations, and future directions for fear and adaptation.

This thesis contributes in three ways: first, by demonstrating that functional near-infrared spectroscopy can be used to detect the presence of fear-related brain activity in virtual reality; second, by co-designing with filmmakers a practical adaptive toolkit for applying this knowledge; and third, by implementing and evaluating an adaptive virtual reality horror experience that successfully modulates fear intensity thus demonstrating the efficacy of this approach in a real world practice setting.

Acknowledgements

This thesis has both tested my will and patience to get through 4 years of consecutive work, but has also rewarded me with amazing opportunities and friendships that I would never have made otherwise.

Firstly, I would like to thank my primary supervisor, Paul Tennent, who led me into the PhD and proceeded to guide me throughout, providing invaluable support and insight to get me to the end. I also wish to thank my other supervisors, Horia Maior and Sarah Martindale, and a special thank you to Jocelyn Spence, who was never afraid to tell me how it is and push me to be a better writer. I also thank Max Wilson, Aleksandra Landowska and the rest of the Brain Team, whose brain skills made the brain analysis a much better process.

I wish to thank both Richard and Rachel Ramchurn from AlbinoMosquito, whose friendship and support allowed this thesis to become what it was and without whom *A Place for Everyone* would have never been possible. An additional thank you to Gary Naylor, Sumit Sarkar, and all the cast and crew who also helped on *A Place for Everyone*.

I would like to thank my sister, Cecilia Berger, who has always been a huge support in my life. My parents, Pippa Stevens-McDaid and Steve Berger, who have been a loving support and encouragement throughout. Finally, I wish to thank Jess Clifford, whose support and encouragement during the final stages helped me see this thesis through.

Acronyms

AI artificial intelligence

AR augmented reality

AR-IRLS auto-regressive iteratively reweighted least squares

ARET augmented reality exposure therapy

AUC area under the curve

BAA block average analysis

BCI brain-computer interfaces

BCI-VR brain computer interface-VR

DLPFC dorsolateral prefrontal cortex

EDA electrodermal activity

EEG electroencephalogram

fMRI functional magnetic resonance imaging

fNIRS functional near-infrared spectroscopy

GLM general linear model

GLMM general linear mixed model

GSR galvanic skin response

HCI human-computer interaction

HMD head-mounted display

HR heart rate

HRV heart rate variability

MOCAP motion and facial capture

OBM object-based media

POV point of view

RtD research through design

SCR skin conductance response

SFX practical effects

SR slope regression

TDDR temporal derivative distribution repair

VE virtual environment

VFX visual effects

VR virtual reality

VRET virtual reality exposure therapy

Contents

Abstract **i**

Acknowledgements **iii**

List of Tables **xi**

List of Figures **xii**

Abbreviations **1**

Chapter 1 Introduction **1**

1.1 Context and Motivation 2

1.2 Research Problem and Aims 5

1.3 Methodological Approach 7

1.4 Overview of the Thesis 9

1.5 Contributions of the Thesis 10

Chapter 2 Literature Review **12**

2.1 Introduction 13

2.2 Defining Terms 14

2.3 The Physiology of Fear 23

2.4 fNIRS for Processing Fear 36

2.5 Fear Within Horror Film, Games, and Virtual Reality 39

2.6 HCI Methodology for Horror Experience Design 55

2.7 Combining Physiology and the Horror Genre for Adaptation 61

2.8 Summary of the Literature 64

Chapter 3 Methodology **66**

3.1 Research Philosophy and Methodological Framework 66

3.2 Study 1: Neurophysiological Experiment on Fear 71

3.3 Study 2: Interviews with Horror Directors 73
3.4 Developing the Adaptive Toolkit 74
3.5 Designing and Developing A Place for Everyone 75
3.6 Study 3a: Evaluation of A Place For Everyone: In the Wild Study 76
3.7 Study 3b: Evaluation of A Place for Everyone: Controlled Lab Study 77
3.8 Synthesising Results and Identifying Contributions 78
3.9 Ethical Considerations 79
3.10 Limitations of the Methodological Approach 81

Chapter 4 Study 1: Neurophysiological Experiment on Fear 82

4.1 Introduction 82
4.2 Methodology 84
4.3 Results 94
4.4 Discussion 101
4.5 Limitations and Future Directions 107
4.6 Conclusion 108

Chapter 5 Study 2: Defining the Horror for Adaptation - Horror Filmmaker Interviews 110

5.1 Introduction 110
5.2 Methodology 111
5.3 Introducing the Filmmakers 114
5.4 Results 117
5.5 Discussion 138
5.6 Conclusion 143

Chapter 6 A Place for Everyone - Design, Filming, and Adaptive Implementation 144

6.1 Introduction 144
6.2 Planning, Designing, and Filming the Experience 147
6.3 Individual Scene Breakdown 163
6.4 Implementation Post Filming 192
6.5 Reflection on Co-creating A Place for Everyone 201
6.6 Adaptive System Development and Integration 202
Chapter 7 A Place for Everyone - Evaluation 210
7.1 Introduction 210
7.2 Study 3a: Evaluation of A Place For Everyone: In the Wild 211
7.3 Study 3b: Evaluation of A Place for Everyone: Controlled Lab Study 220
Chapter 8 Discussion 263
8.1 Recognition of Fear 264
8.2 Application of Fear in Adaptive Storytelling 276
8.3 Implications for Creative Practitioners 284
8.4 Ethical and Governance Considerations 286
8.5 Future Directions for Fear and Adaptation 289
8.6 Bringing the Discussion Together 294
Chapter 9 Conclusion 295
9.1 Research Question 1 295
9.2 Research Question 2 296
9.3 Research Question 3 297
9.4 Research Question 4 298
9.5 The future of Adaptation 299
9.6 Core Contributions 301
Bibliography 303
Appendices 349

Appendix A Study 1: Neurophysiological Experiment on Fear 350

A.1 Ethics Forms 350

A.2 Questionnaire Data 356

Appendix B Study 2: Defining the Horror for Adaptation - Horror Filmmaker Interviews 357

B.1 Ethics Forms 357

B.2 Questionnaire Data 363

B.3 Horror Filmmaker Interview Questions 363

Appendix C Study 3a: Evaluation of A Place For Everyone: In the Wild 366

C.1 Ethics Forms 366

C.2 Questionnaire Data 373

C.3 A Place for Everyone - In Situ Questionnaire 373

Appendix D Study 3b: Evaluation of A Place for Everyone: Controlled Lab Study 374

D.1 Ethics Forms 374

D.2 Questionnaire Data 381

D.3 A Place for Everyone - Controlled Lab Questionnaire 381

D.4 A Place for Everyone - Presence Questionnaire 382

D.5 Practitioner Guide to Implementing the Adaptive Horror Toolkit 383

List of Tables

4.1 T-test results from the aggregated subjective data paired based on conditions. 97

4.2 Statistically significant functional near-infrared spectroscopy (fNIRS) results for 180 seconds analysis when comparing both the calm and fear conditions within the sector D2 - S8. There is a statistical significance for HbR in Calm and HbO in fear. 99

5.1 A representation of the workflow used for thematic analysis. Each phase describes what was completed for that phase, including information on the number of codes or themes available at the end of the phase 112

5.2 Initial grouping of thematic analysis codes into themes . . . 113

5.3 Final themes for thematic analysis 113

5.4 Key components of the adaptive toolkit codeveloped with horror filmmakers 142

6.1 Refugee Key Moments 165

6.2 Camp Key Moments 170

6.3 Plants Key Moments 174

6.4 Raid Key Moments 178

6.5 Processing Key Moments 183

6.6 Supper Key Moments 188

7.1 Condition Assignments Per Scene Across 6 Variations 225

7.2 Descriptive Statistics of Self-reported Calibration Data for Each Condition 233
7.3 Pairwise Comparisons of Self-reported Calibration Data Between Videos Using Wilcoxon Signed-Rank Tests 234
7.4 GSR metrics across different conditions. 235
7.5 Summary of statistical results comparing galvanic skin response (GSR) metrics across conditions Rest, B, C, J, G. p-values are Holm-corrected. 235
7.6 Descriptive Statistics For Post-scene Subjective Questions by Scene and Condition 237
7.7 Significant Mann–Whitney U Test Results ($p < 0.05$) for Self-reported Ratings comparing two conditions at a time per scene 238
7.8 Summary of significant Mann-Whitney U test results comparing key moments across conditions, two at a time 243
7.9 GSR Mean, Peak, and SCR Count by Scene and Condition . 244
7.10 Mean GSR, Peak GSR, and SCR Count unpaired t-tests per condition, per scene with Large Effect Sizes (Cohen's $d \geq 0.8$ or Cohen's $d \leq -0.8$) and/or significance P < 0.05 246
7.11 Significant Spearman's correlations ($p < 0.05$) comparing Mean GSR, Peak GSR, and SCR Count against self-reported ratings per condition, per scene 246
7.12 Significant Spearman's correlations ($p < 0.05$) comparing AUC and Peak HbO/HbR against self-reported ratings per condition, per scene 248

List of Figures

2.1 Russell's Circumplex Model of Affect (Guthrie Yarwood, 2022), pleasant refers to valence and activation refers to arousal. Fear can be seen within the top left quadrant amongst anger and disgust. 18

4.1 Examples of the fear and calm videos. (a) shows a low-lighting fear condition, and (b) shows a relaxing beach scene from one of the calm conditions. 86

4.2 Octamon setup using 8 light sources (S1 - S8) and 2 detectors (D1 - D2) with 2 short separation channels (S4 and S6). . . 91

4.3 The Self-Assessment Mannequin used within the VE. The top row refers to valence, the second row refers to arousal, and the bottom row refers to dominance. 92

4.4 Results of the subjective feedback data analysis aggregating each condition per participant. Left to right per condition shows emotion effectiveness, motion sickness, valence, arousal, and dominance. The error bars extending from the boxplot represent the first and third quartiles to the smallest or largest data points, respectively, within 1.5 times the interquartile range. This provides a visualisation of the data's spread, with outliers appearing as separate data points. . . . 95

4.5 A box plot of the paired subjective data based on the conditions. Overall, the subjective results for the calm condition were, on average, higher than the fear condition results. The error bars extending from the box plot represent the first and third quartiles to the smallest or largest data points, respectively, within 1.5 times the interquartile range. This provides a visualisation of the data's spread, with outliers appearing as separate data points. 98

4.6 Results of the contrast analysis for sector D2 - S8 showing a comparison of functional near-infrared spectroscopy (fNIRS) data during the transition from a calm condition to fear conditions. Solid lines within the same area on both HbO and HbR represent a significant channel (source-detector pairs) with beta values (q ¡ 0.05) after adjusting for multiple comparisons using FDR correction. Significant differences were observed in D2 - S8 (left DLPFC). 99

4.7 Results of the Spearman correlation coefficient and P values (highlighted in green for statistically significant results) comparing functional near-infrared spectroscopy (fNIRS) (HbO and HbR) beta values per participant alongside the subjective feedback per participant. The results of interest for fear are highlighted in orange. A positive correlation can be seen for Fear - HbO alongside Fear - Emotion and Fear - Arousal, and a negative correlation for Fear - HbO and Fear - Valence. Conversely, a negative correlation can be seen for Fear - HbR alongside Fear - Emotion and Fear - Arousal and a positive correlation for Fear - HbR and Fear - Valence. Referring now to P values, looking at Fear - HbO and Fear - HbR, there is no significance for any of the subjective data. 100

6.1 An example setup for volumetric capture from the viewpoint of the user. POV refers to the viewpoint of the user. C1, C2, and C3 are the cameras used for capture. P1 and P2 are the cameras used for pairing. A1, A2, A3, and A4 are the actors within the scene. 155
6.2 An example of a fear trajectory for the scene Camp. Up arrows indicate an activation of adaptation and intended increase in fear intensity, down arrows indicate a reduction and/or removal of adaptation to reduce fear intensity. 158
6.3 Static Shot of the Refugee Scene 164
6.4 Refugee Canonical and Combined Fear Trajectory 166
6.5 Refugee Adaptation Chart 166
6.6 Static Shot of the Camp Scene 169
6.7 Camp Canonical and Combined Fear Trajectory 171
6.8 Camp Adaptation Chart 171
6.9 Static Shot of the Plants Scene 174
6.10 Plants Canonical and Combined Fear Trajectory 175
6.11 Plants Adaptation Chart 175
6.12 Static Shot of the Raid Scene 178
6.13 Raid Canonical and Combined Fear Trajectory 179
6.14 Raid Adaptation Chart 179
6.15 Static Shot of the Processing Scene 182
6.16 Processing Canonical and Combined Fear Trajectory 183
6.17 Processing Adaptation Chart 184
6.18 Static Shot of the Supper Scene 187
6.19 Supper Canonical and Combined Fear Trajectory 189
6.20 Supper Adaptation Chart 189
6.21 Static Shot of the Hub Scene 192
6.22 Hand drawn blueprints for the scene Refugee 193

6.23 Hand drawn blueprints for the scene Camp 194
6.24 Hand drawn blueprints for the scene Plants 195
6.25 Hand drawn blueprints for the scene Raid 196
6.26 Hand drawn blueprints for the scene Processing 197
6.27 Hand drawn blueprints for the scene Supper 198
6.28 The old visuals from the scene Refugee 199
6.29 The new visuals from the scene Refugee 200
6.30 A flow chart representing the flow of functional near-infrared spectroscopy (fNIRS) data from the Octamon brain scanner to the Unity adaptive system within *A Place for Everyone*. . 206

7.1 An example of what the participant fear trajectory mapping may look like for the scene Refugee. This is not an actual participant mapping 228
7.2 Boxplot of Subjective Fear Ratings per Condition. The conditions are: Girl running (G), jump scare (J), bedroom (B), and chainsaw (C) 234
7.3 Mean and median results for the participant presence questionnaire 239
7.4 Mapping of the Refugee participant trajectories combining adaptation, high fear, and low fear participants to visualise the averages of each condition 240
7.5 Mapping of the Camp participant trajectories combining adaptation, high fear, and low fear participants to visualise the averages of each condition 240
7.6 Mapping of the Plants participant trajectories combining adaptation, high fear, and low fear participants to visualise the averages of each condition 241

7.7 Mapping of the Raid participant trajectories combining adaptation, high fear, and low fear participants to visualise the averages of each condition 241
7.8 Mapping of the Processing participant trajectories combining adaptation, high fear, and low fear participants to visualise the averages of each condition 242
7.9 Mapping of the Supper participant trajectories combining adaptation, high fear, and low fear participants to visualise the averages of each condition 242
7.10 Comparison of planned fear trajectory (left) and participant trajectories per condition (right) for the scene Camp 243

A.1 The Self-Assessment Mannequin used within the VE. The top row refers to valence, the second row refers to arousal, and the bottom row refers to dominance. 356

Chapter 1

Introduction

1.1 Context and Motivation

As humans, we have long been fascinated by horror stories. They allow us to safely explore emotions and feelings that in everyday life we might avoid. Fear appears in the art of virtually every culture, and in many traditions horror has emerged as a genre in its own right, evolving alongside media technologies. From Ancient Greek tragedies and Mesopotamiam myths, to Gothic literature, early cinema, video games, and now virtual reality (VR), horror has continually adapted to the expressive tools available at the time. Significant works within the horror genre can be dated back to around the 18th century, defining what was then known as Gothic horror (Bloom, 2017). The use of gothic horror by authors such as Edgar Allen Poe and H. P. Lovecraft helped define a literary genre rooted in atmosphere, dread, and the supernatural. H. P. Lovecraft notes Edgar Allen Poe as being a huge inspiration for his work, going beyond horror writers of his time (Wisker, 2006). The works of both authors established core tropes, such as dark settings, supernatural threats, and psychological unease, which continue to underpin the horror genre today.

The emergence of cinema in the late nineteenth and early twentieth centuries utilised these tropes into a new form of expressive media, with early films such as *Nosferatu* (F. W. Murnau, 1922) and *Frankenstein* (James Whale, 1931) creating visual examples that continue to inform the horror genre (Skal, 1993). Over the years, horror has proven its flexibility as a genre with a huge list of subgenres, shifting from alien horror to asylum, slasher, psychological, serial killer, found-footage, ghost, and many more (Kaay and Kaay, 2016). Changes in the genre reflect broader social anxieties, from civil rights movements to technology surveillance (Cherry, 2009).

Alongside cinema, horror has also thrived in interactive media, particularly in video games. Early *survival horror* titles, such as Haunted House (Orbit Studio, 1982) and Alone in the Dark (Infogrames, 1992), established how gameplay mechanics could reinforce vulnerability and tension (Krzywinska, 2002). More recent works, such as Amnesia: The Dark Descent (Frictional Games, 2010) and Outlast (Red Barrels, 2013), demonstrate how interactivity can enhance immersion, allowing the player to be both participant and victim.

With the rise of VR, horror has found another home to grow in. VR intensifies the genre by combining presence, spatial embodiment, and multisensory cues, creating experiences that feel immediate and unavoidable (Slater, 2009; Madsen, 2016). Many of the earliest widely discussed VR applications from the newer generation of VR headsets were horror experiences, such as Affected: The Manor (Fallen Planet Studios, 2016) and Dreadhalls (White Door Games, 2016), highlighting the genre's natural compatibility with immersive technologies.

VR is an emerging medium that provides a full, visually and audibly immersive experience. Its encapsulation of a user's view places them in a digital and controllable environment, providing an egocentric viewpoint where head movements control the camera. Despite early commercial failures like the Virtual Boy, VR headsets, such as the Oculus Rift DK1 and the PlayStation VR in 2016, launched the market into significant growth (Statista, 2025) driven by both hardware improvements and a growing catalogue of VR-specific experiences. More recently, advances in cheaper high-powered standalone devices, such as the Meta Quest series (Meta, 2023) and Apple Vision Pro (Apple, 2024), have further increased accessibility (for those with the financial means) and broadened the potential applications of VR across entertainment, education, and health. Horror's natural

compatibility with VR, through reliance on presence, immersion, and sensory manipulation, continues to position it as an impactful medium for innovation. Just as horror has historically evolved alongside new media technologies, VR provides the latest platform for innovation in how fear is elicited and experienced. Affective adaptation extends horror, enabling experiences to respond dynamically to individual audience members.

Affective adaptation is an approach used to alter the interaction of an experience or game based on the user's behaviour. These behaviours can be defined as the user's actions, signals or elicited emotional states, which are translated into dynamic feedback data to modify and adapt the experience or game accordingly. Early forms of affective adaptation emerged around 1997, initially viewed as a gimmick (Mark et al., 2005) before being adopted more formally and applied in various educational and entertainment contexts (Bontchev and Vassileva, 2017; Zaib and Yamamura, 2022; Demarque and Lima, 2013; de Lima et al., 2022). The combination of VR and affective adaptation opens opportunities for engaging experiences that can dynamically adapt based on a user's physiology. Measuring physiology in a virtual environment (VE) has become more prominent in research in recent years, demonstrating the possibility of affective adaptation in VR (Martens et al., 2019; Rieder et al., 2017; Angelini et al., 2022).

Applying affective adaptation in horror presents the opportunity to alter a successful genre in new, expressive ways, but poses a series of challenges in doing so. The primary response of horror is fear, but to understand how to adapt fear, we must first establish a definition of what fear is. Through over a century's worth of research, starting from Charles Darwin talking about emotions as "separate discrete entities, or modules" (Ekman, 2009), a clear definition of emotions has been up for debate. Psychologist Paul Ekman states that there are a series of basic emotions grouped by

their unique features, whilst also all having a series of characteristics in common with other emotions. These basic emotions are fear, surprise, anger, disgust, sadness, and joy (Ekman, 1999). This approach is supported by other psychologists (Oatley and Johnson-Laird, 1996; Tomkins, 1962; Izard, 1994). However, some disagree with the idea of basic emotions, finding them to be limiting when looking at all cognitive states of mind (Griffiths, 1998). Although the debate on emotions produces no definitive result on what fear is, the support for Ekman's approach (Hutto et al., 2018) provides an academic grounding for defining fear as a basic emotion within this thesis.

Fear is subjective, meaning that for each individual, what may produce fear in one may not produce fear in another (Baldini et al., 2022). This can cause mixed reactions to horror media, as some audiences may be scared, whilst others are not, ultimately producing mixed responses. Adaptation may change this through dynamically altering the fear in the experience to respond to these individual differences. Through understanding the fear of an individual, the intensity of horror can be modulated according to an individual's physiology to find a manageable level of fear. This thesis aims to advance scientific understanding in fear recognition and adaptation, whilst offering creative and industry impact through the design and development of an adaptive system and using this to design, develop, deploy, assess, and analyse a creative horror experience in practice.

1.2 Research Problem and Aims

The following outlines the research questions to be addressed within the thesis:

1. How can we understand fear from fNIRS data and turn this into usable data that could adapt an experience in real-time?

2. How can we create an adaptive fear-based narrative within VR that modulates fearful experiences for each user?

3. How could media professionals utilise a toolkit for creating adaptive experiences and engage audiences with that content?

4. What are the broader generalisations that can be made about emotionally adaptive experiences?

To answer these questions, a series of studies were conducted. For RQ 1, I investigated how fear can be recognised from brain signals, specifically using functional near-infrared spectroscopy (fNIRS), comparing conditions of fear and calm to identify an area of activation in the prefrontal cortex. For RQ 2, I conducted 7 structured interviews with horror filmmakers to co-design a toolkit for adaptive horror filmmaking. For RQ 3, I co-designed and developed an adaptive experience, titled *A Place for Everyone*, alongside my industry partner and practicing filmmaker, AlbinoMosquito. The experience was evaluated through a qualitative, exploratory, and lightweight review of the public experience, as well as a mixed-methods and experimental within-subject design, to understand the physiological and participant responses to adaptation and non-adaptation. For RQ 4, I discuss the thesis findings, providing a broader perspective on the implications of this research for the creative, educational, and medical industries. This work is important for the development of adaptive media, pushing the boundaries and capabilities of current research in physiological understanding of fear and fear responses through fNIRS, as well as the application of this physiological data through a real-time adaptive experience.

1.3 Methodological Approach

The overarching methodological approach of this thesis follows a hybrid form of empirical mixed-methods research, co-creation, and experimental design and deployment. This approach was necessary because the research questions intersect both scientific and creative domains, from the reliable recognition of fear from fNIRS signals to the translation of this recognition into a real-world adaptive experience. Each study conducted as part of this thesis, therefore, employed its own methodology, contributing to a broader research through design (RtD) approach.

1.3.1 Design-Informed Hybrid approach

This thesis adopts a design-informed hybrid methodology that integrates empirical research with creative practice. For the first study conducted within this thesis, an empirical study was required to establish whether fear could be detected using fNIRS in a virtual environment. This provided the experimental validation needed for the foundational use of fear in adaptation. Following on, creative collaboration and co-creation were essential to situate these findings within the traditions of horror filmmaking, ensuring that adaptation was not only technically feasible but also narratively meaningful. Therefore, the hybrid approach combines:

- **Empirical emotion recognition study:** controlled experiment using fNIRS to identify neural responses to fearful stimuli in a virtual environment.
- **Practice-based co-creation:** structured interviews with horror filmmakers to develop an adaptive toolkit underpinned by their creative

practice.

- **Experimental deployment:** design and evaluation of *A Place for Everyone*, an adaptive virtual reality horror experience, tested with audiences.

This combination of methodologies reflects a RtD direction, in which new knowledge emerges through the making and evaluation of artefacts (Gaver, 2012), but is strengthened here by empirical validation of the underlying scientific claims. While I am not a designer, I am working with practitioners, which leads to design-informed research.

1.3.2 The Involvement of Horror Directors

Horror was chosen as the core genre for this research because of its prominence in both early and current cinema and interactive media, and its unique flexibility in consistently eliciting fear across different audiences and formats. Importantly, horror was also one of the earliest genres to find success in VR. Commercial releases such as *Affected: The Manor* and *Dreadhalls* demonstrated horror's natural compatibility with immersive technologies. Therefore, horror directors and practitioners should be consulted to offer valuable expertise. Interviews with horror filmmakers helped shape the design of the adaptive toolkit by identifying the "knobs and levers" that could be most effectively used within adaptation (e.g. lighting, sound, and atmosphere). Consulting with directors also identified issues of authorship, narrative coherence, and creative control. Their contributions would make certain that the adaptive system would align with typical genre conventions, utilising existing design approaches, to ensure that the thesis positions adaptation not only as a viable tool for neurosci-

entists and human-computer interaction (HCI) researchers, but also as a tool to be used within artistic expression.

1.3.3 Experimental Design and Deployment

The final component of the methodology was experimental deployment. *A Place for Everyone* was co-created with my industry partner and artist, AlbinoMosquito, and provided a case study for applying the adaptive toolkit. This project enabled the transition from theory to practice, producing an artefact that could be evaluated by participants. The evaluation combined physiological data collection (fNIRS and galvanic skin response (GSR)) with self-reported and qualitative feedback, adopting a mixed-methods approach to provide a rich data set. This design ensured that the evaluation garnered evidence from both a controlled lab environment and real-world testing of "A Place for Everyone".

Overall, the methodological approach of this thesis can be characterised as hybrid, interdisciplinary, and iterative. It moves between controlled lab studies and creative practice, reflecting the aim of producing both scientific and artistic contributions. This approach is particularly suited to the emerging field of affective adaptation (Zaib and Yamamura, 2022; de Lima et al., 2020, 2022; Demarque and Lima, 2013), where technical and creative applications must be balanced.

1.4 Overview of the Thesis

This thesis outlines the processes and research conducted to understand, design, build, and evaluate an adaptive VR horror experience. Therefore,

the thesis is organised as follows. Chapter 2 reviews the relevant existing literature on fear, including physiology of fear, the use of fNIRS for processing fear, and fear within different media. It also covers the field of HCI surrounding horror design and looks at the use of adaptation, including affective adaptation, in horror. This provides the theoretical and empirical foundation for the research. Chapter 4 presents the first empirical study, which tests the use of fNIRS to detect fear responses in a VR setting. Building on these findings, Chapter 5 reports on interviews with horror filmmakers, from which an adaptive toolkit was developed to support the creation of fear-based adaptive experience.

Chapter 6 then details the co-design and development of the adaptive VR horror experience *A Place for Everyone*. This chapter also details the use of canonical and personal trajectories of fear to dynamically align the personal experience to the canonical. followed by Chapter 7 where the experience is evaluated in both a controlled lab setting and a real-world setting with participants. These chapters demonstrated how the toolkit was applied in practice and how the adaptive system modulated fear intensity in real-time. Chapter 8 synthesises the literature and findings to discuss the recognition of fear, the application of fear in adaptive storytelling, implications for creative practitioners, and ethical and governance considerations. Finally, Chapter 9 concludes the thesis by reflecting on the research questions, looking towards the future of adaptation, and summarising the key contributions of the thesis.

1.5 Contributions of the Thesis

In this thesis I make the following contributions:

- **Empirical validation of fear recognition in VR:** I designed and conducted an experimental study to test whether fear could be detected using fNIRS in immserive environments. I demonstrate that fear-related brain activity can be reliably observed in the left dorsolateral prefrontal cortex (DLPFC), providing empirical evidence that fear can be inferred from neurophysiological signals in VR.

- **Development of an adaptive toolkit for horror:** I carried out structured interviews with horror filmmakers and co-created an adaptive toolkit that identifies practical strategies for embedding physiological adaptation into horror experiences. I show how this toolkit bridges creative practice with technical feasibility.

- **Real world, empirical evidence of the value of adaptation through the design and evaluation of an adaptive VR horror experience:** I designed, developed, and evaluated *A Place for Everyone* in collaboration with my industry partner, AlbinoMosquito. This work demonstrates, through both public deployment and a controlled lab study, that adaptive systems can increase fear intensity, immersion, and involvement for audiences in real-world settings.

Together, these contributions position adaptive emotion-driven media can be designed, tested, and applied in practice. Through this work I demonstrate its potential not only for creative industries but also for applications in education, training, and digital health.

Chapter 2

Literature Review

2.1 Introduction

This chapter aims to situate the thesis within existing research and establish the theoretical and empirical foundations for investigating fear recognition and adaptive experiences in VR. Because the project follows multidisciplinary practice, the literature reviewed here spans emotion theory, physiological measures of fear, the role of VR as a medium for eliciting fear and existing work on affective adaptation. The review does not attempt to be exhaustive across all of psychology or HCI, but instead focuses on areas most directly relevant to the research questions.

The chapter is organised into four parts. First, I examine psychological and physiological understandings of fear, with particular emphasis on debates around basic emotions and how fear has been understood in prior studies. Second, I review methods for measuring fear, highlighting fNIRS as the primary technique employed in this thesis and considering its strengths and limitations in comparison to other measures. Third, I turn to the various media utilised by the horror genre, noting VR as an emerging medium, drawing on both entertainment and research contexts to show how presence, embodiment, and immersion intensify the experience of fear. Finally, I consider prior research on adaptive systems, including affective computing, adaptive games, and experimental VR applications, to position my own work within this emerging field.

This structure reflects the interdisciplinary nature of this thesis. By linking emotion theory, measurement technologies, media contexts, and adaptive techniques, the review identifies both the opportunities and challenges for developing an fNIRS-based adaptive VR horror experience.

2.2 Defining Terms

Before approaching any application of fear, it is first important to understand how psychologists currently understand fear and how it can be detected by different technologies.

While there is a general consensus in the field that fear is connected to emotional states, the psychology literature reveals significant debate as to whether fear constitutes a "basic emotion" (Griffiths, 1998). "Basic emotions" were first defined by Paul Ekman in 1992 (Ekman, 1992) through having the characteristics of "rapid onset, short duration, unbidden occurrence, automatic appraisal, and coherence among responses". Within the past 40 years, psychologists have begun approaching a consensus with fear being one of these basic emotions, alongside surprise, anger, disgust, sadness and joy (Ekman, 1999; Oatley and Johnson-Laird, 1996). In the next section, I discuss the changes and current understandings of emotions and fear, as well as the research driven by psychologists that has guided what fear is to be within my thesis. I also discuss the literature around the terms phobia and horror and their connections to fear. Although phobia is not an objective of this thesis, a definition of the term can help in the understanding of fear and ensure a safe application of fear within the field of HCI for the use of entertainment. The definition for horror will help to understand later references to the genre and applications in entertainment.

2.2.1 Understanding Emotions and the Placement of Fear

The study and understanding of emotions as we know them today dates back to the 19th century. In the latter end of the 19th Century, Charles

Darwin wrote about emotions being "separate discrete entities, or modules" (Ekman, 2009). This was later contradicted by Wilhelm Wundt, a German physiologist, who saw emotions as "variations in dimensions or continua of pleasantness and activity or intensity" (Ekman, 2009). These two concepts have driven the understanding of emotions in psychology throughout the 20th century, with psychologists generally adopting one or the other.

One psychologist who draws from Darwin's theory is Paul Ekman, an American psychologist. Ekman has been a driving force for the study of "basic emotions" throughout the 20th Century within the field of psychology and continues to be cited to this day in works surrounding emotion recognition (Li et al., 2023; Alarcao and Fonseca, 2019). Although Ekman acknowledges the work of Wundt, he states that, through his research, Darwin's approach to emotions is correct (Ekman, 2009). Ekman's understanding of fear within the field of psychology places fear as a basic emotion alongside surprise, anger, disgust, sadness and joy. This basis is defined by the research of emotions having their unique features whilst also all having a series of characteristics in common with other emotions (Ekman, 1999). Fear itself is a response to a perceived threat, danger, or harm and causes changes to facial expression, such as raised eyebrows and widened eyes.

The idea of "basic emotions" and support of Darwin's work is shared amongst other psychologists such as Philip Johnson-Laird, Keith Oatley, Silvan Tomkins, and Carroll Izard (Oatley and Johnson-Laird, 1996; Tomkins, 1962; Izard, 1994) all of whom are well-cited researchers within psychology. Johnson-Laird and Oatley directly acknowledge Ekman's work within their theory of emotions (Oatley and Johnson-Laird, 1996).

That is not to say, however, that Ekman's approach is agreed upon by all, and due to the interdisciplinary nature of emotions, discussion of emo-

tions tends to overlap between the fields of philosophy and psychology. Philosopher Paul E. Griffiths, also established within psychology literature, critiques Ekman's approach in his interdisciplinary book titled *What Emotions Really Are: The Problem of Psychological Categories*, noting that the use of the term 'basic emotions' is too limiting when looking at all cognitive states of mind (Griffiths, 1998). He also mentions that Ekman's approach directly limits study subjects' choice of emotion by asking them to rate an emotion from a limited list. Griffiths does, however, acknowledge the validity of at least some of Ekman's work on fear, writing, "The experiments of Ekman and others show that people in all cultures respond in a similar way to things that frighten them".

There are some, however, who wish for Ekman's work on basic emotions to be dropped completely, such as philosophers and cognitive scientists Giovanna Colombetti and Rebekka Hufendiek (Colombetti, 2014; Hufendiek, 2015). These standpoints on emotions show that, within the last century, there is still debate as to how we define emotion. One paper published within the sector of theoretical and philosophical psychology acknowledges Griffiths's, Colombetti's, and Hufendiek's criticisms of Ekman's work, but argues against these criticisms, breaking them down in support of Ekman (Hutto et al., 2018). Overall, Ekman provides a well-established and definitive interpretation of fear that is supported by evidence. Because of this, I also refer to Ekman's definition of fear as a basic emotion, separate from that of happiness, sadness, anger, and disgust.

Ekman sees fear not only as a basic emotion but as a system (Ekman, 1999) where fear functions as an organised system composed of physiological, cognitive, and behavioural components. This system-based view of fear was used by Estonian-American neuroscientist and psychobiologist Jaak Panksepp (PARADISO, 2002). This understanding of fear as a sys-

tem envelops certain parts of the brain that, when considered as one, can establish an understanding of fear processing. Panksepp demonstrated that the main contributors to the processing of a fear response were through the amygdala and hypothalamus (PARADISO, 2002), a process that was originally believed to be through the cerebral cortex. This shifts the perception that fear is processed through slower, conscious cortical processing (cerebral cortex) to being processed instinctually for rapid response (amygdala and hypothalamus), highlighting its role as an essential survival mechanism.

Other definitions include that of psychologist Michael Fanselow's, who suggests fear as "the activation of a defensive motivational system referring to the behavioural response to a fearful stimulus" (S. Fanselow, 1984). When interacting with fearful stimuli, the respondent will behave in a way that is designed to defend and protect the individual, by limiting unnecessary behaviours and focusing on those that will provide aid, such as mobility. Fanselow's definition builds upon his previous work alongside psychologist Robert Bolles in their article: The Perceptual-Defensive-Recuperative Model of Fear and Pain (Bolles and Fanselow, 1980). This work provides a more extensive breakdown of how an individual limits behaviours to defend and protect themselves from a fearful stimulus.

Looking further into the responses to fear stimuli, psychologist Alfons Hamm et al. (Hamm et al., 1997) provide evidence of a startle reflex and avoidance behaviour to fearful stimuli as well as increased pulse and skin conductance (Hamm et al., 1989). Arne Öhman and Joaquim Soares provide additional evidence of increased skin conductance in response to fear stimuli (Öhman and Soares, 1994). The evidence provided above is also acknowledged by Ekman within his chapter *Basic Emotions* (Ekman, 1999). Each of these shows that for fear to occur, a threat has to be present, which causes a bodily response. This bodily response can be aligned with

what is known as the 'fight or flight' response originally defined by Walter Cannon (Cannon, 1915). This response involves an increased heart rate (HR) and sweating alongside bodily changes to prepare the body for 'fight or flight'.

So far, the psychology literature provides a useful grounding for HCI work involving fear: first, that it is a basic emotion, and second, that it is a system by which stimuli elicit certain responses. Looking at fear in comparison to other emotions, we can see some distinct characteristics. Psychologist James Russell provides a foundational paper where he introduces his *Circumplex Model of Affect* (Russell and Mehrabian, 1977), giving insight into the mapping of emotions along the dimensions of valence and arousal.

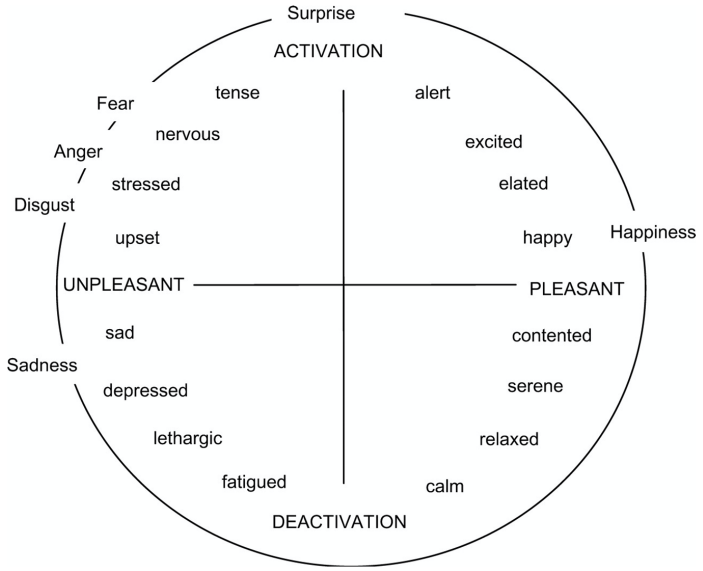


Figure 2.1: Russell's Circumplex Model of Affect (Guthrie Yarwood, 2022), pleasant refers to valence and activation refers to arousal. Fear can be seen within the top left quadrant amongst anger and disgust.

Russell's model places fear amongst the emotions anger, disgust, tense, nervous, stressed, and upset. These all sit in a position of low valence (unpleasant) with high arousal (activation), where varied levels of each define the specific emotion. Opposite emotions to these would include those in the low arousal but high valence region, such as calm, relaxed,

serene, and contented. This placement of fear ties in with Cannon's fight or flight response, as mentioned above, which expresses increased arousal (Cannon, 1915). This also aligns with Ekman's work on fear eliciting a bodily response. Applying Russell's model alongside Ekman's definition of fear provides a spectrum in which fear can sit.

Several alternative models of emotion exist that provide reasons for what causes the emotion of fear to arise. These models include William James and Carl Lange's theory of emotion from 1884 (James, 1884), as well as Stanley Schachter and Jerome Singer's cognitive appraisal theory (Schachter and Singer, 1962) and Joseph LeDoux's dual pathway model (LeDoux, 1998). James and Lange's theory presents emotions as a consequence of physiological change, which somewhat aligns with Ekman's work, but broadens emotions beyond 'basic emotions' as well as removing the idea of a continuum of emotions that Russel provides.

Schachter and Singer's theory focuses on emotions as a result of physiological arousal and cognitive appraisal, our interpretation of the stimulus context. Once again, this theory broadens emotions beyond 'basic emotions'; however, it does align well with Russel's use of valence and arousal. Finally, LeDoux's model posits emotional processing through two pathways: a fast, direct pathway and a slow, cognitive pathway. This supports Ekman's more biological and evolutionary approach to emotions, but doesn't align so well with Russel's psychological model, which can provide insight into more complex emotions, such as fear.

Each of these models provides varied definitions towards the appraisal of emotions; however, the combined approach of Ekman and Russel accommodates both physiological and dimensional aspects of emotions, with fixed basic emotions and the flexibility for context and variation. Therefore, Ek-

man's work alongside Russel's model provides the best way in the available psychology literature to underpin my use of the term fear within the scope of this thesis.

2.2.2 Fear and Phobia

Another term closely linked to fear is phobia. As previously mentioned, fear refers to the emotion and system triggered in response to a threat, active or imagined. Psychiatrist Isaac Marks defines phobia as a specific kind of fear that cannot be explained or voluntarily controlled (Marks, 1969), unlike standard fear, which is more rational and temporary. Further criteria for specific phobias have been detailed by the fifth edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-V) (American Psychiatric Association and American Psychiatric Association, 2013), stating that the fear is recognised through clinical assessment as out of proportion to the danger, as well as lasting for 6 months or more. These definitions imply the need for an elevated level of fear response to a stimulus beyond that of the basic emotion to be classified as a phobia. The hope for this thesis is to ensure that an experience can be altered, inciting more or less fear in an individual than they would experience in a linear film in or adjacent to the horror genre, but not to the "excessive" degree characteristic of phobias. Phobia, however, involves a much more intense level of fear, of which, for ethical, practical, and altruistic reasons, this work will attempt to avoid through transparency of content and potential triggers.

2.2.3 Fear and Horror

The final discussion of this section is horror, as described in the fields of both philosophy and film and media. Defining horror in terms of philosophy, philosopher Robert Solomon distinguishes real-life horror from fear and art-horror in *Real Horror*, a chapter in an edited volume titled *Dark Thoughts: Philosophic Reflections on Cinematic Horror*. As suggested by the titles, Solomon looks closely at the phenomenology of horror and its differentiation from fear and "art-horror" (i.e., horror films). The differentiation of horror comes from horror focusing on individuals being "horrified by a particular and more or less immediate event or object of perception". He goes on to mention how horror differs from fear, as horror is distanced from action, therefore not requiring an action-based response. This also differentiates horror from dread, anxiousness and suspense, which refer more to the anticipation of events (Solomon, 2004). Solomon explains that fear becomes horror once the fear causes an individual to become frozen in place, creating a sense of helplessness. Turning to art-horror, Solomon describes this as imitations of real-life horror, aimed to insight pleasure and a distinctive narrative where real-life horror lacks both.

The term art-horror was coined by film scholar and philosopher Noël Carroll in his book *The Philosophy of Horror* (Carroll, 2003). The term is used to describe a subgenre of horror film focused on the more artistic side of horror, rather than focusing more on the scare factor as seen in traditional horror. Carroll separates these aforementioned genres from natural horror, which refers to real-world horror as described by Solomon. As this thesis is aimed at eliciting and using fear, art-horror goes outside of the intended scope; therefore, I focus on the parent genre, horror. However, to understand horror as a genre, I must turn to the field of media and entertainment.

In the field of media and entertainment, the term horror is used to describe a genre of media that intends to induce fear in its audience. As a broad genre, however, it is complex to provide a concrete definition of horror. As outlined by Kevin Corstorphine, an author of gothic and horror literature, the definition of horror is elusive and has contributed to the growing genre and its creativity (Corstorphine, 2023). Although Corstorphine sees horror as an undefinable term, there are ways of providing meaning to horror through the use of the related emotional states "fear, suspense, terror and anxiety" which bridge insights from film studies to psychology (Schneider, 2004). Ash Law, award-winning game designer and author, however, aims to provide more concrete definitions of these terms about game design (Law, 2020). Law states that there are four types of fear: Unease, dread, terror, and horror. "Unease is the knowledge of something being wrong", "dread is the suspicion, unconfirmed, that something is wrong and is here", "terror is the sure knowledge that something terrible is imminent", and "horror is the revelation and meeting the danger". This definition of horror is relative to the definition provided by Solomon when Solomon mentions the need for a "particular and more or less immediate event or object of perception". By bridging the gap from psychology to media and entertainment, the definitions of Solomon and Law serve to be useful in understanding horror in the contexts of film and media. Horror is used to induce fear through unease, dread, and terror, with horror itself being "the revelation and meeting the danger". Therefore, I use these definitions within the thesis, and further references to horror will refer to horror as a genre, as opposed to the other terms, such as natural horror and art-horror.

This thesis will continue to use Ekman's basic emotions alongside Russel's circumplex model of affect to define fear, a basic emotion that causes physiological responses such as increased heart rate, within the dimensions of

low valence and high arousal. Additionally, Solomon and Law's definitions of horror are used to define horror as a genre, which aims to induce fear through unease, dread, and terror, with horror being the revelation and meeting of the danger. These definitions allow the project to focus on a specific emotion, helping to exclude confounding factors, and to pinpoint which physiological responses can best reveal changes in fearful states in the context of a VR media experience.

2.3 The Physiology of Fear

As discussed above, fear has been shown to create physiological changes that can be obvious, such as raised eyebrows and widened eyes (Ekman, 1992), or more internalised, such as increased HR and GSR (Hamm et al., 1989; Öhman and Soares, 1994). With a definition of fear, it's now important to establish how we can detect this fear within an individual. Retrieving a measurement of fear from physiological changes may not be consistently reliable. A study by Aue et al. looked into the effect of amygdala activation, autonomic responses, respiratory responses, and facial muscle activity on spider phobics alongside a control group (Aue et al., 2012). Phobic and non-phobic groups are a useful way to understand the fear response in individuals, as the phobic group should express a more intense response to fear detectable from physiological measures when exposed to the phobic stimulus. GSR and facial muscle activity over the brow region only showed responses within extreme levels of fear, whilst the left amygdala, HR, and facial muscle activity over the cheek region showed variations in fear intensity within more varied levels of fear. A similar study by Knopf and Pössel (Knopf and Pössel, 2009) looked at phobic and non-phobic women in response to a spider stimulus. The measures used were HR, GSR, eyebrow

muscle activity, and cortisol, a hormone related to stress and danger. On a group-level analysis, the phobic group had increased psychophysiological responses, more negative valence, and more positive arousal. However, as for individual analysis, most physiological ratings and subjective ratings had no uniqueness between groups.

The following section will look deeper into different methods for measuring physiological responses to fear. These are facial recognition, gait, HR, GSR, electroencephalogram (EEG), and fNIRS. Each of these methods is a prevalent measurement technique for emotion recognition and will be looked at for detecting fear-related responses. It is worth noting that direct emotion detection through physiological measures is not possible, but inferences of emotional states can be suggested from measures in relation to study conditions. Any reference to direct emotion detection refers to the inference of emotional states.

These physiological methods will also be looked at in the context of VE. Measuring physiological data within VEs has emerged as a prominent area of research in recent years (Martens et al., 2019; Rieder et al., 2017; Angelini et al., 2022). Gathering physiological data on users has helped researchers understand the impact of VE design on users' sense of presence, a key component within VEs (Slater, 2009). Utilising a VE creates benefits from the capabilities of providing more flexibility and freedom for creating environments when compared to real-world environments as seen in applications such as workforce training simulation (Carruth, 2017), virtual reality exposure therapy (VRET) (Gromer et al., 2019) and immersive storytelling (Shin, 2018). There are also results which show improvements in engagement. For example, observing changes in individuals within a state of meditation in a VE compared to a video showed significant improvements in student exam performance (Kaplan-Rakowski et al., 2021).

2.3.1 Fear with Facial Recognition and Gait

According to Psychologist Albert Mehrabian, in his book titled *Silent Messages*, roughly 93% of interpersonal communication is conveyed by nonverbal communication (Mehrabian, 1972). However, this figure specifically refers to situations of mismatch between verbal and non-verbal communication, such as an individual's words not matching their tone or body language. While the 93% figure only applies to inconsistent scenarios, it does highlight the importance of nonverbal cues for emotions like fear, which are often involuntary and deeply rooted in our physiology. A collection of such data can then provide insight into emotions within an interactive situation. A facial emotion recognition system developed and studied by electrical engineers and computer scientists, Damir Filko & Goran Martinović (Filko and Martinović, 2013), was tested to see if it was capable of automatic emotion detection through still images of facial regions, including fear. Fear, however, proved difficult. It received the worst results and was frequently unidentified. Filko and Martinović were not surprised, putting this difficulty down to the fact that "each individual copes with fear in his/her own way".

Another study on facial emotion recognition by Barman and Dutta (Barman and Dutta, 2019) used a series of artificial neural models for the classification of emotions. These emotions were anger, fear, disgust, sadness, happiness and surprise. Once again, fear was the most poorly classified. These studies show that fear, through facial emotion recognition, tends to be misinterpreted as another emotion. As put by Filko and Martinović, this could be due to the subjectivity of fear and the differences in how individuals cope through facial expression. Attempting facial emotion recognition through VR only becomes more complicated as a head-mounted display

(HMD) obscures parts of a user's face. One study by Ortmann et al. looked at facial emotion recognition in VR using the Meta Quest Pro VR HMD (Ortmann et al., 2024). Although there was some success, fear "was often not recognised" (Ortmann et al., 2024, see p. 5). With little evidence to support facial emotion recognition as a reliable method for detecting and therefore adapting to fear, it will not be considered further within this thesis.

Full-body motion capture is another potential for emotion detection. A study by Birch et al. looked at the identification of emotions from gait presented through video clips (Birch et al., 2016). This required observers to identify emotions based on video clips of walkers emulating a specific emotion. The emotions used were neutral, pride, happiness, fear, and anger. The results showed all five emotional states being identified accurately; however, "neutral, fear and anger were correctly identified on more occasions than pride and happiness". Another study by Venture et al. on emotion recognition through gait found similar results (Venture et al., 2014). They used two methods for emotion recognition: human observers and two computational models, both of which were tested on the same gait videos. The emotions analysed by the human observers were neutral, joy, anger, sadness, and fear. Each emotion was correctly perceived with an accuracy above 90%, except for joy, which was 75% or above. For the two computational models, fear was excluded due to the need for context, such as fear of something specific or a general feeling of fear. Further analysis is required to understand the context of fear before incorporating it into the models.

Looking towards emotion detection through gait analysis in VR, a user's gait is unlikely to be obscured by the user in VR, making it viable for a VR approach. One study looks at gait analysis for depression detection in VR (Shao et al., 2022), while another looks at the feasibility of using gait

analysis in VR to study fear of falling among participants with and without parkinsons (Gomaa et al., 2024). Beyond these, gait analysis of fear in VR remains limited. One potential issue of VR for gait analysis may arise if the VR experience involves little to no interaction or movement, such as a sit-down experience. When there is a lack of movement, analysis focuses more towards analysis of posture (Martis and Balasubramani, 2020), but again, finding research for fear detection through this method is limited. Combining the difficulty of computational fear detection through gait with the potential limitations of static VR experiences, gait does not currently provide promise for an adaptive experience and will not be considered further within this thesis.

2.3.2 Fear with Heart Rate and Galvanic Skin Response

HR detection provides valuable insights into physiological changes within a being's body by monitoring the electrical signals generated by the heart (Léger and Thivierge, 1988). These signals are closely linked to autonomic nervous system activity, which regulates blood pressure and breathing, and can reflect varying levels of arousal, making HR a useful metric for detecting emotional states, including fear. One notable advantage of HR as a form of biodata is its high temporal resolution, with methods capable of detecting changes between ¡1 ms to 10 ms (Chellakumar et al., 2005). Temporal resolution, in this context, refers to the speed at which physiological scanners can capture rapid changes in the body's responses, a useful factor in the accurate inference of fear-related states. Understanding the effects of HR with relation to fear, a study looks at the HR responses to fear conditioning in VR for high-symptom and low-symptom participants with

post-traumatic stress disorder (Roy et al., 2013). An elevated heart rate was found in the high-symptom group during the fear conditioning. These findings support those from Ekman even within a VR context.

HR, however, is not often measured alone. It is commonly paired with other physiological measures for further understanding of an individual's physiology. One of these measures is GSR. GSR uses a small electrical current to measure sweat gland activity and directly reflects the sympathetic nervous system activation, which is a series of nerves which activate the 'fight or flight' response. Therefore, an increase in sweat gland activity is expected by Cannon's definition of 'fight or flight' (Cannon, 1915).

A study combining the use of HR and GSR was able to detect different emotions with varied accuracy depending on the emotion detected (Rathod et al., 2016). The emotions used were normal, happy, sad, fear, and anger. Video clips were shown to participants to induce these emotions, and the bio-signals were then compared to those of facial recognition for accuracy detection. Emotions such as happiness and anger were detected at accuracy rates of 87% and 81.13%, respectively. More notably, however, is the lower detection of fear at an accuracy of 67%. Video clips that induced fear caused a "significant rise in the HR and gradual increase in skin conductance".

Further studies have also used the combination of HR and GSR. Fernández-Aguilar et al. conducted a film mood induction procedure to elicit emotions within a series of young and older adults (Fernández-Aguilar et al., 2019). The emotions examined are neutral, affection, amusement, anger, disgust, fear and sadness. Using support vector machines to classify the emotions, varied accuracy of each emotion was detected. Amusement reached 87.4% with anger receiving the lowest accuracy at 82.4%, and fear is between the

two with an accuracy of 84.5%. Comparing the two studies, there is a vast difference in fear detection accuracy. Both studies used audio-visual stimuli represented by short clips from films designed to induce a specific emotion. The first study (Rathod et al., 2016) produced an accuracy of 67% for fear, while study 2 (Fernández-Aguilar et al., 2019) produced an accuracy of 84.5%. Comparing sample sizes, study 1 had 6 participants with no specified age range, while study 2 had 80 participants with ages ranging between 16 and 26, with an additional 50 participants with ages ranging between 60 to 84. From these results, a larger sample size suggests an increase in the accuracy of fear. Additionally, with study 2 having a much larger sample size, these results provide more reliability and with a fear accuracy of 84.5%, there is validity for the recognition of fear from GSR and HR.

HR and GSR are not without their issues, however, as both are measures of arousal, they could be elevated through other high arousal emotions such as anger or amusement (Wu et al., 2019). These compounding emotions could interfere with fear as they all produce an increase in arousal. Understanding the specificity of these physiological responses relies on further clarity through means such as subjective feedback. Another important drawback of HR and GSR is motion artefacts, which degrade the data, leaving it noisy and difficult to use (Ismail et al., 2021; Weixuan Chen et al., 2015). This is particularly a problem in tasks that require movement, something that VR tends to involve. That is not to say these measures cannot be used in VR (Baldini et al., 2022; Marín-Morales et al., 2021), but that they should be taken into account if considered.

From studies on inference of emotion detection using both HR and GSR, it appears to be a useful approach to combine both biodata devices for increased accuracy and potency in detecting emotional states. However,

while they are quite effective in identifying an emotional response, some limitations affect their suitability for this thesis. Firstly, HR and GSR are limited by their sensitivity to motion artefacts, creating issues of validity when working with VR. Secondly, their measure of arousal causes difficulties when attempting to detect a specific emotion. Although these devices have shown efficacy in VR environments, their current limitations make them less viable for the specific application of this thesis. Future research could refine these approaches for broader usability; however, for this thesis, these methods are not sufficiently effective for detecting fear in an adaptive experience.

2.3.3 Fear with Electroencephalogram and Functional Near-Infrared Spectroscopy

Moving to the neurology of fear, the amygdala plays a key part in the emotional response. Research from 1992 (Davis, 1992) analysed conditioned responses to fear, while more recent research (Adolphs, 2013) has provided an overview of fear by analysing brain data using functional magnetic resonance imaging (fMRI), highlighting the amygdala's involvement in processing fearful stimuli. The amygdala, however, is not specific to just processing fear but also processes a range of emotions as well. One paper (Šimić, Tkalčić, Vukić, Mulc, Španić, Šagud, Olucha-Bordonau, Vukšić and R. Hof, 2021) shows that the amygdala "participates in the regulation of autonomic and endocrine functions, decision-making and adaptations of instinctive and motivational behaviours to changes in the environment through implicit associative learning". This quote emphasises the amygdala's individualised role in regulating responses and behaviours. Through the lens of HCI, it underscores the importance of understanding how users

may subconsciously respond to stimuli, a critical consideration when designing adaptive experiences. This research aligns with the concept of conditioned learning, where the amygdala plays a key role in modifying the behaviours an individual has toward fear. Two forms of mobile neuroimaging tools have shown promise in analysing fear-related activity. These are EEG and fNIRS.

EEG is a neuroimaging technique that measures the electrical signals within the neurons of the human cortex (Kirschstein and Köhling, 2009). Measuring these signals provides an understanding of activation in the brain in response to stimuli. Advantages of EEG come from its high temporal resolution; however, this comes at the cost of spatial resolution, reducing the ability to pinpoint neural activity as well as issues created by noise interference, such as movement artefacts and electrical interference (Chaddad et al., 2023). Despite these challenges, studies have shown insight into brain activity and neural responses to fear stimuli.

Analysing phobic and non-phobic participants with relation to images of spiders has shown an increase in amplitudes of P300 waves, an event-related potential component, when exposed to the phobic material compared to the non-phobic material (Schienle et al., 2008). This means increased cognitive processing in response to the stimuli (Zhong et al., 2019). A similar study on phobic and nonphobic participants of spiders and snakes found the same results of heightened amplitudes of the event-related potential component, P300 (Miltner et al., 2005). These studies provide efficacy for EEG to have potential within the thesis. In addition, EEG is noted as being commonly used for brain-computer interfaces (BCI) within the field of HCI, largely due to being a more mature and commercialised technology.

By contrast, fNIRS is another form of neuroimaging technique but works

significantly differently from EEG. fNIRS works by detecting changes in the concentration of oxygenated and deoxygenated haemoglobin protein in the blood using infrared light sensors (León-Carrión and León-Domínguez, 2012). The use of fNIRS as a physiological measure has increased within recent years, with research going into areas such as mental workload (Midha et al., 2021; Causse et al., 2017). Analysing the mental resources required for varied difficulty in tasks provides insight into human performance. A systematic review by Halbig and Latoschik (Halbig and Latoschik, 2021) provides an understanding of the commonly used physiological measures within VR, their uses and the approaches to recording physiological data. Although fNIRS was not named in the review as a commonly used physiological measure in HCI, it is now reaching consumer devices and becoming more popular in HCI research (Midha et al., 2021; Pike et al., 2016; Ramchurn, Martindale, Wilson and Benford, 2019).

The most commonly used products that integrate brain computer interface-VR (BCI-VR) at the moment of writing are essentially mountings which integrate third-party VR headsets with EEG. Examples include the Galea (Galea, 2024), which integrates dry sensor EEG with Varjo's popular Aero, or the Nurospec DSI-VR300, which integrates dry EEG with an HTC Vive (NEUROSPEC, 2024). However, EEG, particularly dry EEG, is prone to movement artefacts (Komosar et al., 2022). Considering the physical setup of a VR headset (typically a significant weight to the front) as well as activities that often involve whole-body movement, the selling point of modern VR, after all, being six degrees of freedom head tracking, provides a connected system especially likely to deliver movement artefacts.

Conversely, fNIRS is more robust to movement artefacts (Li et al., 2022). Forehead-mounted fNIRS lends itself well to being positioned directly above a headset without being attached, compared to an EEG's need for elec-

trodes across much of the scalp. Whilst EEG detects the electrical activity in the brain, fNIRS detects changes in blood oxygenation regions of the brain, which is known to offer a higher spatial resolution while maintaining portability (Li et al., 2022). The cost, however, is the lower temporal resolution, meaning that the detection of cognitive responses is slower; between 100 milliseconds and 1 second for fNIRS rather than a millisecond for EEG (Li et al., 2022; Nicolas-Alonso and Gomez-Gil, 2012).

When attempting to incorporate adaptation into an experience, higher temporal resolution enables faster interpretation of an individual's physiology, facilitating a more rapid adaptive response. The impact between 1 millisecond and 1 second will depend on the implementation of the adaptation; if rapid adaptations are necessary, then EEG will be more effective. EEG lacks the capabilities provided with fNIRS to localise areas, such as the Brodmann areas (Cohen, 2014). The Brodmann areas cover a vast amount of the brain, but more specific areas, such as Brodmann areas 9 through 11, cover the frontal regions of the brain that indicate emotional regulation (Ochsner and Gross, 2005). fNIRS is capable of measuring these frontal regions of the brain (Masataka et al., 2015; Pinti et al., 2019).

A review of fNIRS in the field of neurophotonics (neuroscience and optics) details fNIRS as having "a very high experimental flexibility" (Quaresima and Ferrari, 2019). For advantages, the authors write that "fNIRS is silent, tolerant to movement artefacts, and allows for long-time continuous measurements". As for disadvantages, "fNIRS does not provide anatomical information, and fNIRS measurements are restricted to the outer cortex and have a low spatial resolution (2–3 cm)". As mentioned previously, though, the spatial resolution is still an improvement on EEG. Another practicality worth considering here is that fNIRS is generally more inclusive to a wider range of ethnic groups (Bronkhorst et al., 2019).

The lack of spatial resolution in EEG within emotional understanding/processing is what limits and ultimately removes EEG from the discussion of measuring emotional responses. Additionally, but no less importantly, while EEG is robust to skin colour, it is not robust to hair types and styles such as afros, dreadlocks, and weaves that are often associated with or inseparable from people of darker skin tones. That incompatibility with some hair types and styles can limit access to this technology in a discriminatory way. Since fNIRS sits directly on skin that tends not to be covered by hair (i.e. the forehead), it is a more socially robust technology and thus better suited to consumer products.

Some research has provided evidence of fear detection in fNIRS. Higher activations of brain activity have been detected within the areas of the amygdala and prefrontal cortex in response to being confronted with video clips of spider stimuli (Rosenbaum et al., 2020). Another study, from the perspective of exposure therapy on acrophobia (fear of heights), showed an increase in oxygenated haemoglobin concentrations within the DLPFC (Landowska et al., 2018). These studies indicate that researchers can confidently infer fear states from significantly high activation of the prefrontal cortex in areas correlated with fear responses.

It is worth noting that although fMRI is a useful technology for brain imagery, it is not currently mobile and therefore not useful for this thesis. Before disregarding fMRI entirely, however, it is worth discussing the relation between fMRI and fNIRS. Studies using fMRI show neural activation in regions of the pre-frontal cortex when observing fear extinction (Fullana et al., 2018; Fumero et al., 2022). fMRI has a higher spatial resolution than that of fNIRS, allowing it to reach deeper regions of the brain; however, as mentioned, it is limited as the subject is heavily restricted in mobility. Due to the regions of activation in the brain being similar to that of fNIRS

about fear, this provides efficacy for fNIRS in inferring fear processing.

From previous research, it is shown that both EEG and fNIRS show promising results towards the detection of fear-related states from a stimulus. However, with the increase in research towards fNIRS and the higher spatial resolution, this makes this neuroimaging technique more beneficial when looking into accuracy. The reduction in temporal resolution provides slower feedback of data; however, the time reduction is not enough to discount the use of the technology. It is important to note that with the use of VR headsets, finding a device that can fit comfortably on a participant and be compatible with VR headsets without affecting immersion from the experience. Some studies have found that the Octamon wireless fNIRS system from Artinis Medical Systems (Artinis Medical Systems, 2018*b*) worked well alongside VR (Landowska et al., 2018; Pöhlmann et al., 2023). This sets the Octamon as a validated device for combined VR and fNIRS research.

Before finalising which physiological measure is best for this approach, according to the literature, I first reiterate which measures are up for debate. These are HR, GSR, and fNIRS. HR and GSR showed efficacy for detecting fear-related states; however, issues arose when looking into noise interference (Ismail et al., 2021; Weixuan Chen et al., 2015), something that fNIRS is less susceptible to (Quaresima and Ferrari, 2019). Additionally, HR and GSR directly measure arousal, whilst fNIRS provides the spatial resolution to more accurately localise activity. There is the potential for a combined approach, but this adds further complexities to research through data synchronisation and analysis. It is worth initially understanding an approach to adaptive experiences first, before applying additional modalities. Therefore, fNIRS will be used in this thesis to study physiological responses and support the development of an adaptive experience.

2.4 fNIRS for Processing Fear

Having established fNIRS as the physiological measure for use within this thesis, I now investigate the literature around how fNIRS data is processed and which methods may be applicable for real-time adaptation.

2.4.1 Processing and Preprocessing Methods forfNIRSData

Before the data is processed, fNIRS data must first be preprocessed to filter the data for noise. Drifts in data can be caused by a multitude of factors, such as physical or natural processes, referring to slight movement or light source intensity, respectively. These drifts contain no useful information for fNIRS and are therefore removed early in the stages of preprocessing (Patashov et al., 2023). Many open-source tools provide techniques for preprocessing, such as NIRS Toolbox (Santosa et al., 2018) and HOMER 2 & 3 (Huppert et al., 2009). Within these tools exists techniques such as auto-regressive iteratively reweighted least squares (AR-IRLS), temporal derivative distribution repair (TDDR), Band-pass filtering, and Wavelet-based filtering (Huppert et al., 2009; Brigadoi et al., 2014; Klein and Kranczioch, 2019; Chiarelli et al., 2015).

AR-IRLS is a combination of both auto-regressive models and iteratively reweighted least squares. It provides a prediction of future values which is linearly dependent on previous values (auto-regression) (Deodatis and Shinozuka, 1988) whilst fitting outliers through a weighted system (iteratively reweighted least squares) (Upton and Cook, 2008). TDDR is a motion correction procedure aimed at correcting spike artefacts and baseline shifts caused by motion (Fishburn et al., 2019). Band-pass filtering removes unwanted noise by filtering the fNIRS signal into a specified frequency

range (Klein and Kranczioch, 2019). Wavelet-based filtering detects contaminated time-frequency points, decomposes the fNIRS signal, suppresses the wavelet energy of these contaminated time-frequency points, and then brings the signal back to a time series (Duan et al., 2018).

Due to the methods of these preprocessing techniques, no single technique is better for real-time applications, as they all have their advantages and disadvantages. Band-pass filtering has been shown to work (Kober et al., 2014), but a combination of preprocessing techniques is advised. Using too many of these methods, however, may apply too much preprocessing to the data, making it unusable. Therefore, a limited combination is advised.

Machine learning is a popular approach to processing and preprocessing data. It is designed to emulate human learning through an iterative process ((El Naqa and Murphy, 2015)). It can make predictions based on trends in data and classify data. When looking into analysis of fNIRS, two commonly used models are the general linear model (GLM) and general linear mixed model (GLMM). The GLM is used to describe the relationship between a dependent variable and one or more independent variables through a linear function (Friston et al., 1994). The GLMM builds on the GLM, allowing for both fixed effects (constant and controlled independent variables) and random effects (random and not predefined independent variables), which makes them useful for clustered data (Tak and Ye, 2014). This makes GLMM useful for situations involving groups of data; however, GLM is more convenient for individual data.

When looking into real-time data analysis, as the real-time application is only towards one viewer, GLM is likely to be the better option. Additionally, due to the increased complexity of GLMM over GLM, it would be less time-consuming computationally to use GLM, which is an important factor

to consider when aiming to achieve real-time data analysis and adaptation. The issue with GLM, however, is the complexity of creating a working real-time model. Turbo-Satori (Turbo-Satori, n.d.) provides software for real-time fNIRS analysis using GLM; however, pricing places this outside of the capabilities of the PhD, so an alternative is required.

Looking outside of the aforementioned models, another approach is block average analysis (BAA) and slope regression (SR). BAA works through segmenting (blocks) and averaging the fNIRS data in relation to a stimulus onset (Dawson, 1954). This can then be used to compare blocks on a specific feature, such as the average of a waveform across time. Although the technical complexity of this technique is not as advanced as techniques such as GLM, a study comparing GLM and BAA found that both techniques produced the same group-level experimental conclusions (Luke et al., 2021). When looking into single-trial data, however, issues can arise if the preprocessing of the data is not sufficient (Klein and Kranczioch, 2019). Without sufficient preprocessing, noise data is used as feedback instead of brain activity; therefore, for any use of BAA, data filtering must be rigorous.

An advantage of using BAA is the reduction in computational load when compared to the model-based analysis techniques. As no complex models are used, no data training is required, and data can be segmented and analysed; however, this approach is infeasible for real-time analysis as it is an offline paradigm. It does, however, provide potential use for research into understanding fear from brain activity. Looking at SR, this approach observes the degree of cortical activation and ultimately the rate of change in the oxygenated and deoxygenated haemoglobin over time (Mandrick et al., 2012). This can be used to observe continuous changes in the haemodynamic response for basic classification of either an increase or a decrease based on whether the slope is positive or negative, respectively (Mandrick

et al., 2013). A key aspect of this method is that it could be used in real-time by continuously analysing data over a *sufficient time window of stimulation* (Mandrick et al., 2012). It is also mentioned as not being computationally expensive, which, for real-time applications, is beneficial.

From research on different papers looking into the analysis of emotion, there is a consistency with the use of machine learning as a technique for the analysis of brain activity data. The advantage of this is that models can be created and trained towards the problem that is being solved. When analysing the brain activity data within my research, machine learning will likely need to be used when aiming to understand fear processing from brain activity data. The literature looking into these models has highlighted GLM as having the best potential for this. Using this approach, I aim to show that a specific region of the brain can provide some inference of fear from which a more focused approach can be used to analyse for fearful changes. However, when working in real-time, SR is more viable due to less complexity and computational intensity whilst maintaining viability as an analysis technique when compared to the approach of the more rigorous models. Once a specific region of the brain is successful in observing some inference of fear through GLM, SR can provide a more efficient approach to real-time application of inferred fear processing.

2.5 Fear Within Horror Film, Games, and Virtual Reality

Previous sections have covered the running definitions of fear and horror for the thesis, as well as solidifying the use of fNIRS and the preprocessing/processing techniques. The next sections will cover literature on fear

within entertainment, focusing on film, games, and VR. Instances of screen horror, regardless of the medium, use similar tropes of jump scares, uncomfortable creatures, and uneasy environments, but the expression and agency can differ. In the following sections, I examine how each medium uses concepts and approaches to the horror genre.

The concept of using fear for entertainment takes the unusual standpoint of applying a negative emotion to achieve a pleasurable outcome. Questioning the motive behind why we wish to subject ourselves to fear for pleasure has been the focus for some researchers. Film Studies Professor, Julian Hanich, defines this as the 'paradox of fear' (Hanich, 2011); the concept of exposing ourselves to an emotion that we avoid in our daily lives. We see such applications within experiences such as roller coasters or skydiving; activities that provide a sense of thrill at the cost of danger. This is not limited to real danger, however, as passive activities can create a similar sense through media such as horror films. Although there is no real threat to the viewer, the fear can feel all too real.

2.5.1 The Horror of Horror Films

To understand fear within horror films, we must first establish what horror means within the context of horror films. Professor of psychology G. Neil Martin details the position of the horror genre in his article *(Why) Do You Like Scary Movies? A Review of the Empirical Research on Psychological Responses to Horror Films* (Martin, 2019). When talking about the horror genre, Martin says, "The primary aims of the horror film are to frighten, shock, horrify, and disgust using a variety of visual and auditory leitmotifs and devices". This is in line with the aforementioned definition of the horror genre by Solomon and Law. To reiterate this, they say that hor-

ror as a genre aims to induce fear through unease, dread, and terror, with horror being the revelation and meeting the danger. This isn't to say that horror can't be combined with other genres. Horror-comedy is a successful subgenre, as noted by the previously mentioned film scholar and philosopher Noël Carroll in his article titled **Horror and Humor** (Carroll, 1999). Here Carroll discusses how the success of films such as *Ghostbusters* (Ivan Reitman, 1984), *The Addams Family* (Barry Sonnenfeld, 1991), and *Gremlins* (Joe Dante, 1984) combine the use of comedy with horror to create a unique alteration between laughter and screaming. At its core, however, these films still maintain the horror elements, but combining other genres can produce creative subgenres, showing off the flexibility of horror.

Noting the success of horror, there are many acclaimed films within the horror genre that have defined the genre as a whole. Films such as *Scream* (Wes Craven, 1996), *Halloween* (John Carpenter, 1978), and *Texas Chainsaw Massacre* (Tobe Hooper, 1974) were all successful films within the horror genre that generated significant profits. Taking *Texas Chainsaw Massacre* as an example, according to IMDB (www.imdb.com), the estimated budget was $140,000 and the estimated gross profit worldwide was $30,859,000. Despite this success, the horror genre in general has struggled financially and is regarded as being less successful than other film genres (Martin, 2019). Referring back to Martin's article, Martin puts the disparagement of horror down to the cheaper budgets, with horror typically being less expensive to create than other genres.

Looking back at the films *Scream*, *Halloween*, and *Texas Chainsaw Massacre*, one thing all of these films have in common is the use of a serial killer, a well-known trope of the horror genre. Tropes are recurrent themes used within a genre, so taking the horror genre for example, small and unlit spaces, large and empty places, darkness, and night are all tropes that play

into what the horror genre is known for (Blake, 2013). These recurrent themes are commonly used to incite fear in an audience. Authors Marc Blake and Dr Sara Bailey wrote a book called 'Writing the Horror Movie' (Blake, 2013) which details the extensive processes involved in creating horror films. Within their book, Blake and Bailey mention that a threat from 'the unknown' is the heart of horror. This unknown must pose a consistent threat and require characters to attempt to overcome this in some way to produce a resolution. Alongside this, they provide a list of tropes in what they label "the five basic tropes". These are: unease, dread, terror, horror, and disgust. Blake and Bailey say that these are not directly required for horror films, but are very commonly found. These 'basic tropes' are in line with the definition described for this thesis, adding disgust as the visceral, memorable, and personal reaction to the abject. The abject refers to that which disturbs identity, system, and order through such examples as bodily fluids, the corpse, and the maternal body (Kristeva, 1982).

Also detailed within Blake and Bailey's book is a three-act structure. The three-act structure is a common formula used in screenwriting, popularised by author Syd Field in their book *Screenplay: The Foundation of Screenwriting, 1979* (Field, 2005). This structure details Act 1, providing the setup, Act 2, creating rising action, and Act 3, the resolution. The 3-act structure detailed by Blake and Bailey pertains directly to horror. Act 1 is "unease, dread, character, and milieu", Act 2 is "modulating fear, terror, and horror", and Act 3 is "tragic and redemptive findings". This follows a similar trend to the standard 3-act structure, however, in terms of horror; setting up the horror with unease and dread, before revealing it with terror and horror, and finally providing a sense of resolution through tragedy and redemption.

As discussed, horror may not be the most revered genre for film, but it has

a successful complexity of tropes and terms. Horror can break the barrier between genres as long as the foundations of horror itself are maintained. Additionally, mixing the terms into the structure of horror helps formulate the narrative and maintain the traditional three-act structure whilst horrifying the audience.

2.5.2 The Mechanics of Fear in Horror Films

With an understanding of the structure used in horror films, looking towards the fear-evoking content of horror films can help to understand how horror can be adapted to manipulate the emotion of fear. Below is a breakdown of the audio and visuals used in well-established horror films, reporting on the specific techniques of each and how they are applied.

Audio and Visuals Within Horror Films

The presence of music within horror films has created iconic soundtracks from *Psycho* (Alfred Hitchcock, 1960) by Bernard Herrmann to *Jaws* (Steven Spielberg, 1975) by John Williams. These tracks elicit tension and shock, emotions commonly provoked by the horror genre, through techniques designed to twist into discomfort. One technique used by Herrmann in Psycho is glissandi, specifically upward glissandi (Brown, 1982), where a note is raised or lowered continuously in pitch. Herrmann also uses what is known as an x cell, defined as "a semitone interval from a fundamental pitch to the second-lowest pitch of the chord" (McAlpine et al., 1999). Both techniques are used during the shower scene within Psycho, a well-known stressful moment within the film involving the death of a character in a vulnerable state.

Rick Beato, known for being a YouTube personality, multi-instrumentalist, music producer and public educator, provides a list of what he believes makes music sound creepy. He suggests the following: "Low/deep sounds, slow music, screeching, sudden sounds, toy piano sounds, tremolo, fast glissandos, chromatic melodies, punctuated chords, dark chords (minor 6/9 chords, minor major 7th chords, suspended chords, augmented chords), pulsating rhythms, and dissonant intervals" (Beato, 2022). Beato goes on to mention the use of pulsating rhythm, minor major 7th chords, and augmented chords in the score of *Silence of the Lambs* (Jonathan Demme, 1991) by Howard Shore.

Music and psychology professor Patrik Juslin provides a list of acoustic patterns to convey fear in music and speech. His list is as follows: "fast speech rate/tempo, low voice intensity/sound level (except in panic fear), much voice intensity/sound level variability, little high-frequency energy, high pitch level, little pitch variability, rising pitch contour, and a lot of micro-structural irregularity" (Juslin, 2019). Breaking this down, generally, the musical components aim for either low or high variations, such as voice intensity and pitch. Pitch contour refers to a rise in voice over the course of a word or phrase, and micro-structural irregularity refers to subtle, intended changes to the music, such as tempo, pitch, and loudness throughout the life of the music score.

A study in 2023 looked into the acoustic and structural differences in fear music (Trevor et al., 2023). The findings were as follows: "Terrifying music has a brighter, rougher, harsher timbre, is musically denser, and maybe faster and louder than anxious music. Anxious music has a greater degree of loudness variability". The same primary author also conducted an earlier study in 2020 on the use of screams in music (Trevor et al., 2020). They found that screams and scream-like music were rated lower in valence and

higher in arousal compared to non-scream-like music and non-screaming vocalisations. Relating this to Russel's circumplex model of affect (Russell, 1980), this would place screams and scream-like music within the region of fear, anger, and disgust.

All three cases mentioned above provide techniques for horror film music and fear-inducing sound. Commonalities between the lists include manipulation of tempo, intensity and loudness, as well as pitch. Using (and/or avoiding) these techniques and manipulating them can allow for music to mix into fearful provocation, including subcategories such as terror and anxiety.

Although the techniques defined above are important to the creation of horror music, it's also important to understand what horror music does for an audience. The musical score of a film has been shown to affect the stress experienced by an audience (Thayer and Levenson, 1983). Another study by Meinel and Bullerjahn (Meinel and Bullerjahn, 2022) backs the use of music for an increased effect of shock in horror. They also suggest that the use of music before a shock moment can increase stress levels when compared to either no music or music timed with the shock moment. Music can also be used to provide a sense of emotion in characters as studied by Tan et al. (Tan et al., 2007). They also provide evidence for music in foreshadowing, but state that music does not have to be concurrent with the visuals to affect a viewer's thoughts of the film. This suggests that music has an important role to play in the effect of horror, but that the music does not need to reflect the visuals to impact the fear.

Horror music is just one aspect of what creates an effective and affective horror film. Visuals are another important element which make up the scene and context. Visuals consist of many components which comprise

the mise-en-scène, including lighting, location, props, actors, set décor, costumes, and makeup (Sipos, 2010). The composition of these components can create certain atmospheres, such as those used within the horror genre. Determining how these components work towards horror can provide us with a list of alterations that could be applied to an experience in real-time for fearful adaptation.

The use of lighting in horror films largely manipulates the visual fidelity of what is seen by the audience. *Horror Film Aesthetics: Creating the Visual Language of Fear* (Sipos, 2010) provides a breakdown of different lighting techniques and approaches in horror filmmaking. One such technique is Sipos' 'Hiding in the Dark' (Sipos, 2010) where they mention how the use of darkness can be used to mask or reveal characters and monsters for perceived safety or threat. Combining this with sound design can lead to horrific scenes clouded by darkness. One such example is in *Halloween*, where a panicked character flees through the darkness before we see the mask of the villain floating in the darkness. Looking more specifically at light compositions, Ammer (Ammer, 2020) researched different lighting and colour techniques from a range of well-known horror films and produced a checklist for the design of both techniques in horror films. For lighting, this includes "key of light, light source angle, light distribution, light contrast, key of light & contrast". An example used is in the movie *Saw* (James Wan, 2004), where there is a mixture of diffuse lighting and high-key lighting, creating overexposure and low contrast. A key light refers to the main light within the scene (Sipos, 2010), and is often the most significant light in the lighting setup. For the viewer, this creates a dreary bathroom scene with uncomfortable lighting.

Shadows and silhouettes are two other techniques with strong efficacy in horror films. Both reveal only outlines of characters and objects, allowing

the imagination to fill in the gaps. Examples of this approach can be seen in films such as *Aliens* (James Cameron, 1986), *Jeepers Creepers* (Victor Salva, 2001), and *Suspiria* (Dario Argento, 1977).

Location plays a large part in setting the scene of a horror film by placing the characters in typically scary environments. Some examples from well-known horror films include a haunted house (*Woman in Black*, Herbert Wise, 1989), a creepy village (*Sleepy Hollow*, Tim Burton, 1999), a dark forest (*Cabin in the Woods*, Drew Goddard, 2011) or even a deserted city (*28 Days Later*, Danny Boyle, 2002). The use of these locations brings a sense of darkness and isolation from the rest of the world, themes commonly associated with the horror genre (Royer and Cooper, 2013). However, these locations would be incomplete (at least to induce fear) without the sense of a threat. Horror films have created prominent villains to scare their audience, from Michael Myers in *Halloween* to Pennywise in *IT* (Andrés Muschietti, 2017). But not all horror films contain a visible character threat; *The Blair Witch Project* (Eduardo Sánchez and Daniel Myrick, 1999) follows a group of film students out to uncover the truth of the Blair Witch. One by one, each character is taken before ending with the final character being attacked by an unseen entity. This film provides good evidence of how fear can be induced even without the visible threat of a villain, focusing more on fear of the unknown through the location and setting. A heavy focus on isolation and feeling trapped is typical of films and games in this genre.

Horror films present a foundation towards what horror is today. Many works have been produced which define the tropes and cliches of horror and provide direction for other media to build upon. At the most basic level, horror is comprised of a unique set of audio and visual elements that collaborate to express fear in the audience. These are a mixture of high/low

pitch, tempo changes, irregular musical structures, lighting, atmosphere, and environment. Building upon this, horror has found a natural home within games, where developers can utilise these features and extract them into a unique form of interactive horror.

2.5.3 Horror in Games

Horror in games provides a new twist to the horror genre in the context of agency. You are no longer an observer; you have become the victim. When observing horror films, the audience is at the mercy of the characters, unable to control the next action, waiting in anticipation of what is to come; however, with horror games, the audience becomes the character, directly controlling and influencing their actions to fight for survival. Horror has seen great success within the world of video games, from titles such as *Silent Hill* (Team Silent, 1999) and *Resident Evil* (Capcom, 1996), both of which are still developing new titles and have been adapted into successful horror films. Professor of cinema, Bernard Perron, discusses the use of horror in video games in his book titled *Horror Video Games: Essays on the Fusion of Fear and Play* (Perron, 2014). Here, he mentions how the goals of video games and the horror genre are complementary, where the horror genre lets an audience test their fears, something video games can amplify through interaction. An article by Professor of Screen Studies Tanya Krzywinska, titled *Hands-On-Horror*, discusses a cross-comparison of techniques used in horror games versus horror films, specifically noting the use of spatial orientation, tension, cut-scenes, point of view, and control (Krzywinska, 2002).

Spatial Orientation

One key facet of video games in comparison to horror films is their ability to provide a variable and controllable perspective. A first-person perspective enables a player to take control from the eyes of the playable character, immersing them within an unrestricted 3D space. As mentioned by Krzywinska, in their example *Clive Barker's Undying* (EA Los Angeles, 2001), a horror first-person shooter game, "This freedom to look and explore in *Undying* marks a departure from the way horror films use editing and framing to create tension and claustrophobia". This liberation from forced perspectives provides opportunities for a new creative input into world-building, as well as a change in pacing. This is not to say that a cinematic approach within games isn't compatible. Krzywinska provides another example *Resident Evil 3: Nemesis* (Capcom, 1999), a survival horror game, where a third-person perspective is adopted with fixed and controlled camera angles, using filmic techniques to control the space and effect of the horror. Periods of forced viewpoints in first-person can also create tension by limiting a player's perspective, typically in confined spaces, such as vents (*Still Wakes the Deep*, The Chinese Room, 2024). This change in perspective can alter the dynamic of pacing, control, and agency (Pinchbeck, 2009).

Storytelling

Game designer and writer Richard Rouse III discusses the use of ambiguity in game storytelling in his article titled *Match made in hell: The inevitable success of the horror genre in video games* (III, 2009). In this article, Rouse discusses how a simplistic story is better: "A lot of nuance can be worked into the environment and the characters the player meets, but the

plot is something that needs to be immediately understood". He explains how horror benefits from a lack of explanation to leave the player to their imagination. Examples of this can be seen in games such as *Outlast* (Red Barrels, 2013), where you play as an investigative journalist who was sent an anonymous email about inhumane experiments at Mount Massive Asylum and go to investigate. *Alien: Isolation* (Creative Assembly, 2014) is another example, where you play as a daughter investigating her mother's disappearance on a space station. Both examples drop players into a game with a straightforward goal and integrate the environment and characters to provide more details and context to the world they are in. This simplicity of storytelling can give more attention to the world and its inhabitants whilst enabling the player to grasp the story from the start (III, 2009).

Tension

Typically, within a horror film, a fear of the unknown is used to provide a consistent threat throughout (Blake, 2013). A similar approach can be seen within horror games, where the player may be tasked with hiding from, running away from, or fighting a threat. The position of the player and the threat may not always make it plausible to keep the danger in view, raising the tension through suspense. If a player turns a corner or hides within a scene, they may no longer have sight of the threat, but this does not remove the threat from posing danger to the player. Referring back to Krzywinska's article (Krzywinska, 2002), the use of a first-person perspective increases the visual proximity to the player's surroundings, inducing more tension from potential threats that may be nearby. Another technique in horror games is to use environmental factors to restrict player vision to hide threats, be it walking through the murky streets within Silent Hill (*Silent Hill*, Team Silent, 1999), or sneaking across the pitch black cor-

ridors of Mount Massive Asylum (*Outlast*). This restrictive view leaves a lot to the imagination, dangling the player in suspense about what may lie beyond the wall of fog or around the next corner.

Agency

Perron argues that agency is a crucial aspect of the experiential nature of video games (Perron, 2014). Following the same foundational definition of agency used by Perron is that of professor of literature, media, and communication, Janet Murray, where her seminal work *Hamlet on the Holodeck* defines agency as "the satisfying power to take meaningful action and see the results of our decisions and choices" (Murray, 1997). This definition fits well into this thesis surrounding adaptation. Within this thesis, adaptation aims to provide a level of agency to viewers about their level of fear by adapting horror elements within an experience. This then allows them to directly see the outcomes as a result.

An article by Kyle Madsen titled *The differential effects of agency on fear induction using a horror-themed video game* compares the effects of agency between passive viewing and playing a video game (Madsen, 2016). The results of the study showed that physiological reactions, respiratory rate, skin conductance, and heart rate of fear were higher when playing a horror game than when watching someone play the game, but self-reported measures of fear were the same between both conditions. Although the physiological reactions imply that an increase in agency can potentially induce more fear, the self-reporting suggests that users either didn't feel different or that a different physiological response other than fear is occurring.

As discussed, horror games draw a lot of techniques from horror films, yet the ability to take control creates a divide. Chad Habel and Benjamin

Kooyman discuss this in their article titled *Agency mechanics: gameplay design in survival horror video games* (Habel et al., 2014). Crediting Krzywinska's work as an influence, they build upon it, looking further into the management of player agency and the control of the game world. Using *Dead Space* (EA Redwood Shores, 2008) as an example, Habel and Kooyman note the use of constriction in movement through tight spaces and locomotion, as well as the environment through gravity manipulation mechanics (Habel et al., 2014). These techniques allow enemies to still attack the player while limiting the player's ability to fight back. They also mention the use of lighting to limit the player's vision, further limiting their sense of control over the gameworld. Whilst some games may provide a way to fight back against threats, others leave the player helpless, forcing them to flee or hide, which leads back to the discussion of tension surrounding limited visibility. These manipulations of agency can affect the impact of fearful events and the ability of the player to control and respond to these events. Spatial orientation and storytelling also directly affect the agency. Limited storytelling provides a withdrawal in agency due to simplicity, whilst spatial orientation can restrict a player's view and control.

Horror within video games builds upon its success in film through control of spatial orientation, storytelling, tension, and agency. Horror naturally fits within the world of video games and flourishes, as demonstrated by various successful works. Emerging technologies present other forms for presenting horror, most notably VR, which allows for further immersion into the world of horror.

2.5.4 Horror in Virtual Reality

As technology has aged, so has the presentation of horror media (Littles, 2023), with common mediums involving 2D film. It has been shown, however, that the use of cinematic VR can provide a stronger emotional effect, where Ding et al. (Ding et al., 2018) showed that cinematic VR can boast a stronger emotional experience and physiological reaction than that of 2D film, but the design of VR strongly influences emotional processing. When observing fearful stimuli, VR can provide an environment that is immersive and controlled, popular amongst research within VRET (Chesham et al., 2018; Botella et al., 2017). Compared to horror films and games, horror in VR applies the additional layer of directly encountering threats as if they are part of the real world (Slater, 2009). As VR encapsulates the player's view, were the game to plunge the player into darkness, they would be blinded, replicative of what would happen in the real world.

Distinguished investigator of virtual environments, Mel Slater and British computer scientist Sylvia Wilbur provide a framework on immersion and presence within VR (Slater and Wilbur, 1997). Their paper suggests that immersion can be "objectively assessed as the characteristics of a technology" and "has dimensions such as the extent to which a display system can deliver an inclusive, extensive, surrounding, and vivid illusion of a virtual environment to a participant". Talking of presence, they refer to presence as "a state of consciousness that may be concomitant with immersion, and is related to a sense of being in a place". Despite the paper being written in 1997, this work is still cited by researchers today for research within VR (Giang Barrera and Shah, 2023; Puntoni, 2024).

The utilisation of fear within VR is studied by a distinguished professor in media and information studies, Tammy Jih-Hsuan Lin, (Lin, 2017), using

a theory of presence in VR proposed by Slater (Slater, 2009). This theory uses two concepts: place illusion (PI), often synonymised with presence, defined as the feeling of *being there*, and plausibility illusion (PSI), referring to the illusion of events and actions being real. Lin uses this theory and applies it to fear to identify two measurable fear elements: the fear of PI and the fear of PSI. Through a study involving participants engaging with a VR horror game titled *The Brookhaven Experiment* (Phosphor Games, 2016), Lin found that participants perceived PSI elements as causing more fear than PI elements. Lin also notes that PSI distinguishes VR from other media as "In VR games, the 'self' is the protagonist. Therefore, PSI has a greater capacity to cause fear than PI.".

Agency is an important aspect of horror. As previously mentioned, in film, the use of agency is more passive for the viewer, whilst video games apply more control over the agency a player has. Within VR, agency builds upon video games to provide the potential for more control over choices and actions. For example, VR allows for physical movement in a digital environment as opposed to controller or keyboard movement in video games. As previously mentioned, Madsen's study showed that passive viewing and active game playing produced higher physiological reactions (Madsen, 2016). Madsen also mentions that the use of VR in future studies would be an ideal scenario due to its greater potential for immersion.

As technology has evolved, so has the horror genre. From creating foundational horror archetypes in film to becoming the protagonist within a terrifying world. Although the visual representation of fear has stayed relatively the same, the presentation and mechanics of horror have changed to accommodate emerging technologies. Video games provided more control of spatial orientation, storytelling, tension, and agency, while VR built upon this to introduce potential for greater immersion. As this thesis aims

to encapsulate a user in an emotionally immersive environment, VR will be used. This provides the best possibility of eliciting fear and having control over the mechanics of the horror elements.

Having established the physiological measure for detecting fear (fNIRS) and the medium with which to express the horror content (VR), I now look into how horror experiences are typically designed within the field of HCI. This provides understanding of how to design the adaptive horror experience in VR following HCI methodologies.

2.6 HCI Methodology for Horror Experience Design

Examining HCI methodologies from the past 20 years, research has demonstrated that this field is ever-evolving, continually pushing to develop new design methods and explore the next direction for HCI (Wright et al., 2006; De Haan, 2015). In 2006, a group of researchers noted that the requirement for design changes is due to "technological developments and new conceptions of 'the user' " (Wright et al., 2006). Later in 2015, Researcher Geert De Haan posited that these design changes are due to three factors: "increasing extension of user-centred design, increasingly higher level software tools and frameworks, and the application of agile design and design exploration" (De Haan, 2015). Within this path of changing designs and concepts lies a vast array of methodologies for designing experiences. As technologies such as VR have become more commonplace, design methods for these technologies have evolved.

The design of immersive environments presents a series of HCI challenges.

As immersive environments provide an open playing field in which to create seemingly endless ideas, this comes with the problematic nature of 'ease of use' for users amongst various other complexities (Jerald, 2015; LaViola et al., 2017). HCI methodologies can provide a design focus on the creation of user-centred, intuitive, and effective interactions between humans and digital systems. With a range of different methodologies, these should ensure that the end experience provides a positive and easy-to-use experience. When looking into HCI methodologies for adaptive VR horror experiences, however, this becomes a little more complicated due to the specificity of the research. The use of fear within the context of HCI looks into a variety of topics, such as fear therapy (Dechant et al., 2021), fear understanding (Elhai et al., 2021), and fear utilisation (Lin, 2017). Looking more specifically at the design of fear within HCI, the Uncomfortable Interactions paper (Benford et al., 2012) provides techniques for designing experiences that cause discomfort by laying an experience out using trajectories (Benford et al., 2009). This use of trajectories within the context of discomfort provides a potential link between fear and HCI and will be further discussed in Section 2.6.1. Another paper proposes the idea of a three-factor model for the appeal of horror in VR (Lin et al., 2018). Horror self-efficacy, fear and arousal are used to understand the enjoyment of horror content. Finding the right levels of each provides the best balance for enjoyment.

When looking into creating an experience to elicit a specific emotional response, realism, especially in VR horror, is important to ensure that the emotion elicited is intentional and impactful. Without a sense of realism, an experience may deter the audience. Horror and VR both require the audience to feel immersed and engaged; otherwise the elements of fear may not be effective. This makes Slater's PI and PSI concepts important

components in the design of the virtual environment, but this is only one component of experience design. Understanding the emotional journey of the audience is also important.

The use of participation and spectating within experiences does not define the two to be disconnected from one another, yet potentially in unison. Using spectators as participants can provide an adjustment to the experience that could alter the way an individual interacts with an experience. Referring back to the study of uncomfortable interactions (Benford et al., 2012), interactions mentioned, such as Ulrike and Eamon Compliant, provide availability for a previous participant to become an audience member, unbeknownst to the current participant being watched. This level of interaction change can change a user's reflection on an experience and the way they perceive the experience.

Forming meaningful experiences requires creating an environment and foundation that engages with an individual. In the field of HCI, the formation of these experiences is constantly evolving and progressing towards providing value for an individual (Blythe et al., 2009). How this value is imagined can vary greatly, including less conventional ways such as uncomfortable interactions (Benford et al., 2012), of which fearful experiences are a prime example. When structured effectively and appropriately, discomfort and uncomfortable interactions can provide a new outlook on experiences that may have previously been perceived negatively, or perhaps more simply, uncomfortable experiences can be thrilling and enjoyable in their own right.

2.6.1 Narrative Structure of Fear

There are methods for managing the narrative structure of uncomfortable experiences, such as Gustav Freytag's pyramid (Freytag, 1863). Freytag was a German novelist and playwright renowned for his work in the 19th century, with specific works such as Freytag's pyramid, which are regarded as "the building block of a narrative structure" (Harun et al., 2013). Freytag's pyramid details a series of events. These are exposition (the initial setup of the experience), rising action (the build-up of the experience in action), climax (the moment in which the suspense reaches a climactic moment), falling action (a period to reduce the intensity of an experience), and dénouement (the moment for reflection). This framework defines an overarching structure for an experience, which is useful to establish the general narrative. However, this does not map to an individual or personalised structure for participants. One framework that does map individual structures is the trajectories framework by Benford et al. (Benford et al., 2009). The trajectories framework provides a clear and structured path that experiences follow. This framework defines two specific trajectories, the 'canonical' trajectory and the 'participant' trajectory. The canonical trajectory is the author-intended path of the experience. The participant trajectory is the actual path that an individual takes throughout the experience. If a participant detours from the canonical trajectory, actions can be taken to attempt to realign the participant with the canonical trajectory. The use of trajectories as a way of describing an emotional account of an experience, in this case within the context of discomfort, provides a potential untapped link between fear and HCI. Tennent et. al describe the use of the trajectory approach as a way of articulating emotion (Tennent et al., 2021). While that paper may be more focused on the articulation of experience, it could also be applied more directly and measurably. There-

fore, I use the notion of a canonical and personal trajectory of fear to create an experience that aims to dynamically align the personal to the canonical. To understand how this method of control might be applied, we now look to the current state of fear in HCI, how adaptation can help us better understand individual behaviours, and how we can manage these behaviours.

The foundations of this thesis follow a similar approach to that of Keith Bound, who developed a framework for measuring suspense within his thesis titled *'TERROR & TENSION' Psychophysiological Suspense: Defining a framework to measure cinematic suspense in 21st century horror films* (Bound, 2016). For this framework, Bound measured GSR responses in participants exposed to 32 film clips from eight horror films (Bound, 2016). In this study, the suspense of participants was observed, measuring an anxiety response and specifically analysing the durability and intensity. These two variables were then used to categorise if a participant experienced 'momentary fear', sudden spikes, or 'extended fear', sustained arousal. Bound found that it was possible to measure sudden moments of fear alongside sustained fear, providing a way to objectively measure suspense within horror. This framework bridges the gap between narrative structures of fear and physiological response, setting a foundation for measuring fear responses.

2.6.2 Design-informed and Practice-led Research

RtD is an approach where the process of designing generates new knowledge (Pieter Jan Stappers and Elisa Giaccardi, 2014). This is typically done in the form of creating a prototype that plays a central role in generating new knowledge. One such example of this was conducted by Desmet et al., who carried out a user study aiming to design telephones for defined groups

(Desmet et al., 2001). Through this method, they found their approach to be successful for designing products with added emotional value.

Practice-led research is a methodology where research leads primarily to new understandings about practice (Candy, 2006). One example of this methodology is a mixed reality documentary titled "Once Upon a Time in Palestine" (Dahdal, 2023). The purpose of this project was to examine the engagement of undergraduate students and their willingness to learn new technologies and apply this new knowledge to improve the quality of the outcome. The study results showed that, despite a steep learning curve, the students successfully engaged and applied themselves to produce professional-quality work. Similar examples include (Hawkins and Wilson, 2017; McNamara, 2012; Mäkelä and Nimkulrat, 2018), where practice-led research was used to further understand engagement with the methodology. A book chapter titled "Practice-led and Interdisciplinary Research" discusses how combining practice-led research with interdisciplinary approaches may lead to positive research outcomes (Weinel and Cunningham, 2021). This informs our approach, which integrates practice-led research with co-creation to explore interdisciplinary collaboration.

HCI methodologies provide valuable insight into the design tools for creating an adaptive VR horror experience. I use the trajectories framework, taking the canonical and personal trajectory of fear to create an experience that aims to dynamically align the personal to the canonical. I also include Freytag's pyramid to follow his foundational approach to structuring the narrative. Finally, designing, developing, and deploying an adaptive VR horror experience is likely to take on a hybrid methodological approach. At its core, however, will sit both RtD and practice-led approaches. I now look at combining physiology and the horror genre, looking into existing approaches through affective adaptation.

2.7 Combining Physiology and the Horror Genre for Adaptation

With an established understanding of both the physiology of fear and the use of fear within film and media, the use of both can be investigated. While most adaptive experiences to data have focused on user actions, behaviours, or performance metrics, such as dynamic difficulty adjustment in Left 4 Dead's AI direction (Robin Hunicke, 2005), narrative adaptation in Silent Hill: Shattered Memories (Ewan Kirkland, 2010), or behavioural adaptation in Alien: Isolation, there are far fewer examples of systems that adapt base don direct physiological measures. The following section will look into the domain of physiological adaptation, provide literature on terms such as affective adaptation, and show how the combined use of physiological feedback and VR can create real-time adaptive experiences.

2.7.1 Affective Adaptation and Fear

Affective adaptation has been used within games and experiences to alter interaction within entertainment based on the behaviour of the user. This behaviour of an individual can be defined as the signals or emotional states they elicit, which can then be translated into dynamic feedback data to modify and adapt a game or experience accordingly. The use of this approach allows for a greater level of immersion, engagement, and excitement (Bontchev, 2016). This form of adaptation has been around since 1997, with initial implementations being demonstrated more as a gimmick than any form of serious development (Mark et al., 2005). Affective adaptation, however, isn't directly specific to that of pure entertainment. A study conducted by (Alchalcabi et al., 2017) used EEG to adapt a game for the aim of

improving focus, specifically for those with attention deficit hyperactivity disorder (ADHD). Through testing, they found that by using EEG-based controls over a keyboard, there was an improvement of 10% in engagement and 8% in focus.

Since being adopted more formally, further research has provided insight into the applications of affective adaptation. Bontchev and Vassileva (Bontchev and Vassileva, 2017) developed a video game for educational purposes, which used facial expression and psychophysiological signals to adapt game features, including the difficulty of tasks, based on adaptive data collected from a previously completed task. Another affect-based adaptive game focused on predicting player affective states based on brain activity and HR signals (Vachiratamporn et al., 2014). The environment of a survival horror game, altering the timing of horror events based on a player's affective state, showed promise for future research within affective gaming. There was, however, no difference in player evaluation based on the timing of horror events.

Some studies have shown the application of adapting fear within a VE. A study by Zaib and Yamamura (Zaib and Yamamura, 2022) combines the use of HR and machine learning techniques to adapt the sound and lighting effects of a horror VE. Two studies by de Lima et al. (de Lima et al., 2020, 2022) rely solely on gameplay data with machine learning techniques to alter the intensity of horror elements. Gameplay data includes that of player position, rotation, and time taken through various events such as walking and standing still. The use of physiology to observe a subject and understand their affective state has shown viable results, especially towards more commercialised technologies.

Studies have also shown how audio can be used to manipulate an experience

for a user. A study by Soares de Lima and Demarque (Demarque and Lima, 2013) used auditory hallucinations, a disorder that causes an individual to hear a noise without an external stimulus. The use of this was to establish an effect on the user's fear with and without these hallucinations. Users found that auditory hallucinations created a scarier experience overall in comparison to the experience without auditory hallucinations.

Another useful approach to providing adaptation to different elements is through object-based media (OBM), where content is separated into different 'objects' that can then be assembled or adapted at runtime (Ursu et al., 2020). This can include audio, visual, and environmental elements. The approaches of OBM provide a practical model for adaptive storytelling as they separate assets from linear sequencing, allowing for adaptive composition.

Affective adaptation is promising within games and experiences, using biofeedback, including brain activity data, to alter the features of the entertainment. There is yet to be research conducted into the way that affective adaptation could be used to alter narrative progression, specifically within the horror genre, which my research will aim to provide insight into. It could also be used to alter other aspects, such as audio, to trigger reactions based on a participant's fears.

2.7.2 Virtual Environments and fNIRS

Utilising a VE creates benefits from the capabilities of providing more flexibility and freedom for creating environments when compared to real-world environments as seen in applications such as workforce training simulation (Carruth, 2017), VRET (Gromer et al., 2019) and immersive story-

telling (Shin, 2018). There are also results which show improvements in engagement. For example, observing changes for individuals within a state of meditation (Kaplan-Rakowski et al., 2021), meditation within a VE in comparison with a video showed significant improvements in student exam performance.

Measuring physiological data while within a VE has become more practised research in recent years (Martens et al., 2019; Rieder et al., 2017; Angelini et al., 2022). The physiological understanding has aided in underpinning the impact of VEs on presence, a key component within VEs (Slater, 2009). A systematic review by Halbig and Latoschik (Halbig and Latoschik, 2021) provides an understanding of the commonly used physiological measures within VR, their uses and the approaches to recording physiological data.

2.8 Summary of the Literature

The literature reviewed demonstrates that horror is a genre uniquely positioned for adaptive experimentation due to its reliance on emotional intensity, audience engagement, and a long history evolving alongside media technologies. Across cinema, games, and VR, horror has consistently proven its flexibility in eliciting fear and suspense through a range of audiovisual and narrative techniques.

Within affective computing, existing research has shown that fear and other emotions can be inferred from physiological and neurological signals, with fNIRS among the most promising measure for use in VR. These findings validate the potential of integrating physiological monitoring into adaptive systems, though challenges remain in terms of robustness, ecological validity, and ethical considerations.

In parallel, research on adaptive experiences has largely focused on player actions rather than physiology, leaving a clear gap in the design and evaluation of physiologically adaptive systems for entertainment. The reviewed work on emtoin recognition and adaptation in educational, medical, and entertainment contexts provides a foundation, but also reveals the lack of tools and creative frameowkrs that can bridge scientific measures of emotion with the artistic practices of horror storytelling.

Through this thesis, I address that gap by combining empirical validation of fNIRS-based fear recognition, co-creation with filmmakers to translate creative needs into an adaptive toolkit, and the design and deployment of a VR horror artefact. In doing so, it builds directly on three strands of literature: 1) emotion recogntion and affective computing, 2) adaptive and interactive media design, and 3) horror as a historically adaptive genre well-suited to immersive technologies. Together, these literatures frame the methodological and conceptual foundation for the research that follows, justifying both the focus on horror and the pursuit of adaptive, emotion-driven experiences in VR.

Chapter 3

Methodology

3.1 Research Philosophy and Methodological Framework

Designing and developing an adaptive VR horror experience, in the case of this thesis: *A Place for Everyone*, can be broken down into a series of processes. These are: measuring an inference of fear from physiological data, defining the variables to be used within adaptation, designing and developing a VR horror experience with an adaptive system, and evaluating the experience through testing and analysis. The general overarching methodology follows a hybrid form of empirical mixed-methods research, co-creation, and experimental design and deployment, followed by deep reflection on the synthesis of data and experience from these activities. The thesis consists of interspersing mixed methods and experimental studies to create a foundation to develop, test, and reflect on *A Place for Everyone*.

The first study aimed to establish whether fear could be reliably measured in participants using fNIRS within a generalised VR horror environment.

While fNIRS has previously been shown to respond to specific fear stimuli, such as phobic triggers or controlled experimental tasks (Landowska et al., 2018; Rosenbaum et al., 2020), it remains unclear whether these responses generalise to a more varied and immersive context of VR horror. Demonstrating this link is essential to developing adaptive systems that function beyond narrowly defined laboratory conditions. This is a precursor to the rest of the thesis; without being able to detect an inference of fear, an adaptive system cannot function. To do so, I conducted a within-subject study comparing calm and fear stimuli on participants within a VE. This aims to provide empirical, verifiable evidence that fNIRS can detect an inference of fear. Results from this study confirmed that the left DLPFC could detect significant changes in brain activity between calm and fear conditions, providing a method by which to detect inferences of fear for the adaptive system.

Having established a method of inferring fear from fNIRS, the next step is to understand how horror films are made and the variables to use in adaptation to develop an adaptive VR horror experience. Understanding how horror filmmakers make horror films can provide insight into the variables to be used within the adaptive system. These variables will be the "knobs and levers" by which a creative can adapt the level of fear delivered by an experience, and thus personalise it. Since the creation of horror experiences (films, games, etc.) is an artistic endeavour, relying on expertise and experience, an appropriate approach was to try to elicit that expertise from domain experts. To do this, I conducted a series of interviews with horror filmmakers to establish their approach to creating media within the horror genre, how they inspire fear in their audiences, their attention towards the audience and audience journey, as well as their thoughts on the use of adaptation and its place within film. The data from these interviews were

analysed using the thematic analysis method developed by psychologists Braun and Clarke (Clarke and Braun, 2017). This involved transcribing the interview data, splitting the data into codes, and developing themes, grounded by groups of codes, that described the filmmakers' perspectives on the creation and evaluation of horror films and adaptation within horror media.

With the capability to infer fear from brain activity and an understanding of designing horror films and the variables to be used for adaptation, the next step was to put this capability into practice. I moved towards developing an adaptive VR horror experience. This artefact builds upon the previous research, combining the fNIRS study, which established the brain region for inferring fear, with the adaptive variables to define the adaptive system itself.

This project followed a hybrid methodological approach that combined empirical experimentation with design-informed research. In particular, it drew on practice-based study, where knowledge is generated through the making and reflection of artefacts (Frayling, 1994), and on strands of RtD, which use design processes as a drive for producing new understanding (Gaver, 2012). In this thesis, these approaches are applied to inform the way the adaptive system was designed, developed, tested, and reflected upon within "A Place for Everyone". This design-informed perspective was essential for situating empirical findings within a creative, practice-led context, ensuring that adaptation was evaluated not only as a technical mechanism but also as an artistic and experiential contribution. My role combined that of creative technologist, embedded collaborator, and empirical researcher, creating a hybrid approach in which I draw on both my observation and collaboration with creative practitioners (i.e. my industry partner), and my own experience of developing the system, before turning

to the audience to empirically verify the value of adaptation in horror.

The artefact serves as both an outcome and a context for inquiry, where the primary contribution lies in understanding how adaptation can be technically and experientially embedded in immersive storytelling. To do this, I closely collaborated with my industry partner AlbinoMosquito, a film production company that creates adaptive films using physiological data. AlbinoMosquito acted as the artist for this work, where I assisted the artist and took a self-reflective observational position. As an adaptive VR horror experience that adapts audiovisual stimuli in response to live data from fNIRS has not been developed before, documenting and researching the development process can provide a lot of insights for future researchers looking to create similar adaptive artefacts. As the artist, AlbinoMosquito handled the directing of the experience, including scripting, casting, and filming. As the researcher, I ensured that the scripts provided an opportunity for adaptation based on the suite of abstract adaptable characteristics developed based on the insights from the horror filmmaker interviews, such as the environments for scenes, key moments within the scenes and timings of events. I also assisted with the filming and worked alongside a visual artist, Sumit Sarkar, and an audio artist, Gary Naylor, to develop the adaptive content in order both to provide them with the necessary understanding of the capabilities, and to provide me with a deep observation about how these capabilities would be used in the hands of practitioners before I developed the adaptive system to be implemented into the VR experience.

Having developed the experience, it needed to be tested and analysed both in an ecologically valid real-world environment to draw breadth of information from 'real' audiences, and in a more detailed lab study to gain depth of information under more controlled circumstances. This involved conduct-

ing two separate studies, the first to get a lightweight qualitative review of the public experience for general feedback to understand the ecological validity of adaptive experiences. The second study followed a mixed methods design to gather a deeper data set.

The first study involved deploying the experience to the public following an exploratory qualitative approach with semi-structured interviews. This study aimed to act as a lightweight review of the public experience to gather real-world insights into adaptive systems, using *A Place for Everyone* as a case study. The interviews were conducted not to refine the prototype itself, but to capture the breadth of audience perspectives in an ecologically valid setting. In doing so, they provided insights into how adaptation was perceived outside the lab, and supported the practice-informed evaluation of the artefact as a creative work situated within public exhibition contexts. To gather this data, I focused on film festivals to establish how the public responded to the experience. Participants were made aware of adaptation throughout the experience. Post-experience interviews were conducted to gather their thoughts and opinions on the horror elements, adaptation, and future perspective of using adaptive systems beyond this experience.

The second study followed a mixed-methods and experimental within-subject design within a controlled environment. At the cost of ecological validity, a much deeper data set was produced to further analyse the contrast of adaptation and non-adaptation. Participants were not made aware of the use of adaptation ahead of taking part in the experience. This was to ensure genuine reactions to the content so as not to affect the results. The experience was also split into three conditions, where two scenes were adaptive, two scenes contained no alterations, and two scenes were put to the highest stage of fear possible. Scene-condition counterbalancing was applied to ensure that the order of scenes per participant was different

and that each condition appeared equally across all scenes, up to six participants, as six unique variations of scene-condition order were used. Six variations were chosen as fewer variations may introduce more bias through untested condition combinations, whilst more variations create more complexity and would demand a higher sample size. Quantitative data was gathered through measuring fNIRS and GSR throughout the experience, whilst self-reporting was gathered throughout the experience and through a post-experience interview. Subjective and quantitative data were cross-analysed to validate whether adaptation proved to adjust based on a fear response, whilst thematic analysis was used once again for the interview data.

3.2 Study 1: Neurophysiological Experiment on Fear

The possibility of measuring an inference of fear from fNIRS is crucial to the underlying research of this thesis. Without this, the adaptive system cannot function and therefore, the first study to be conducted looks into how this can be done. As outlined from the literature, fNIRS is to be used as the physiological measure to understand an inference of fear. Previous studies have shown the efficacy of using fNIRS for fear detection (Landowska et al., 2018; Rosenbaum et al., 2020), however, it is important to test fear detection with the specific use case of generalised horror. The previous studies noted above have looked at the stimuli of heights and spiders, whilst for an adaptive horror experience, a more generalised set of horror stimuli is studied. This is to understand the brain response when measuring a general response of fear to horror stimuli and determine

whether there are significant changes in the prefrontal cortex. To do this, a mixed methods approach within a controlled laboratory experiment is used to gather data from fNIRS and non-parametric self-reporting, before cross-analysing the data to find correlations.

Self-reporting is a common technique for validating a participant's emotional state (Barrett, 2004; Fuentes et al., 2017). This subjective data can be used to identify levels of fear to better understand potential variations in the brain activity and attempt to establish a form of inferring fear from the brain activity. Additionally, a within-subject design was used for the experiment to ensure all participants underwent the same conditions. The conditions consisted of alternating between fear stimuli and calm stimuli, utilising Russell's circumplex model of affect (Russell, 1980) to determine two opposing emotions for comparison. To collect the fNIRS data, the Octamon wireless fNIRS system from Artinis Medical Systems was used (Artinis Medical Systems, 2018*b*). This device has been proven to work alongside VR (Landowska et al., 2018). Additionally, this device measures the prefrontal cortex, an area of the brain shown previously to respond to changes in fear (Landowska et al., 2018; Rosenbaum et al., 2020).

Self-reported data was collected through a Likert scale (1 to 5), collecting a rating of Emotion Effectiveness, Motion Sickness, Valence, Arousal, and Dominance per condition. Analysing the fNIRS data will be done through GLM as established from the literature in section 2.4.1. Analysing the subjective data was done through visualisations of the data as a group and Wilcoxon signed-rank tests (Wilcoxon, 1945). As the self-reported data is non-parametric comparing two conditions, this fits the criteria of the Wilcoxon signed-rank tests compared to other tests, such as the paired samples t-test (Ross and Willson, 2017). With a defined method for measuring an inference of fear, I could move from understanding an inference of

fear in a viewer to establishing the variables to be used within the adaptive system to manipulate the VR horror experience.

3.3 Study 2: Interviews with Horror Directors

Understanding the design and creation of horror films can help determine the variables to be changed within the experience as part of the adaptive system. This process will help design the adaptive system, as well as the VR horror experience to ensure adaptation fits into typical tropes and themes of the horror genre. To do this, I conducted structured interviews with 7 film directors who have directed a film within the horror genre, focusing on 4 key areas:

- Their interpretation of the horror genre and approach to creating horror media
- Their understanding of the audience for horror
- Their consideration of the audience journey and engagement
- Their thoughts on adaptation of fear within horror

Structured interviews were chosen to ensure consistency amongst the filmmakers and provide comparability between answers. Guided by the work of psychologists Braun and Clarke, thematic analysis was employed to assess the interview data and identify common codes and themes (Clarke and Braun, 2017). Codes refer to the labels assigned to interesting features from the interview data, and themes are groupings of similar codes based

on patterns. These codes and themes were chosen based on their relevance to understanding the current process of creation and evaluation of horror films from the perspectives of the filmmakers, as well as understanding how they feel adaptation may affect horror films and understanding what adaptation may mean for horror media. I followed a process of refinement with the thematic analysis, starting with familiarisation of the data and an initial coding process. Codes were then refined through combining codes or removing codes with few references. Themes were then generated from the remaining codes, producing 3 themes: dynamic storytelling and creative flexibility, directorial coordination and processes, and managing the audience's journey. The use of thematic analysis in this case allows for an interpretive approach to the data, seeking patterns to inform theoretical understanding of the data.

3.4 Developing the Adaptive Toolkit

The themes identified in the director interviews were synthesised into a practical adaptive toolkit. The purpose of the toolkit was to transfer filmmakers' creative insights into actionable design principles for adaptive VR horror. Rather than functioning as an exhaustive set of rules, the toolkit acted as a flexible framework to guide where and how adaptation could be most effective, ensuring that technical interventions aligned with established creative practices.

The toolkit outlined:

- Which elements of horror (e.g., sound, lighting, atmosphere) are most amenable to adaptive modulation.

- How adaptation should be applied (e.g., modulating intensity rather than altering the narrative structure).
- When adaptation is best introduced in the audience's emotional trajectory (e.g., at moments of heightened tension or calm).
- constraints around adaptation (e.g., preserving narrative coherence and directorial vision).

This toolkit served as the intermediary step between theory and practice, where it is informed by filmmakers, but structured so that it could be operationalised within an adaptive VR system. The subsequent design and development of *A Place for Everyone* drew directly on this toolkit, embedding its principles into both the adaptive system and the artistic direction of the experience.

3.5 Designing and Developing A Place for Everyone

Building on the adaptive toolkit, the design and development of *A Place for Everyone* followed a hybrid form of design and practice-led approach. As the researcher, contributions focused primarily on the technical design, development, and evaluation of *A Place for Everyone*. The artefact was developed alongside my industry partner, AlbinoMosquito, who took the role of the artist for this work. Although research through design (Gaver, 2012) is the overarching methodology for this artefact, elements of performance-led research in the wild (Benford et al., 2013) were embedded within the design and development stages of *A Place for Everyone*. Performance-led research treats live artistic practice and public performance as the basis of

study, where knowledge is generated through iterative making, staging, and audience interaction in real-world contexts. In this project, this was evident in the development of the adaptive system, which I co-designed and iteratively refined through collaboration with AlbinoMosquito and subsequent public festival deployments. To understand how adaptation would work, a process was developed to establish a specific threshold per participant. A user-specific physiological calibration process grounded in a user-centred affective computing approach was employed. Participants viewed four short and distinct VR horror experiences while micromolar data from the Octamon fNIRS device was recorded. To account for individual differences in affective reactivity, a user-specific emotional threshold to fear was calculated by averaging the peak micromolar concentration values per second for each video. This threshold was then used to inform the adaptive system's response to real-time physiological signals during the main VR experience.

3.6 Study 3a: Evaluation of A Place For Everyone: In the Wild Study

Having created *A Place for Everyone*, the adaptive experience was exhibited at film festivals to understand audience responses to the adaptive elements in the context of live viewing. This follows a performance-led research in the wild approach (Benford et al., 2013) to understand the impact of *A Place for Everyone* within an in-situ environment through the public. This is a qualitative, exploratory, lightweight review of the public experience to gather real-world insights into adaptive systems, using *A Place for Everyone* as a case study. The aim is to complement the design and development of the artefact with the empirical research by gathering subjective

feedback after having audience members watch the experience. Subjective feedback was taken in the form of a post-experience interview evaluating how the viewer found the experience in relation to horror, adaptation, and future implications of adaptive systems. As used within the previous interviews with the horror filmmakers, Braun and Clarke's thematic analysis was employed to analyse the interview data. The same approach was also followed as for the horror interview data analysis, beginning by familiarising myself with the data, defining codes, refining the codes, and finally establishing themes.

3.7 Study 3b: Evaluation of A Place for Everyone: Controlled Lab Study

The research aim of this study is to understand how adaptation alters the experience for a viewer. This study involves putting participants through an experience that adapts in response to their fear processing, as established from changes in brain activity in the prefrontal cortex. Participants will include students, researchers and the public. To evaluate the effectiveness of the adaptive system, fNIRS data was collected to check for significance between adaptation and non-adaptation. Additionally, as a potential complementary measure, GSR data was collected to determine any significant responses to fear, looking for any correlation in GSR and fNIRS responses. The hypothesis for this is that the use of adaptation in an experience, as opposed to a non-adaptive experience, can create a more emotional and enjoyable experience. Comparing adaptive and non-adaptive scenes and repeating the same adaptive scene twice can provide insight as to whether this hypothesis is true. Quantitative and qualitative data are gathered,

leading to a mixed methods design.

3.8 Synthesising Results and Identifying Contributions

While each study in this thesis was designed with its own methods and objectives, the overarching methodological approach required that each study's outcomes be brought together into a coherent collective. This process of synthesis was essential for moving beyond individual findings to identify broader insights and contributions. The methodological work did not end with individual analysis, but extended into the comparison, integration, and reflection of the results in relation to the research questions and existing literature.

The synthesis process followed three steps. First, findings were examined within their immediate methodological context. The empirical study on recognising inferences of fear through fNIRS provided evidence of technical feasibility, the interviews with horror filmmakers revealed creative priorities and constraints, and the adaptive VR horror experience demonstrated how these could be operationalised in practice. Second, connections were drawn between these findings, with particular attention to how technical evidence of fear detection informed the toolkit, and how both informed the design of *A Place for Everyone*. Third, the integrated results were reflected upon in relation to the research questions and key themes in the literature, such as the recognition of fear, applications of fear in adaptive storytelling, and the implications for creative practitioners.

This reflective synthesis is central to how the contributions were derived.

The contributions emerged from recognition of patterns, challenges, and possibilities that appeared from the empirical findings, creative insight, and practical deployments. The methodology, therefore, encompasses the collection of data and its integration and critical reflection. This aligns with hybrid design-informed research traditions (Gaver, 2012; Benford et al., 2013), where contributions are generated through both the making of artefacts and the reflective analysis of their implications.

In summary, the act of synthesising across studies forms a methodological bridge to the Discussion and Conclusion chapters. It ensures that the contributions claimed later in the thesis are methodologically grounded in a systematic process of integration and reflection, rather than being claimed retrospectively.

3.9 Ethical Considerations

When conducting research that involves eliciting fear, even within an entertainment context, it is essential to prioritise the psychological well-being and safety of participants. All studies were conducted in accordance with established ethical guidelines, including procedures for informed consent, the right to withdraw at any time, and the careful selection of content to avoid unnecessary distress. All studies were approved through a thorough well defined ethical process with the University of Nottingham ethical board.

For each study, all data was handled securely through a OneDrive within the University of Nottingham to ensure that the data was protected. As some studies contained personal data (including sensitive physiological data), it is important to protect the privacy of the participants. In cases

where personal participant data was collected, a mapping of the participant identifiers was securely stored on the OneDrive. This allowed for anonymisation of all data with a link between different participant data, without easy identification of a participant's collected data. The mappings were later removed after all data had been collected, with participants being aware of this, providing a time frame for them to remove their data if requested.

The horror-based content used in the study was explicitly designed for entertainment purposes and by an experienced horror filmmaker rather than for therapeutic or clinical contexts. As such, potentially triggering content, such as extreme violence, gore, or themes related to social anxiety, was deliberately excluded. This approach aimed to evoke fear in a controlled and ethically responsible manner.

In one study, participants were intentionally left unaware of the adaptive system within *A Place for Everyone* to preserve the validity of their responses. This disclosure was ethically approved and justified on the grounds that revealing the adaptive system could influence participant behaviour, thereby compromising the aims of the study. To address this, participants were fully debriefed following their involvement, including a clear explanation of the adaptive system and the reasons for the initial disclosure. This ensured transparency while maintaining the integrity of the study design.

3.10 Limitations of the Methodological Approach

When working with physiological data and self-reporting, there is potential for the self-reported data to be skewed by an individual's subjectivity. This can be based on participants having difficulty pinpointing reasons for their attitude, hesitation of honest answers based on social desirability, and rationalising answers to questions (Ciuk et al., 2015). If participants fail to provide honest or correct feedback when self-reporting, especially when attempting to align physiological data to an emotion, this may skew the results and provide incorrect data. This is difficult to avoid; however, participant self-reporting was kept anonymous and done in private to reduce the potential influence or impact of environmental factors on the efficacy of the data.

Chapter 4

Study 1: Neurophysiological Experiment on Fear

4.1 Introduction

Ensuring a fearful response is key to making an effective horror experience, and understanding how fear is elicited in different people provides the foundation for designing adaptive systems that can alter the emotional intensity. VR is particularly suited to this task, as its full sensory immersion helps stimulate emotions and can be coupled with physiological sensing through head-mounted displays. Previous research has shown how VEs can elicit fear for therapeutic purposes, such as exposure therapy (de With et al., 2022; Miloff et al., 2016), and studies in entertainment contexts demonstrate that fear in VEs can be effectively stimulated (Voigt-Antons et al., 2021; Lin, 2017). However, far less work has explored how fear can be recognised and adaptive to in real-time within VR for entertainment applications, despite the games industry being a rapidly growing market, with VR projected to rise from $1.6 billion in 2022 to $2.4 billion in 2024

(Statista, 2021).

Recent studies applying adaptation in horror VEs (Zaib and Yamamura, 2022; de Lima et al., 2020, 2022) suggest that dynamically adjusting content based on physiology can heighten immersion and intensity. Yet these approaches often rely on peripheral measures, such as HR or GSR, which capture arousal but do not provide insight into underlying neural processing. By contrast, fNIRS measures blood oxygenation changes in the cortex, offering spatial resolution to localise brain activity while remaining portable and more movement-tolerant than other neuromaging techniques, such as EEG. Importantly, fNIRS sensors align with regions in contact with VR headsets, making them promising for integration into consumer experiences.

This chapter presents a within-subject study using fNIRS to compare brain activity in calm and fearful VR conditions, aiming to establish a detectable brain region for fear processing that can support adaptive VR horror. Thirty-five participants (n = 35) experienced alternating calm and fear-inducing environments, and their fNIRS data were analysed to detect differences in activation. The study specifically examined the left DLPFC, a region previously associated with fear processing (Landowska et al., 2018), alongside self-reported measures of fear. Two hypotheses guided the study:

- Fear can be inferred from distinct physiological markers in fNIRS brain activity patterns.
- Higher levels of fear reported by individuals will positively correlate with increased fNIRS activation in relevant brain regions.

Results revealed significant changes in activity within the left DLPFC under fearful conditions compared to calm, confirming fNIRS as a viable measure

for recognising fear in VR. These findings provide a critical foundation for the rest of the thesis; without reliable detection of fear processing, an adaptive system would not be possible. The contributions of this study are as follows:

- The identification of a significant difference in hemodynamic response in the left DLPFC when comparing calm and fearful conditions using VEs. This ensures the study is in line with existing research resulting from fNIRS analysis of fear processing.
- The future implications for the use of the measured fear response in adaptive VR horror experiences to personalise a participant's emotional trajectory in real time.

4.2 Methodology

A within-subject study was conducted to investigate whether calm and fearful conditions create a significant difference in brain activation, measurable using a portable research-grade fNIRS. Subjective feedback was gathered between conditions to provide comparable results to those of the fNIRS measurements. The following hypotheses are proposed:

- H1: There will be a significant difference in brain activity between the calm and fear conditions.
- H2: There will be a significant difference in subjective data reporting of arousal, valence, and dominance when comparing the calm and fear conditions.

An experimental model was followed, outlined by Putze et al., that defines

a series of guidelines for reporting on brain signals within HCI practices. The model outlines 6 categories which are *technical aspects of recording*, *task description*, *participants*, *experiment flow*, *data processing*, and *brain signal integration* (Putze et al., 2022). For coherence with existing terminology within this study, these exact terms were not adhered to, but instead followed the same concepts.

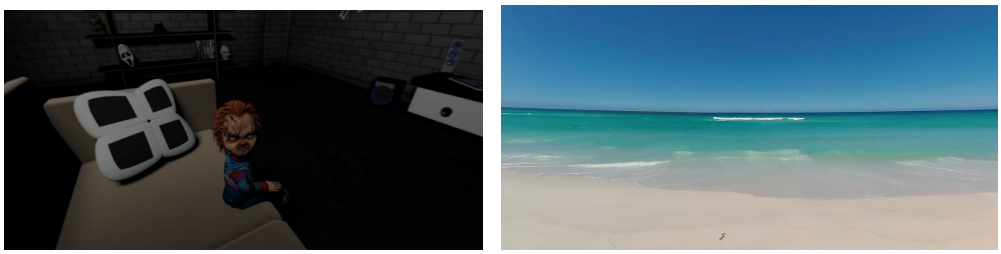
4.2.1 Study Conditions

As the focus of this study is understanding fear, 'calm' was chosen as the comparison state based on Russel's Circumplex Model of Affect as shown in Figure 2.1 (Russell, 1980). This model is a frequently cited and robust depiction of basic emotional states that can be detected using fNIRS. It also operates on only two axes, which makes it suitable for both the simple data that fNIRS can provide and for the quantitative data that is to be collected.

This model plots emotions on a graph of valence against arousal. Valence refers to the positivity of an emotion, while arousal refers to its intensity. Russel placed fear within the sector of low valence and high arousal, and calm within the sector of high valence and low arousal, directly opposite fear. In Russell's model, valence and arousal overlap to form a two-dimensional space where emotions are organised according to their positivity and intensity, allowing ratings to be placed within this model. A VE was created that was intended to be rated according to valence, arousal and dominance in the hopes of measuring responses to fear and calm. 'Dominance' is taken from the Self-Assessment Mannequin (Bradley and Lang, 1994) and measures the degree of control a participant feels over their emotions. Heightened levels of fear would be expected to correlate

with lower levels of dominance, as the person does not feel in control of the fears they might be subjected to. This model is particularly important when trying to match participants' physiological data to their self-reported experience.

Conditions are represented through 360-degree videos within VR. For the sake of obtaining the best quality fNIRS data in this initial study, these videos were non-interactive, and participants were limited to 3 degrees of freedom (no walking). The calm condition contains scenic visuals of beaches, forests, underwater, and mountains, accompanied by relaxing audio typically used in meditation. For the fear condition, scenes contained a mixture of elements commonly found within horror media. These include low to no lighting, unsettling environments, inhuman creatures, objects used to jump-scare participants, and unnerving sound effects. Videos contained minimal to no movement to minimise sensory conflict and possible motion sickness. Not only is motion sickness a concern for a participant's health, but it can also affect physiological feedback and therefore, was mitigated as much as possible (Pöhlmann et al., 2023). Figure 4.1a shows a low-lighting fear condition, while figure 4.1b below shows a relaxing beach scene from one of the calm conditions.



(a) Fear Video Example (b) Calm Video Example

Figure 4.1: Examples of the fear and calm videos. (a) shows a low-lighting fear condition, and (b) shows a relaxing beach scene from one of the calm conditions.

The context of fear is an important factor when analysing the results.

Different fear contexts, such as body horror and suspense, are aimed at triggering different responses surrounding fear. These responses can include disgust, anxiety, dread and terror. The fear conditions presented to participants aimed to produce a difference in fear response, with video 1 being visual and suspense-oriented, video 2 audio and unease-based, and video 3 focused on gore/body horror.

Independent Variables

- Condition State: A 360° video segment corresponding to the next condition, calm or fear, is played for 3 minutes. 3 minutes is chosen to resemble the potentially longer duration of scenes within the VR horror experience, as well as accommodating typical neuroscience study settings (Somech et al., 2022). The video order is set out as calm, fear, calm, fear, calm, fear. The order aims to provide respite for participants from the fear condition and allow comparison of measurements from fear to calm and calm to fear.

- Rest State: A view with a white background and a black cross straight ahead. This state requires the participant to rest and clear their mind for 30 seconds ±5 seconds for variability. This is designed to reduce the crossover of physiology between conditions to get more accurate measurements, and to return the participant to a baseline recording after the interactive and cognitive nature of the feedback state (below). The use of a 30-second rest period is supported by other academic studies (Kato et al., 2018; Sudo et al., 2017; Ando et al., 2010; Chen et al., 2017) with one study finding 30 seconds to produce the greatest haemodynamic response when compared to shorter and longer rest periods (Obrig et al., 1997).

- Feedback State: A series of questions relating to the experience presented in the video from the most recent condition and an assessment of the participant's physiology within the video.

Dependent Variables

- fNIRS data: Gathered using the Octamon wireless fNIRS system from Artinis Medical Systems (Artinis Medical Systems, 2018*b*). The fNIRS data is compared across conditions to identify any significance in changes of haemodynamic response from one condition to another.

- Self-reported data: This included a questionnaire about: *Emotion Effectiveness* - how effective each video was at eliciting the emotion expected of the video (fearful or calming); *Motion Sickness* - how motion sick the participant felt during the video stimuli; and a Self-Assessment Mannequin (Bradley and Lang, 1994) which collects participant values of valence, arousal, and dominance in each condition to be compared between conditions and participants.

4.2.2 Study Procedure

Before being placed in VR, the participant is asked about their prior experience with VR. Understanding a participant's familiarity with VR helps determine if they are aware of what to expect and can be further informed if necessary. The Octamon is then placed correctly on the participant's prefrontal cortex as well as the HMD, and they are presented with the resting screen view and are ready to begin the experience. Whilst within the experience, real-world interaction with participants is kept to a minimum where possible. Only during the feedback state could conversation

happen if required. If a participant has issues or wishes to withdraw, they are reminded that they can reach out at any point to stop the study, keeping participant safety as the highest priority. Each condition contains 3 different videos, 6 total, taken from YouTube, with an alternating viewing of calm condition (C) and then fear condition (F): C, F, C, F, C, F. This ordering was fixed, rather than random, to ensure the next condition was always different to the previous condition: calm to fear and fear to calm. There is no intended overlap of conditions, meaning that the calm condition is focused only on inducing a calm emotive response, whilst fear is focused on a fearful response.

Within each condition (calm or fear), participants progressed through three different states: the rest state, the condition state, and the feedback state. The use of states helps to maintain a consistent flow of the study across all participants. Throughout the experience, when a participant moves from one state to the next, for example, going from a rest period to a video condition, the beginning of this state is captured as an event. Events use a key entry to capture moments in time. These events are then used within the analysis to separate the conditions, analysing only the measurements captured within the 3-minute segment after each calm and fearful video event trigger. When the final video is finished, the participant completes the feedback state for that video, and the experience ends. For the feedback state, the participant is asked questions about how fearful or calming the participant found the video and how motion sick it made them feel. After these, participants fill in a self-assessment mannequin. This provides a series of questions aimed at understanding their valence, arousal, and dominance within the video. All questions are answered through VR, using a controller to point and select each option before continuing. This is the only moment within the experience that a participant is given a controller

for interaction. Once all conditions have been completed, participants are then taken out of the VR experience, ending physiological recordings and the study.

4.2.3 Technology setup

To measure brain activity changes in combination with the Oculus Quest 2 VR headset, the Octamon wireless fNIRS system from Artinis Medical Systems was used (Artinis Medical Systems, 2018*b*). The Octamon is a wearable, non-invasive fNIRS device that captures relative changes in HbO and HbR levels in the brain. The Octamon has a flat, low profile, and it is designed to cover participants' foreheads, making it highly suitable in combination with the VR Headset. Observing the Octamon alongside other fNIRS headsets, other available devices, such as the Brite (Artinis Medical Systems, 2018*a*), offer wider spatial resolution than the Octamon through the use of a full head cap. However, this provides issues for combined use with VR. A full head cap with a VR headset would apply pressure on sensors on the top of the head. Additionally, a full head cap is much less accessible for varied hair types. The Octamon covers the prefrontal cortex, removing these constraints at the cost of spatial resolution. Based on previous research, however (Landowska et al., 2018; Pöhlmann et al., 2023), there is validity in using the Octamon, and hence it is chosen for the work of this thesis.

4.2.4 Participants

Ethical approval was granted by the Research Ethics Committee at the University of Nottingham. Thirty-five (n = 35) participants with a variety

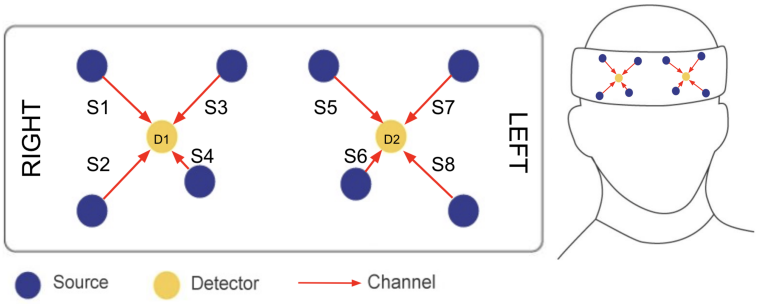


Figure 4.2: Octamon setup using 8 light sources (S1 - S8) and 2 detectors (D1 - D2) with 2 short separation channels (S4 and S6).

of interests towards the horror genre were recruited from the University of Nottingham, School of Computer Science. Demographics consisted of 13 male, 14 female, and 8 who chose not to declare. Participants consisted of an average age of 22.3, ranging between 19 to 44.

4.2.5 Subjective Feedback Questionnaire

Participants rated the self-assessment mannequin on a scale of 1 to 5, 1 being not calming/fearful or motion sick, and 5 being very calming/fearful or motion sick. Emotion effectiveness provides insight into how effective the condition was at eliciting the desired emotion, whilst motion sickness, as previously mentioned, can interfere with physiological feedback if too high. For a more thorough qualitative description, the Self-Assessment Mannequin was used (Bradley and Lang, 1994), which has participants measure their valence, arousal, and dominance in each VE on a non-verbal pictorial scale. Each question aims to provide comparative data for conditions per participant.

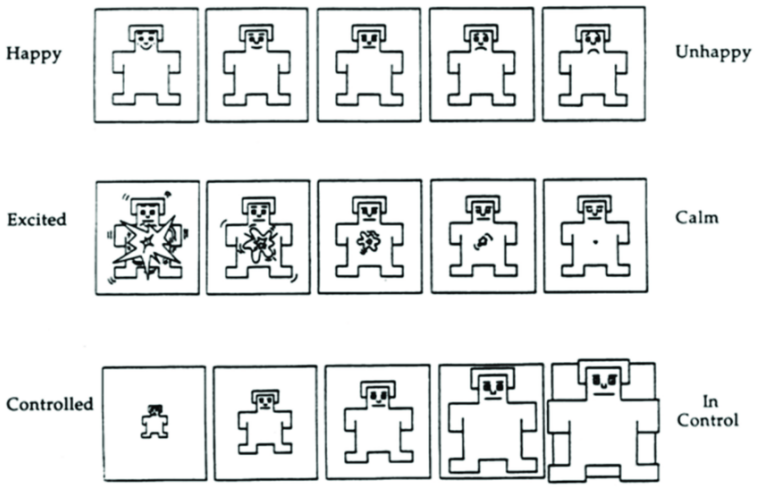


Figure 4.3: The Self-Assessment Mannequin used within the VE. The top row refers to valence, the second row refers to arousal, and the bottom row refers to dominance.

4.2.6 fNIRS Data Collection

The Octamon was placed on each participant's frontal cortex, approximately over the forehead, just above the eyebrows. Data capture was done through data channels, each of which consists of an infrared light source and a nearby detector. Eight light sources (S1 - S8) were used with 2 detectors (D1 - D2). The optodes were positioned on each participant's forehead as shown in Figure 4.2. Six sources were placed at a distance of 35mm, while two sources, S4 and S6, were placed at a distance of 10mm, creating two short separation channels. The Octamon emitters used 760 nm and 850 nm wavelengths while data was acquired at 10 Hz. To capture event markers, upon the trigger of a condition, they were manually inserted during experimentation. The data was recorded using the Oxysoft software provided by Artinis Medical Systems (Artinis Medical Systems, 2019).

4.2.7 fNIRS Data Processing

The analysis follows a similar method to that of Pöhlmann et al. (Pöhlmann et al., 2023). They used the same device and setup. Even though their study and my own are analysing different conditions, their study provided validity for this device and setup. To analyse the fNIRS data, NIRS Toolbox was used (Santosa et al., 2018). Initially data was down-sampled from 10Hz to 4Hz before being converted to optical density changes. Beer-Lambert law was used to convert the signals into HbO and HbR estimates (Strangman et al., 2003), preparing the data for analysis. The toolbox employs the AR-IRLS method to address motion artefacts and physiological noise, supplemented by the use of short separation channels.

To then analyse the data, the general linear model (GLM) was used in conjunction with a BoxCar function, which estimates the hemodynamic response in separation of the systemic physiological interference, cleaning noise in the data (von Lühmann et al., 2020). The boxcar function was chosen despite its lower sensitivity due to the block duration of 180 seconds. This was due to our limited ability to predict the exact timing of the hemodynamic response. By using the boxcar function, the focus was on simply identifying whether or not there was a response to the stimuli, rather than its precise timing (Landowska et al., 2018). Although 180 seconds is not a typical duration for the use of GLM, previous research has shown that this approach is viable (Pöhlmann et al., 2023).

Group analysis was also performed using a mixed effect model (Tak and Ye, 2014), which combines the use of a fixed effect model and random effect model, with the following formula: beta -1 + cond + (1—subject). False discovery rate (FDR) correction was also applied with a significance level of $q \leq 0.05$. Only channels showing a significant negative correlation

between haemoglobin species - HbO and HbR, were considered significant (Cui et al., 2010). Contrast analysis was then applied between each condition to observe the differences.

4.3 Results

Below, the subjective results are presented to demonstrate that the conditions instigated the correct responses, and then the fNIRS results; identifying regions of significant change in oxygenation in the observed parts of the brain.

4.3.1 Subjective Feedback Analysis Results

Analysis of the post-video subjective feedback shows a comparison of each condition's impact on emotion effectiveness, valence, arousal, dominance, and motion sickness. Figure 4.4 compares the results between the calm and fear conditions across all participants.

For each video sample, self-reported data provided insight into the following: *Emotion Effectiveness* - how effective each video was at eliciting the emotion expected of the video (fearful or calming), *Motion Sickness* - how motion sick the participant felt during the video stimuli, and a scale of *Valence*, *Arousal*, and *Dominance*. Comparing the two conditions as shown within Figure 4.4, the calm condition was seen as being more effective at inducing calm than the fear condition was at inducing fear. Motion sickness was rated low for both conditions, showing little to no impact of motion sickness on participants. This was included to make sure fNIRS data was not conflicted by the experience of motion sickness (Pöhlmann et al., 2023).

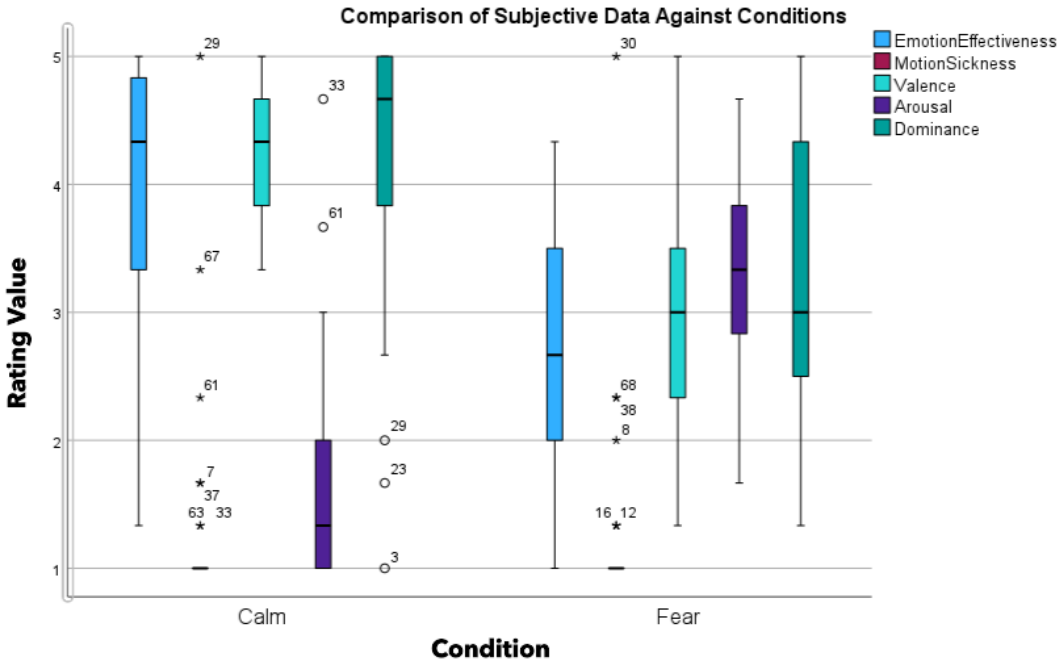


Figure 4.4: Results of the subjective feedback data analysis aggregating each condition per participant. Left to right per condition shows emotion effectiveness, motion sickness, valence, arousal, and dominance. The error bars extending from the boxplot represent the first and third quartiles to the smallest or largest data points, respectively, within 1.5 times the interquartile range. This provides a visualisation of the data's spread, with outliers appearing as separate data points.

For valence, arousal, and dominance, fear was rated with higher arousal and lower valence and dominance when compared to calm. This reflects that, with Russel's Circumplex Model in Figure 2.1, both conditions were rated as expected of their emotions.

A series of Wilcoxon signed-rank tests were conducted to determine significant differences between conditions (calm and fear) in the subjective data. As each participant watched 6 videos, there were 105 samples of self-reported data per condition. All 210 samples have been represented within the box plot Figure 4.4. As the self-reported data is non-parametric comparing two conditions, this fits the criteria of the Wilcoxon signed-rank tests compared to other tests such as the paired samples t-test (Ross and Willson, 2017).

Emotion Effectiveness. Of the 105 samples, the calm condition was rated as having a higher impact on the expected emotion (Mean = 4.02, SD = 1.02) than the fear condition, with only a few examples of the fear condition being rated higher (Mean = 2.79, SD = 0.98). A Wilcoxon signed-rank test determined a statistically significant decrease in emotional effectiveness when subjects were within the fear condition compared to the calm condition, z = -4.514, $p < .001$. These results indicate that the calm condition was seen as being more calming than the fear condition was fearful.

Motion Sickness. No statistically significant difference was found in participants' experience of motion sickness between the two study conditions (calm condition: Mean = 1.28, SD = 0.80; and fear condition: Mean = 1.25, SD = 0.74).

Valence. The calm condition was rated as having a higher valence (Mean = 4.28, SD = 0.57) than the fear condition (Mean = 3.01, SD = 0.94). A Wilcoxon signed-rank test determined that there was a statistically significant decrease in valence when subjects were within the fear condition compared to the calm condition, $z = -4.632, p < .001$.

Arousal. The calm condition was rated as having a lower arousal (Mean = 1.70, SD = 0.87) than the fear condition (Mean = 3.29, SD = 0.81). A Wilcoxon signed-rank test determined that there was a statistically significant increase in arousal when subjects were within the fear condition compared to the calm condition, $z = -4.883, p < .001$.

Dominance. The calm condition was rated as having a higher dominance (Mean = 4.18, SD = 1.00) than the fear condition (Mean = 3.33, SD = 1.11). A Wilcoxon signed-rank test determined a statistically significant decrease in dominance when subjects were within the fear condition compared to the calm condition, $z = -3.775, p < .001$.

For the calm condition, these results show that on average, participants were happy, relaxed, and in control of their emotional state. For the fear condition, these results show that on average, the participants were neither happy nor sad, somewhat aroused, and somewhat in control of their emotional state.

Following the individual category analysis, the aggregated subjective data were paired based on conditions. The paired data is visualised in a box plot in Figure 4.5.

This shows that the calm condition, on average, was rated higher overall compared to the fear condition. The categories included were emotion effectiveness, motion sickness, valence, arousal, and dominance. The t-test results can be seen in Table 4.1

Table 4.1: T-test results from the aggregated subjective data paired based on conditions.

Statistic	Parameter	P Value	Confidence Interval Lower	Confidence Interval Upper	Mean Difference
4.80326784	34	3.08594E-05	0.206586493	0.509603983	0.358095238

Broadly, there results show that the difference between the two conditions is statistically significant. Based on the results of both analysis approaches, subjective data indeed showed significant differences between the two states; hence, the null hypothesis was rejected and H2 was accepted.

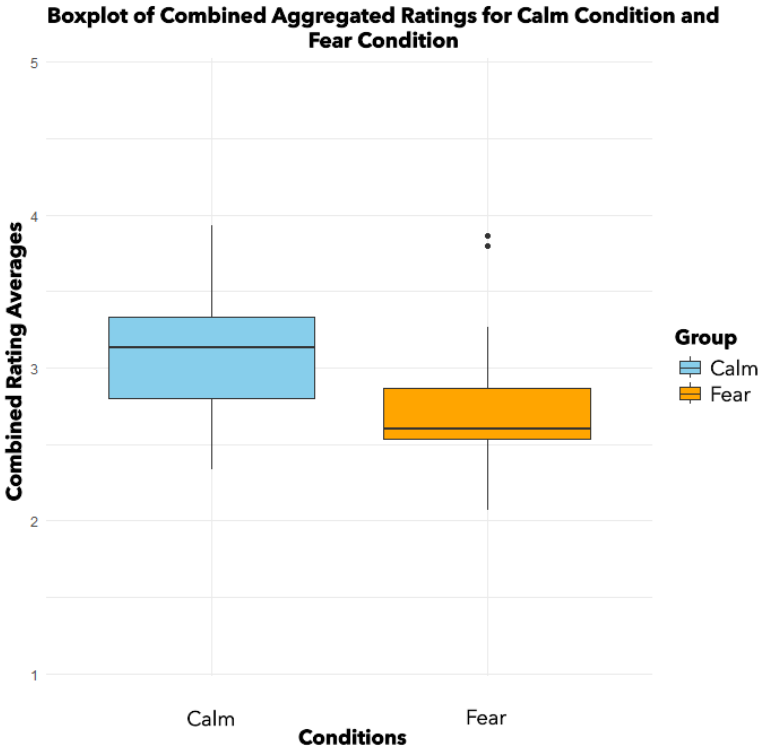


Figure 4.5: A box plot of the paired subjective data based on the conditions. Overall, the subjective results for the calm condition were, on average, higher than the fear condition results. The error bars extending from the box plot represent the first and third quartiles to the smallest or largest data points, respectively, within 1.5 times the interquartile range. This provides a visualisation of the data's spread, with outliers appearing as separate data points.

4.3.2 Functional Near-Infrared Spectroscopy

fNIRS results indicate a significant change in brain activation in the left dorsolateral prefrontal cortex (DLPFC) when comparing the calm condition and fear condition results. Figure 4.6 and Table 4.2 show significant changes in both HbO (increase) and HbR (decrease) when comparing the transition from a calm condition to a fearful condition. The left DLPFC is represented by the sector D2 - S8. No significant reverse correlations (HbO and HbR) were found in any other brain regions.

In line with our hypothesis H1, these results indicated that there was indeed a significant difference in brain activation measured with fNIRS between

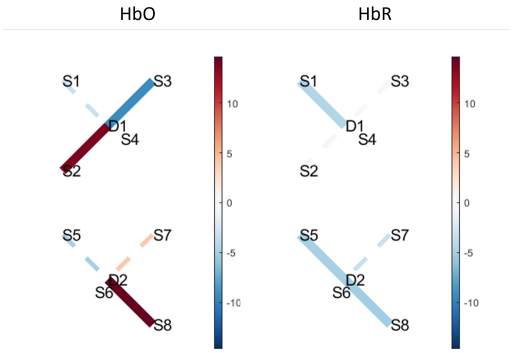


Figure 4.6: Results of the contrast analysis for sector D2 - S8 showing a comparison of fNIRS data during the transition from a calm condition to fear conditions. Solid lines within the same area on both HbO and HbR represent a significant channel (source-detector pairs) with beta values (q ¡ 0.05) after adjusting for multiple comparisons using FDR correction. Significant differences were observed in D2 - S8 (left DLPFC).

calm and fear conditions; hence, the null hypothesis is rejected and H1 is accepted.

Table 4.2: Statistically significant fNIRS results for 180 seconds analysis when comparing both the calm and fear conditions within the sector D2 - S8. There is a statistical significance for HbR in Calm and HbO in fear.

Source	Detector	Type	Condition	Beta	SE	tstat	p	q
S8	D2	'hbo'	'Calm'	-3.3050	3.0574	-1.0810	0.2835	0.5234
S8	D2	'hbr'	'Calm'	2.9687	1.4822	2.0029	0.04918	0.1475
S8	D2	'hbo'	'Fear'	11.8332	3.0946	3.8238	0.0003	0.0035
S8	D2	'hbr'	'Fear'	-2.4051	1.5053	-1.5978	0.1147	0.2402

4.3.3 Combined Correlation Analysis of fNIRS and Subjective Feedback

Following the results of both the subjective data and the fNIRS data, correlation analysis was performed, comparing the fNIRS beta values per participant within the region D2 - S8 with the average subjective feedback per participant. Spearman's rank correlation was used to provide both correlation coefficient and p-values for comparison. The coefficient values

can be seen in Figure 4.7. Looking at the results, the area of interest is the comparison of the fNIRS fear condition beta values (Fear - HbO and Fear - HbR) to the subjective fear values within the bottom left quadrant. The HbO values here show positive correlations for emotion and arousal and a negative correlation for valence. This shows that higher measures of HbO for a participant during the fear condition had an increase in their subjective feedback of emotion and arousal and a decrease in their valence. These correlations are reflective of the significance of the channel D2 - S8 showing support for an increase in HbO, having the effect of an increase in reported fear. Looking at the HbR measures, the correlations are the opposite, with emotion and arousal being negatively correlated and valence being positively correlated. This further supports the findings of HbO and HbR of D2 - S8 relating to a fear response.

	Calm - HbO	Calm - HbR	Calm - Emotion	Calm - MotionSickness	Calm - Valence	Calm - Arousal	Calm - Dominance
Calm - HbO	1	0.166106443	0.105923195	-0.247014546	-0.022595716	-0.3226608	-0.068785982
Calm - HbR	0.166106443	1	-0.056369314	-0.246012052	0.186772183	-0.085889164	0.397239048
Calm - Emotion	0.105923195	-0.05636931	1	-0.091265916	0.602697652	-0.234632469	-0.14731505
Calm - MotionSickness	-0.24701455	-0.24601205	-0.091265916	1	0.106970825	0.328741259	-0.092316909
Calm - Valence	-0.02259572	0.186772183	0.602697652	0.106970825	1	-0.037081721	0.194615568
Calm - Arousal	-0.3226608	-0.08588916	-0.234632469	0.328741259	-0.037081721	1	-0.126660791
Calm - Dominance	-0.06878598	0.397239048	-0.14731505	-0.092316909	0.194615568	-0.126660791	1
	Fear - HbO	Fear - HbR	Fear - Emotion	Fear - MotionSickness	Fear - Valence	Fear - Arousal	Fear - Dominance
Fear - HbO	1	-0.17927171	0.14557777	0.097684992	-0.10129647	0.157265051	-0.0926785
Fear - HbR	-0.17927171	1	-0.209276853	0.083443443	0.320560238	-0.024162016	0.279024447
Fear - Emotion	0.14557777	-0.20927685	1	0.251685555	-0.594002833	0.65657439	-0.860760358
Fear - MotionSickness	0.097684992	0.083443443	0.251685555	1	-0.040669451	0.243039665	-0.174413267
Fear - Valence	-0.10129647	0.320560238	-0.594002833	-0.040669451	1	-0.340293618	0.751389483
Fear - Arousal	0.157265051	-0.02416202	0.65657439	0.243039665	-0.340293618	1	-0.609321557
Fear - Dominance	-0.0926785	0.279024447	-0.860760358	-0.174413267	0.751389483	-0.609321557	1

Figure 4.7: Results of the Spearman correlation coefficient and P values (highlighted in green for statistically significant results) comparing fNIRS (HbO and HbR) beta values per participant alongside the subjective feedback per participant. The results of interest for fear are highlighted in orange. A positive correlation can be seen for Fear - HbO alongside Fear - Emotion and Fear - Arousal, and a negative correlation for Fear - HbO and Fear - Valence. Conversely, a negative correlation can be seen for Fear - HbR alongside Fear - Emotion and Fear - Arousal and a positive correlation for Fear - HbR and Fear - Valence. Referring now to P values, looking at Fear - HbO and Fear - HbR, there is no significance for any of the subjective data.

The p-values of the results can also be seen in Figure 4.7. Looking at the bottom right quadrant for fear, the p-values that show significance (p ¡

0.05) are highlighted in green. From the results, there are no values for the fear condition for either HbO or HbR that show significance compared to the subjective data. This suggests that there is a correlation that supports the argument of a fear response being detectable within the area D2 - S8, supporting hypothesis 3: Higher levels of fear reported by individuals will positively correlate with increased fNIRS activation in relevant brain regions. However, more data is needed before any significance can be found.

4.4 Discussion

The findings are now examined through three specific lenses concerning the study results: Implications of fNIRS Results for Understanding Fear, Opening the Design Space, and Ethics.

4.4.1 Implications of fNIRS Results for Understanding Fear

The study presented above found that fear processing can be observed in the left dorsolateral prefrontal cortex (DLPFC). This finding is in line with previous studies, such as those by Landowska et al (Landowska et al., 2018) where fear responses from participants during a VR exposure therapy study showed changes in HbO and HbR within the left DLPFC in response to a specific fear stimulus onset (heights). This study validates and expands upon Landowska et al.'s results by investigating fear (and calm) from the perspective of non-interactive immersive media. By providing multiple scenarios of extrinsic fears through horror videos, focusing on more traditional fears used in horror media, insight has been provided into fear from a more

generalised viewpoint than aiming at a specific stimulus onset.

These results also provide evidence to support hypothesis 1: An individual's level of fear can be reliably identified using specific measurable data. With this research, a real-time setting can be understood for immersive media, using fear, to adapt a fearful VR in response to an individual's brain activity. It can further be inferred (Landowska et al., 2018) that occurrences of fear are not being precisely detected, but rather the processing of it is being detected, since the prefrontal cortex is concerned with the processing of emotion (Dixon et al., 2017). When participants are subjected to fearful stimuli, the effects can be seen in the prefrontal cortex, which attempts to exert control over the amygdala. So what is being detected is people's attempt to 'handle' the fearful stimulus. A detectable indicator of fear is present in the neural pipeline, accessible at the surface level through fNIRS. However, there is no discrimination of the 'level' of this fear. Its presence can be detected, but we can't reasonably determine the 'type' of fear.

Looking at the subjective results, because these are presented on a scale, the 'fear' emotion can be more precisely placed within Russell's Circumplex Model of Affect (Russell and Mehrabian, 1977), which is predicated on having a value for arousal and a value for valence, wherein the combination of these allows you to position an emotion: for example, low valence and high arousal suggests terror or perhaps disgust. (POSNER et al., 2005). Our model is more crude than that, but also more specific. Rather than inferring emotion from valence and arousal, a specific area of the DLPFC can be associated with fear. The use of valence and arousal is useful, however, for decoding fNIRS results in understanding the affective state of a participant (Ruotsalo et al., 2023) as fNIRS measures are separate from valence and arousal.

Observing the cross-analysis of fNIRS and subjective data, correlations supporting fear processing can be seen with expected subjective ratings, with fear HbO showing a positive correlation on arousal and emotion rating and a negative correlation on valence. This connects with Russel's Circumplex model (Russell and Mehrabian, 1977) and shows that the readings observed through fNIRS can arguably be placed within the sector of what is stated as fear. When understanding the significance of these results, however, there was no significance observed within HbO or HbR for fear when compared with emotion, valence, or arousal. Previous studies show that brain signals and self-reports do not always align (Rimbert et al., 2019; Grassini and Laumann, 2020), which can provide some context as to these results.

One of the challenges for technology working with Russel's Circumplex model (Russell and Mehrabian, 1977) is that while it is fairly easy to capture arousal through a range of sensors (heart rate, electrodermal activity, skin temperature, blood pressure, EEG, etc.) (Cacioppo et al., 2007), it is much more challenging to detect valence. Often this is self-reported, and sometimes computer vision is used (Valstar and Pantic, 2006; Benford et al., 2022) to analyse facial expressions, or audio processing to analyse speech patterns. For example, in (Trigeorgis et al., 2016), the authors note that "[valence is] much more difficult to predict from speech compared to arousal". Hence, these approaches are not especially robust. They depend on users' emoting, and as seen in (Benford et al., 2022), users often do not emote through expression to detectable or comparable degrees. Emoting is also highly culturally influenced (Engelmann and Pogosyan, 2013). People also tend to emote less when consuming content alone, as emoting is a significant social cue (Haxby and Ida Gobbini, 2007). Thus, it is often seen as noncontextualized arousal.

It might be reasonable to infer from what somebody is doing as to what

the arousal means, but it can be quite ambiguous, high arousal on a roller coaster might mean terror or joy or excitement or several other emotions that are high on the arousal axis in Russel's Circumplex model. Knowing someone is on a roller coaster is only part of the story because our experiences are so driven by both experience and immediate bodily context. Our feelings about a ride on a roller coaster may be very different before and after a big lunch! Returning to our findings, and moving us away from Russel's Circumplex, instead, there is a recognition that fear is being processed. If combined with arousal, this may then allow for the contextualisation of arousal with the specific label of 'fear' and now use that arousal to scale between nervous and terrified, covering a range of emotions within the broad category of fear. The latter Section 7.3 provides the initial steps for this by measuring arousal through GSR combined with fNIRS.

4.4.2 Opening the Design Space

This foundational work opens up opportunities through the ability to detect fear processing. The HCI literature is well established concerning bioresponsive experiences. Taking games as an example, there is a range of examples that respond to arousal, for example, in (Dekker and Champion, 2007), the game difficulty changes based on galvanic skin response-measured arousal to add more or fewer zombies as the player becomes more or less aroused. Similarly, many games use heart rate to in some way moderate difficulty, for example (Ninaus et al., 2019). Other systems use biofeedback not to control the difficulty but as a core mechanic, for example, brainball (Hjelm and Browall, 2000), which introduced the 'relax to win' genre of biofeedback games and invites the player to win by being calmer than their opponent.

It is suggested that it may be possible to personalise games not just in gross terms of difficulty but more narratively, by recognising which aspects of a game introduce a fear response, then dynamically tailoring the narratives to increase or decrease instances of fear. In a world where different people want different things out of their entertainment, adaptation of this 'fear factor' may be very desirable. A well-designed narrative will take people through a trajectory of fear back and forth through climax and catharsis (Benford et al., 2012). Tailoring direct experience and manipulating stimuli in response to detected fear may paradoxically make it more possible to match canonical with user trajectories, i.e., creator intentions based on assumptions about typical audiences with actual individual audience experiences (Benford and Giannachi, 2011).

It is not just games that would benefit from adaptations of these trajectories. Ramchurn et al.'s work on brain-controlled movies (Ramchurn, Martindale, Wilson, Benford and Chamberlain, 2019) shows the opportunity for adaptation of a movie experience based on neurological responses. Applying fear responsiveness in this context is taken forward in this thesis through the design of a horror experience that dynamically responds to an audience's fear levels, to ensure a level of fear in line with their acceptable amount of fear. The ability to sense fear processing underpins the design of the adaptive VR horror experinece developer in later chapters, which adapts horror content to an individual, in real-time. The use of brain-adaptive content in this design space raises opportunities within artistic and design domains.

Outside the entertainment industry, there are other opportunities. There has been much scholarly work around the use of VR for exposure therapy. A meta-analysis of VR exposure therapy for anxiety conducted as far back as 2008 suggested that VR exposure therapy worked slightly more effectively

than in vivo treatment (Powers and Emmelkamp, 2008). The opportunity to objectively measure the success of exposure therapy, as also suggested by (Landowska et al., 2018), should be of value to practitioners. Similarly, VE is used extensively in training, such as fire safety training within companies (Morélot et al., 2021). It may be desirable to make such training 'realistic' in various ways, for example, Lawson et al. used heat and smell to add to the realism of their training (Lawson et al., 2019). It is posited that measuring whether a genuine fear response in these cases might be useful for validating their real-world simulation efficacy.

4.4.3 Ethics

A reasonable first response to technology for detecting fear would be concern about the ethical implications. This is acknowledged; however, the following considerations are proposed. Firstly, people demonstrably enjoy being scared. The global market for horror games, movies, thrill rides, immersive experiences, books, and more makes this an undeniable fact. Our measurement approach seeks to enhance our ability to deliver fearful experiences. Secondly, making uncomfortable experiences is not necessarily a bad thing. Benford et al. showed (Benford et al., 2012) that there was a strong case from both a designer and an audience perspective for supporting the development of uncomfortable interactions as long as designers consider factors like informed consent, right to withdraw, privacy and risk management. This work can be seen as the enabler for the development of uncomfortable interactions, and the foundational work for adapting such content. For this content to be possible, it would be necessary to be able to measure fear and change or end the experience if it is met. Thirdly, HCI is notoriously risk-averse, but as Marshall et al. suggest, (Marshall

et al., 2023), there is a design opportunity in risk. As they suggest reframing traditional approaches to risk as 'adventure', it is suggested that the creation of fearful experiences might be 'adventurous'. Finally, of course there is the opportunity for malicious use of any technology, but putting that aside, since we've established that it might be desirable to be scared, and its been further established that design for discomfort is not inherently problematical, then taking a responsible research and innovation approach it is arguably more ethical to develop technologies that can recognise fear and help users to avoid it, or amplify that fear depending on their informed preferences and choices. Instead of allowing fear to disempower users, offering control over that fear as empowering: after all, as Mark Twain once put it, "Courage is not the absence of fear, but the mastery of it".

4.5 Limitations and Future Directions

Although the choice for study design involved the alternation of calm and fear conditions, the study is restricted by always starting with a calm condition, which may affect results. Moving forward, further studies will introduce a random approach to ensure that the start condition is not always the same. Additionally, for study design, a common approach to using GLM for analysis of fNIRS data is for conditions to be in 60-second segments. The approach used for this study, however, used 180-second segments due to the nature of the fear condition, taking a horror media approach of including tension and suspense, rather than immediate jump scares and attempts of surprise. Another study has shown that the use of 180-second conditions with GLM can also find significance in results (Pöhlmann et al., 2023).

Although the choice for study design involved the alternation of calm and

fear conditions, the study is restricted by always starting with a calm condition, which may affect results. Moving forward, further studies will introduce counterbalancing to ensure that the start condition is not always the same.

As previously mentioned in section 4.4.1, no significant correlation was found between fNIRS signals and subjective fear ratings. This might be due to differences in how people feel and report fear, the accuracy of brain measurements, or timing issues. Previous studies show that brain signals and self-reports do not always align (Rimbert et al., 2019; Grassini and Laumann, 2020). To understand this further, future research will be conducted with more participants following a similar study design to further understand the possible relation between the subjective feedback and fNIRS response. Additionally, later chapters of this thesis apply these findings to the adaptation of a VR horror experience (See Chapter **??**). Focusing on measurements obtained from the left DLPFC, through this thesis I create an experience that is capable of understanding a fear response and altering the fear trajectory to establish a consistent level of personal fear amongst all individuals who take part in the experience.

4.6 Conclusion

The study discussed within this chapter showed that the comparison of fear and calm as presented in a VE caused a significant difference in blood-oxygen levels within the left dorsolateral prefrontal cortex. Comparing the brain activity of a calm condition to a fearful condition created a significant increase in HbO within the D2-S8 sector and a significant decrease in HbR, as represented in Figure 4.2. Subjective feedback provided results indicative

of a calm emotional state for the calm condition and towards a level of fear for the fear condition.

Through a cross-comparison of the fNIRS results with the subjective feedback, I have established a specific area of the prefrontal cortex that I can associate with fear. This builds upon existing research that has observed similar fNIRS results in the same region of the brain. I propose that combining these results with the use of arousal could allow me to better contextualise the fear being measured.

Practically, I make the case that fNIRS could usefully be built into the forehead mount of a VR headset. The ability to better tackle motion data than other BCI, such as EEG, as well as the positioning of the measured region for fear processing make this an attractive prospect. Even more so if future work supports the detection of other emotion categories in the prefrontal cortex.

Applying these results within the thesis demonstrates how the use of fNIRS in VR for the adaptation of fear-based experiences. Researchers have already begun looking into bio-responsive adaptation in horror games; however, with the identification of a reliably detectable fear response, I could deepen the effectiveness of this by being more able to correctly respond to fear and create personalised 'fear trajectories' through experiences. I suggest that this control over fear trajectories is not only desirable for designers but also empowering for users.

Chapter 5

Study 2: Defining the Horror for Adaptation - Horror Filmmaker Interviews

5.1 Introduction

This chapter offers insight and analysis into filmmakers' perspectives on creating horror films. There is currently a lack of conventions for creating adaptive media within the horror genre. Therefore, interviews were conducted with horror filmmakers, focusing on their interpretation of the horror genre, their consideration of the audience's journey, and their thoughts on how adaptation may, or may not, fit into the world of film and media. This was done to identify ways in which adaptation may fit into existing methods for the design and creation of horror films and experiences. Using Braune and Clarke's thematic analysis (Victoria and Braun, 2014), 3 themes were identified: 'Dynamic Storytelling and Creative Flexibility', 'Directorial Coordination and Processes', and 'Managing the Audiences'

Journey'. This analysis has then been used to provide a toolkit for creating adaptive horror media, which aims to answer RQ 3.

5.2 Methodology

Structured interviews were conducted with 7 film directors who have directed a film within the horror genre, focusing on 4 key areas: their interpretation of the horror genre and approach to creating horror media, their understanding of the audience for horror, their consideration of the audience journey and engagement, and their thoughts on adaptation of fear within horror. The questions for these interviews can be found in the Appendix B.3. Each interview lasted between 1 and 2 hours and was conducted through online interviews. Most filmmakers were found through film festivals and social media platforms (Reddit, X), except Richard Ramchurn, who is a member of my industry partner, AlbinoMosquito. Each filmmaker voluntarily consented to be identified by name. The filmmakers were: Janine Pipe, Mat Johns, Noah Bunyan, Richard Ramchurn, Rob Maguire, Sean Hogan, and Steven Sheil. By not being anonymised, each filmmaker can be identified by their input within the co-creative process of this work.

Guided by the work of psychologists Braune and Clarke, thematic analysis was employed to assess the interview data and identify common codes and themes (Clarke and Braun, 2017). Codes refer to the labels assigned to interesting features from the interview data, and themes are groupings of similar codes based on patterns. These codes and themes were chosen based on their relevance to understanding the current process of creation and evaluation of horror films from the perspectives of the filmmakers, as

well as understanding how they feel adaptation may affect horror films and understanding what adaptation may mean for horror media. I now provide details on how these codes and themes were identified.

Table 5.1 provides details of the thematic analysis process.

Analysis Phase	Description	Code/Theme Count
Familiarisation	Initial identification of codes across all transcripts	115 Codes
Remove and Combine	Removal and merging of any codes that are unrelated or similar to other codes	93 Codes
Theme Development	Identification of themes from patterns within the codes	9 Themes
Theme Refinement	Removal or merging of themes that have limited references or are similar to other themes	3 Themes

Table 5.1: A representation of the workflow used for thematic analysis. Each phase describes what was completed for that phase, including information on the number of codes or themes available at the end of the phase

An initial run through of thematic analysis on each interview transcript produced 115 codes. Sorting these codes by reference count showed that many codes only occurred once. These codes were then either merged into a similar code or removed entirely if deemed unrelated. After this process, 22 codes were merged or removed, leaving 93 codes in total. Examples of final codes with high reference counts include Audience Journey Focus, Horror Cross Genres, Fantasy vs Reality, and Budget Limitation. From this, I began grouping the codes into themes, producing 9 themes shown in Table 5.2.

Once again, I began to refine these themes, organising them by references and looking at those with limited references or similarities to other themes to see if they could be merged. This final process of refinement finalised the thematic analysis with 3 themes: 'Dynamic Storytelling and Creative Flexibility', 'Directorial Coordination and Processes', and 'Managing the Audiences' Journey'. Themes, subthemes, and code counts are shown in Table 5.3.

Theme	Code Count
Balancing Adaptation and Narrative	10
Directorial Coordination and Processes	24
Dynamic Storytelling and Creative Flexibility	115
Enhancing Fear Through Adaptation	18
Expectations and Rewatchability	20
Handling Cliches and Subversion	26
Infrastructure and Scalability	29
Interactive and Immersive Experiences	12
Managing Audience Journeys	74
Personalisation and Ownership	12

Table 5.2: Initial grouping of thematic analysis codes into themes

Theme	Subthemes (Bolded from Original 9 Theme Set)	Code Count
Directorial Coordination and Processes		47
	Budget Limitation	9
	Horror Department Coordination	9
	Infrastructure and Scalability	29
Dynamic Storytelling and Creative Flexibility		75
	Horror Across Genres	14
	Subjectivity of Horror	6
	Fantasy Versus Reality	8
	Tropes and Clichés	17
	Enhancing Fear Through Adaptation ‘	20
	Balancing Adaptation and Narrative	10
Managing Audience Journeys		41
	Managing the Emotional Arc	18
	Interactive and Immersive Experiences	6
	Expectations and Rewatchability	10
	Personalisation and Ownership	7

Table 5.3: Final themes for thematic analysis

The final themes encapsulated the previous themes into larger groups, as many of the subthemes fit within an existing theme. Handling Cliches and Subversion was split and spread across the 3 themes, as its codes did not conform to a single specific theme. 3 final themes were decided as they each hit a core area of the filmmaker discussions and provided sufficient information to generate a toolkit for adaptation.

5.3 Introducing the Filmmakers

Before discussing design processes and adaptation, the interviews began with an introduction from each filmmaker. The following outlines an introduction for each filmmaker and their work:

- Janine Pipe is a filmmaker, screenwriter and author. Janine has directed two short horror films: *Her* (2023) and *Footsteps* (2024), as well as one action short *Charlie Foxtrot* (2024).
- Mat Johns is a filmmaker based in Manchester and works as a freelancer on projects such as documentaries, music videos and promotional videos. Mat also directs narrative films, such as the short drama film *Inertia* (2021), and is working towards making feature films. As for horror, Mat has directed a series of shorts including *A Father's Day* (2020), *Smile* (2013), and *Last Person* (2013).
- Noah Bunyan is a director, writer, and editor. He has directed the feature-length horror film *The King in Yellow* (2022) as well as two horror shorts, *Pickman's Model* (2022) and *One for the Road* (2019).
- Richard Ramchurn is a visual artist, filmmaker and researcher working on adaptive narrative experiences. He describes these as "usually filmic or cinematic, which are interactive or adaptive and change mostly based on physiological data from the audience". Richard's first work was done in 2004, with a more specific push towards horror in 2007 with *The Keswick Zombie Massacre*. It is worth noting that Richard is the industry partner supporting this PhD and is also the director of the adaptive artefact that has been made as part of my research.

- Rob Maguire is a writer and director from Ireland, with his first short film being a classical old-style ghost story titled *A Twist in the Wind* (2023). Rob says that he has been writing for roughly five years and directing for about a year.

- Sean Hogan describes himself as a genre filmmaker, referring to someone who creates films within a specific genre, which, in this case, is horror. He made his first feature film called *Lie Still* (2005), which was played at a series of film festivals and is how he established himself as a filmmaker. Since then, he has worked on some different projects, and more recently, a folk horror film called *To Fire You Come at Last* (2023).

- Steven Sheil is a screenwriter and director, as well as a co-director of the Nottingham-based Mayhem Film Festival, which has run for almost 20 years. He also writes short fiction, predominantly in the horror genre. Steven released his first feature film *Mum and Dad* in 2008. Since then, he has focused on writing scripts and working on other developments with more recent work, including the horror short *Unmade* (2019).

There is a range of experience amongst the filmmakers, with some having developed films over 15 years ago and others being newer to the process. Additionally, some have worked outside of being a director in other aspects of film and horror media content creation. Introductions were followed by asking if each filmmaker considered themselves a horror filmmaker, which sparked an interesting variation in response:

Noah and Janine said yes without any particular follow-up. Both Matt and Richard said no, with Matt saying "I don't consider myself a horror filmmaker. I make films that contain horror" and similarly Richard saying

"I wouldn't say exclusively horror film director, although other people may disagree", also mentioning that a lot of his work contains horror elements. Rob also wouldn't describe himself as a horror film director, but says, "I wouldn't be allergic to the definition". When asked if he describes himself as a horror film director, Steven said "yes, but not exclusively" also mentioning that "I've never had to kind of worry about being identified as a horror filmmaker". Sean also said yes, but added that "I've never had any shame about being a horror film director". Although Noah and Janine's responses are straightforward, Sean, Steven, and Rob present the idea of caution around the label of horror filmmaker, as well as Rob mentioning not being allergic to the definition.

This splits the group with 4 considering themselves horror filmmakers, and the other 3 having worked within the horror genre or used elements of horror. The caution surrounding the definition of 'Horror filmmaker' presents the idea that, to some, this is an unfavourable title. Steven provides a possible reason for this by saying that horror is seen as a 'lower class of genre' as well as being known for its low-budget approaches. Horror literature backs this, with evidence of horror typically using a lower budget compared to other genres (Nowell, 2014; Worland, 2024). This does not necessarily mean that those not defining themselves as horror filmmakers are cautious of the title, but it does explain the comments from Steven, Sean, and Rob surrounding the potential 'shame' of being a horror film director.

Ending the introductions, when asked about their interest in the horror genre, each director tended towards the intensity and thrill of being scared, underscoring the ability of horror to leave a lingering feeling that lasts beyond the film itself. These effects highlight the power of horror to emotionally impact audiences through a memorable experience. Interestingly,

there were also comments mentioning how horror creates a visceral reaction, similar to comedy. This juxtaposition highlights the unexpected similarities between the two genres. While fear and laughter appear as opposing emotional responses, the underlying structures and cognitive processing for both are very similar (Straßburger, 2022).

5.4 Results

This section shows the findings of the interviews with the horror filmmakers. This includes each filmmaker's understanding of the horror genre, their approach to horror films and connection to the audience. Additionally, this will look at the use of adaptation within horror, how adaptation could affect the design and creation processes, as well as what adaptive content could mean for audiences. The themes to be covered are Dynamic Storytelling and Creative Flexibility, Directorial Coordination and Processes, and Managing the Audiences' Journey. These themes will be linked back to the creation of a foundational approach to adaptive horror for film and experience makers to use when making adaptive media.

Before delving into the themes themselves, a question posed to the filmmakers was whether they had or had wanted to show more than one version of their films before. Only Richard has shown more than one version of his films before; however, this is also the nature of Richard's approach to filmmaking with adaptive narratives manipulated by physiological data. The other filmmakers had mixed responses to the notion of multiple versions of their films. Mat was enthusiastic about the idea, having previously worked with Richard on his adaptive films, whilst Janine and Rob, for example, say that the way their films are made is as they intended them to be, with

Rob going on to mention, about his films, "I'm very much in it. That's what it is. And I don't want it to be anything else". Rob presents himself as a figure akin to the film auteurs defined by Andrew Sarris (Sarris, 1968), where the director projects their style and personality into their films. It would appear that Rob and Janine both feel that adaptation may take away this authorship from their films.

Upon discussing my research with each filmmaker, although the concept of adaptive content was sometimes confusing at first, the idea of adaptive experiences was very well received and the conversations sparked a lot of positive comments; "sounds like the ultimate kind of horror" (Janine), "I think it's really fascinating as a big fan of experiential horror" (Rob), "I think it's something really interesting about the potential to do that" (Steven). Additionally, a lot of the filmmakers were very interested to be able to try this type of horror experience for themselves, whether that be making adaptive experiences or simply being an audience member, reflecting on the novelty of an adaptive approach. There were, however, concerns and considerations mentioned that will be discussed in each theme.

5.4.1 Dynamic Storytelling and Creative Flexibility

This theme covers the way in which the filmmakers tell the story of their horror films, the approaches they take and the design considerations taken into account. The discussion then moves towards adaptation, and how adaptation can build upon these and maintain a story without detracting from the experience. Understanding the approach and design choices provides insight into how a tool set for adapting horror can fit into the current techniques for creating horror and provide scene variability to play on suspense and uncertainty in the audience.

Horror Across Genres

A key facet when considering the creation of the horror film is understanding what fits into the horror genre and what defines the horror genre. Almost all the filmmakers mentioned that horror isn't restricted to a single genre and that even the perception of a horror film as being within the horror genre is not universal. When talking about the horror genre, Steven said, "I think it's very amorphous", with Janine adding, "horror again can cross over with other genres". This crossover allows filmmakers to draw from other genres and apply their techniques within horror. Janine provides an example of this within the context of the action genre: "quite often in something, like if it's a police based action film and you know you're on one side of the door waiting for something to happen on the other side of the door, that might be because the police are about to bash down the door in an action film. But that kind of fear and tension and everything is something that you can utilise in horror film". However, there does appear to be a twist on genre elements that allows them to fit within horror. Mat comments that "horror has a particular style I suppose, you know, usually use lots of light and shadows, high contrast ratios, night time settings, use of silhouettes and hard lighting and all that kind of stuff". This implies that even though elements of other genres can be depicted within horror, it's important to still create the atmospheric nature and settings that horror is known for. Looking back to the literature discussed in section 2.5, the use of subgenres in horror, such as horror-comedy, can create unique alterations whilst maintaining the horror elements.

Subjectivity of Horror

When observing fear within horror, the mention of subjectivity was raised as a part of the nature of horror. Speaking with Mat, he mentioned the following when observing the audience ratings of one of his films that had just been screened at a film festival: "I snuck a look at their sheets and one person gave it one out of five and my heart sank and I was like ohh God and the person next to him gave it four out of five and they were together". It is unclear if these specific ratings are based on the fear experienced by the participants, but they do reflect the individuality towards films, and in this case, horror.

The subjectivity of fear is also portrayed in the creation of horror. A majority of the filmmakers noted how the content that they create is heavily focused on their interest in horror, their state of mind at the time of filming, and addressing big and fundamental questions. Steven explains this: "Horror is a space wherein you can process ideas around violence and, you know, and death and trauma, and you can process it within a kind of fictionalised space that is kind of like a safe space".

Despite the subjectivity of fear, certain approaches are known to be quite effective according to the filmmakers. Setting is an important aspect when putting an audience into the mindset of horror. When talking about the setting, there were repeated mentions of lighting, sound, and atmosphere being important in creating an immersive world and mood for the audience. Sean mentions even that plot is not necessarily what drives horror, but "some of the greatest [horror films] are much more about sort of mood and atmosphere than they are about plot". Although no specific examples were given, looking back at the literature section 2.5.2 highlights how films such as *Jaws* (Steven Spielberg, 1975) and *Aliens* (James Cameron, 1986)

are renowned for their visuals and/or audio. There are also mentions of tension being an important aspect of horror, building tension to prepare the audience for situations or events that may occur and also the release of tension through scaring the audience or potentially subversion.

Subverting expectations can trick audiences and provide different routes for releasing tension or twisting the narrative. Rob refers to an idea of the 'cold penny drop scare' where you end up with a 'cold realisation' about the story. On a similar idea, Noah mentions "you need people to basically realise that they don't understand a situation they originally thought they did". There is also the 'fake jump scare' mentioned by Janine, where you trick the audience into expecting a jump scare where there isn't one or by delaying the jump scare. Rob provides an example of a 'fake jump scare' known as the 'Lewton bus' from the film *Cat People* (Jacques Tourneur, 1942). A scene within the film depicts a character being followed, building tension until the expectation that the character is going to be caught by a stalker is subverted by a 'fake jump scare' of a bus arriving, where the character then gets on the bus.

Fantasy Versus Reality

In horror cinema, the line between fantasy and reality is not only blurred but strategically manipulated to provoke fear. Reality within this context refers to realistic events and scenarios, such as maintaining real threats to characters without becoming unbelievable. Filmmakers craft worlds and scenarios that, while sometimes fantastical, must still maintain a sense of reality to retain believability and elicit genuine fear. This balance between fantasy and realism is crucial, as an overly fantastical narrative risks losing the audience's investment. Horror creators often navigate this tension

by grounding their stories in relatable experiences before introducing fantasy elements. By doing so, they create a space where the familiar space suddenly produces possible threats. Referring to a zombie film, Mat provides context on this: "So immediately, as far as like the believability, even though there's zombies and zombies don't exist, when you watch a horror movie with zombies in where the makeup's [bad], people just don't tune in. All they're doing is looking at it, going, I don't believe it, even though it's a zombie and zombies don't exist". If an audience can perceive fantasy elements as non-threatening, this can ruin the ambience and feel of a horror movie. When addressing this, Steven mentions, "I think the sort of humanness, you have to keep it on a very kind of human level." If an audience member is able to perceive the content as believable despite it being fictitious, then there is a greater possibility of capturing the audience's attention.

Horror films aren't limited to fantasy, however, and incorporating reality within the narrative can be a key facet of tapping into what the filmmakers describe as 'primal fear'. Throughout the interviews, there were several mentions of 'primal fear' being the bridge between fantasy and reality. Janine directly notes this about believability, "leaving believability at the door", knowing that the horror in horror films is fake, "you know, sort of like if it's vampires, where all those kinds of things you know that that's not real. But spiders they're in the house. Yeah, those things are real. That's a real primal fear. And that's not good for me". This leads to Janine avoiding spiders as an audience member and director due to them being a real-world fear. Mat, however, mentions that tapping into primal fear is a part of what makes a horror film, referring to it as something that triggers a fight or flight response. Steven also mentions the use of primal fear being core to horror: "[Horror is] about fear, about loss of control, they're very

kind of primal and fundamental fears that people have". From Mat and Steven's perspectives, it appears that tapping into primal fear is what can elicit the response that horror aims to achieve. However, for Janine, this causes an aversion to certain horror films. This opens up an opportunity for adaptation. For audiences who are averse to certain fearful stimuli, these could be removed from horror through adaptation to provide more accessible content, whilst keeping these elements for those who are less susceptible to them. Additionally, working with fear within horror should provide the ability to trigger a sense of real threat, whether the content is fantastical or not.

Tropes and Clichés

As expressed by the filmmakers, a common approach to the creation of horror movies is through tropes, whilst avoiding clichés. As discussed in section 2.5.1, tropes refer to recurrent themes used within a genre, such as small, unlit spaces and large, empty places for the horror genre (Blake, 2013). Clichés, however, are essentially overused tropes, leading them to have lost their meaning (Sachar, 2024). Issues were raised with the use of tropes. Mat feels that the use of tropes can take away from the meaning of horror at times, saying, "When you think of horror, you sometimes think of a guy in a mask running around and stabbing people and stuff, and horror can be so much more than that". Mat does, however, say that certain tropes, or gags as he refers to them, can be effective, such as "revealing new information, making characters, making audiences jump". Richard says that he plays into tropes, "I play on existing tropes so I either directly referencing films or themes"; as well as Rob providing some affinity for them, "I do like the classical tropes". Talking with Janine, she mentions how fans of horror are 'loyal' to the genre, which plays a big part when

working with horror tropes. She mentions how altering tropes can cause complaints amongst fans if not explained properly. One example she gives is regarding werewolves: "If you're going down the road of werewolves and things, you'd better make sure that there's a silver bullet in there. And if there isn't, you better make sure you have a good explanation as to why yours is slightly different". If adaptation is to be used alongside well-known tropes, it appears important that adaptations should maintain the lore that is established within horror or, if this is altered, provide a reason for doing so.

Enhancing Fear Through Adaptation

As mentioned above, the idea of adaptation within horror was met with a lot of enthusiasm from the filmmakers. Despite this, there were questions raised about how this would work. One such question raised by Rob was "The subjectiveness is the key one. Is that what is scary for individual people? So I would feel like you need to have a like a test reel at the start or something to measure what are the things that that are going to get individual people scared". As discussed in sections 5.4.1 above, subjectivity provides such a range of responses to horror. Being capable of understanding the fears or fear levels of an individual before an experience provides valuable information for adaptation. This also links to Janine's comment on spiders in section 5.4.1. Understanding an individual's fears, however, would require multiple different adaptive pathways for an experience; for example, understanding a fear of spiders allows an experience to adapt specifically to spiders. With subjectivity, the requirement of more specific fears grows, and scalability becomes an issue. Therefore, it would be more manageable to implement tropes that horror films use as found in the literature section 2.5.2. Adaptation can then focus on detecting when

someone is fearful and altering tropes rather than implementing a specific fear.

An interesting point raised by Richard is about whether adapting fearful elements does alter the 'scariness' of the experience: "if you look at like horror films, there's a lot of horror films that are very understated and don't use like a lot of the big horror tropes for it and they're still very scary. So by bringing certain things down, like bringing the scary music down, or the look of it, is that making it less scary?". This leads directly into the subjectivity of fear, with alterations of fear affecting viewers differently. If a viewer actively chooses to watch a horror film, they know they are subjecting themselves to content that is intended to scare them. Reducing the fearful content in a film or experience can only go so far before it has the potential to remove the horror altogether, at which point it could be argued that this is altering the genre.

Balancing Adaptation with Narrative and Adaptation Beyond Film

When adapting content within media, it was mentioned amongst the filmmakers about how to balance adaptation alongside the existing content and ensure that the narrative is not affected negatively by alterations. Sean mentions that "[Adaptation is] kind of taking away the primacy of the storyteller and putting it in the audience member's hands". This approach is in reference to adapting the narrative. Examples of this can be seen within video games, such as *Detroit: Become Human* (Quantic Dream, 2018), where player decisions can lead to different storylines and endings. In this context, Sean sees this as a barrier to adaptation as "I think there is a desire in human beings to be told stories that they can't control". Sean

did say that he is not against this approach, but that he believes this to be different to what he does.

Other filmmakers shared this thought on adaptation being different to film. Rob called it "film adjacent", whilst Steven said that it is "a different mindset to filmmaking" based on the process of altering the level of fear. This creates a separation between traditional film and adaptive film as adaptation goes beyond linear film through introducing live alterations. With new approaches, however, come new challenges. Discussing this with Mat, he mentions that one barrier to adaptive media is the knowledge gap introduced. Upon mentioning the idea of a framework for filmmakers to follow, he was very enthusiastic about the idea. Similarly, Noah mentions that a "good solid foundation" is needed to create this type of content. Having made adaptive content before, Richard mentions, "there's no set way of making an adaptive film. You're always gonna be figuring out these new processes based on that rule system that you've come up with at the beginning". Richard's approach leans into the lack of foundation, relying on the rules of adaptation, whilst Mat and Noah believe a foundation to be more suitable. To provide a balance of both approaches, a toolkit for creating adaptive media could provide an unconstrained framework for filmmakers to use that supports creativity without restricting innovation.

Adaptation is not limited to only narrative elements. As previously mentioned in Section 2.7.1, adaptation has been used for altering sound design, lighting, and other horror elements. These tend to link to horror tropes by applying specific horror-based audio or low lighting. When discussing the approach of audio, visual, and lighting adaptation with Noah, he mentioned that with this approach, he'd be more interested in this than the adaptive narrative approach, saying, "I mean that's very new like I've seen things that have adapted story before, but I haven't really seen what you're

describing with that". Additionally, Mat had a similar enthusiasm for the approach of adapting elements: "the ability to add or take dread out of the sonic landscape of the film, the music. Or if someone's absolutely scared and you go right, OK, this next part of the story, the lighting will be increased so it's not quite so dark. Like, it's incredible."

With adaptation, the ability to alter the content in real-time introduces a lot of directions for filmmakers and experience designers, but this brings its challenges. Although there is no set way to create adaptive film, creating a foundation or tool set for creatives to build upon would allow for a starting point to assist with these challenges and for new processes to build upon.

From these responses, adaptive narrative poses potential problems for creatives in addition to those already existing within film and other media. The use of adapting elements, such as sound, lighting, and visuals, however, appears more novel. There has been research focused on this approach (Section 2.7.1), but within this sample of filmmakers, there is a lot of enthusiasm for the creation of a film that can alter elements to manipulate the fear of an audience member. For this reason, the tool set for creating adaptive content will focus on the elements of sound, visuals, and lighting.

Linking to an Adaptive Toolkit

Throughout these interviews, 'primal fear' is highlighted as a fundamental aspect of creating effective horror. The ability to tap into deep, instinctual fear is a powerful tool for filmmakers as it can resonate across different audiences. Looking into this application within adaptive experiences, including content aimed at triggering a primal fear response, referring to fear that triggers a fight or flight response, and measuring these responses could aid in understanding whether the content is provoking an audience member.

These can be integrated into the setting elements such as sound, lighting, atmosphere or other elements.

Horror walks a fine line between the fantastical and real. This balance is crucial because if an audience member perceives the fantastical to be non-threatening, the horror can fall flat. Using adaptation can allow for the manipulation of existing fears within an experience to ensure that if moments of intended fear aren't reaching expectations within an audience member, the system can dynamically adjust to reintroduce more relatable and grounded fears, maintaining immersion and fear. In practice, this refers to adjusting lighting, atmosphere, or fearful elements (e.g. bodies, silhouettes) to build upon existing layers of fear and bolster the horror present within a scene.

Both Mat and Janine mentioned how the believability of horror elements impacts the audience's emotional investment. If elements are becoming unconvincing, then the audience is likely to disengage from the horror. In these cases, an adaptive system could monitor and shift focus if there is a loss in fear and aim more towards a more believable and grounded fear.

Subjectivity within fear presents an opening for horror through adaptation. If the content of a film or experience is able to optimise the presentation of fear stimuli, then there is likely to be a greater chance of frightening an audience member. Focusing the adaptive tool set on the manipulation of setting components also provides an interesting approach to adaptation beyond the adaptive narrative already seen within film, such as *Bandersnatch* (2018).

Overall, feedback from the filmmakers indicates that a foundation for adaptive experiences requires the ability to understand what causes a spike in fear, as well as being able to shift fearful sequences when levels of fear begin

to drop to maintain immersion and believability.

5.4.2 Directorial Coordination and Processes

This theme discusses the limitations of the budget when approaching filmmaking, the coordination between different departments, as well as the potential pitfalls for infrastructure and scalability introduced by adaptation.

Budget Limitation

When discussing the limitations of creating horror, 6 of the 7 filmmakers mentioned that budget was the foremost limitation. This is unsurprising due to the need for a budget to accommodate almost all processes in filmmaking, such as actors, set creation, editing, etc. This limitation is not uncommon for horror, with Steven saying, "Horror is a traditionally low-budget kind of genre and I think there's you know, it demands a lot of inventiveness". Steven provides more context on this, saying that one of his films, titled *Mum and Dad* (2008), had to alter scenes relying on visual effects (VFX) to work with practical effects (SFX) as it was cheaper to do so, which also involved altering the scripts. In addition to this, Janine mentions that one reason for her affinity with horror is that she prefers the use of SFX over CGI, so she will always seek to use SFX where possible. Using SFX as opposed to VFX could also affect the believability of the content within horror. As mentioned when discussing fantasy and reality, believability is a key component of horror in ensuring that the audience is engaged in the content. If either the VFX or SFX is low budget, they may not be as believable to an audience and therefore cause less of an impact

through the fearful content.

One workaround for budget limitations, done by Rob, was to use AI to assist in creating the film, as it helped reduce costs within the limited budget. The development of AI has advanced rapidly in recent years, so the use of AI within filmmaking is likely to increase as its capabilities improve. Although the use of AI in film was not explored within the interviews, it poses an interesting question on the use of AI in assisting with horror creation and its potential use for adapting horror content for audiences. If AI were capable of understanding what scares an audience, could this alter the content in real time to scare the audience further and if so, what would be the ethical implications of this? AI could open the door for horror, especially with the limited budgets that horror films tend to receive; however, maintaining the boundaries of how far AI can go within adaptation may cause issues with audiences if it, for example, begins to target specific fears of an audience member. Due to AI not being in focus and raising ethical questions, it will not be implemented into the tool set, but will be discussed later in the discussion Sections 8.4 and 8.5 within the thesis to understand its future applicability.

The issue of a budget, however, is still relevant to adaptation. Adaptation demands more content than a traditional one-track design within the creation process of films. With more content comes the need for more money to accommodate the resources required to make the additional content. Therefore, this limits the amount of adaptation to the budget available and may require some inventiveness to provide adaptive content. This could include repeated content, such as reusing effects or sounds, or providing more subtle effects than highly detailed content.

Department Coordination

Working across all departments when directing helps maintain the focus of the project. Pinning down particular departments of importance is more difficult, as generally no one department is defined as being the most important when compared with the others. When asked about the departments for keeping the audience journey in focus, Janine says, "All departments, there's not one person on a film set that's not vital to that". Collating across all interviews, however, there are some particular repeated mentions.

- **Editor**: Frequently highlighted due to their impact on the final piece. Sean describes this as the point at which you're 'rewriting the film', reiterated by Janine who said, "the editor basically makes the difference between a good film and a bad film". In relation specifically to horror, Steven mentions how the editor brings everything together to build the elements of shock and surprise. As the editor is key in finalising the film and bringing the elements together, they must understand the scope and aim of the project in its entirety.

- **Sound Department**: Essential in constructing the soundscape and atmosphere. As mentioned by Steven, "sound design and music is very important in horror because it's one of the things that really, really unnerved an audience". This links back to the previous section 5.4.1, where adaptive sound was described as having the ability to manipulate the dread within a sonic landscape.

- **Actors**: Crucial in conveying emotional intent and ensuring that characters are portrayed as envisioned by the creative team.

- **Cinematographer**: Janine notes their importance as "ultimately on set, they're the person that is actually filming." The camera team

assists, similar to the sound department, in creating the atmosphere and visuals for the story being told.

Referring back to Janine's quote on the importance of departments in regards to audience focus, a toolkit for adaptation requires a similar collaborative workflow. All departments are needed to understand how adaptation will work within the content that is being created. It is just as important when working with adaptive content that these departments are kept in focus, especially those of particular mention above. These departments enable the creation of adaptive content through sound and visuals, with the editor bringing everything together, ensuring that the adaptive content works as intended. For the purpose of this PhD, I take on an additional role as an adaptive researcher, identifying the adaptive elements, their placement within the experience, and the layers of fear involved in each scene.

Infrastructure and Scalability

When discussing the use of adaptation within horror, scalability was mentioned frequently as one of the barriers to adopting the approach. An adaptive system needs to be able to generally cater for a wide audience and adapt for a crowd, whilst also being practical within budget. Richard puts this into perspective "There's limitations of how do you screen [adaptive content]. There's always going to be some kind of infrastructure that is non-standard that's built around how this film is adaptive, and then what is the added cost of how these films are screened, and what does that mean for scalability?".

Creating adaptive content for a wide audience requires a method for reading the physiology of the audience. Working specifically with brain activity,

this is a complex issue as identified in the literature section 2.3.3. Due to this complexity, the approach of wide audiences will not be used within the tool set; however, it will be discussed within the discussion Section 8.1.4. Instead, the focus will be on single participants. Scalability still concerns single participant adaptation. As mentioned by Noah, "a lot of thought needs to go into [adaptive content], you know, think about the different possibilities, different options". Even with single participants, the target audience will still vary in subjectivity of fear, as mentioned in section 5.4.1.

5.4.3 Managing the Audience Member's Journey

Adaptive horror provides direct feedback from the viewer and therefore requires a consistent audience journey to ensure that the feedback is working. To understand how directors think about an audience journey as well as their considerations of it, an understanding of the audience journey was an important part of the interviews.

Managing the Emotional Arc

"On a very basic level, horror films are sort of often intended to scare people" (Sean). The horror genre is known for being designed to scare people, but there's much more to horror than simply scaring someone; "some horror movies can be quite awe-inspiring. You have horror movies that are funny. You have horror movies that are sad." (Sean). There is no one approach to designing an audience journey within horror, but understanding the structures that are in place can provide insight into how a toolkit could be used for adaptive horror while maintaining an audience journey.

One key facet of the audience journey and the design of horror films is the idea of the horror genre simulating a roller coaster and containing 'beats'. These beats seem to refer to a key point within the audience journey aimed at eliciting an emotion, be it fear or otherwise. According to Rob, they can be "as vague as to be horrified". Janine and Mat discuss the weight of beats in eliciting reactions and giving the heartbeat to a horror film. The reference to a roller coaster was mentioned by Janine and Noah. When asked what makes a horror film, Janine said, "It's something that evokes like a roller coaster of emotions" and "It does have to be that kind of lull. So the heart rate goes back down again and then boom, you're scared again and then it goes back down again". When asked how they would define the audience for their film, Noah said, "people who wanna be scared by something and sort of go on a roller coaster ride". So these beats coincide with the peaks of the roller coaster, creating moments of intense or increased fear to frighten the audience, release the tension and bring them back down to a more eased state.

A toolkit designed for adaptive content could provide more control in the structure of a roller coaster, with the ability to manage the intensity of the beats and peaks of the roller coaster. If the content is malleable, fear content can be increased or decreased in response to the current state of the viewer. For example, a viewer with an already heightened fear level may not wish to be scared at the original intensity of the upcoming beat, and therefore, it can be reduced. As for those not feeling fear, the upcoming beat can contain an increased level of fear intensity to heighten their fear experience.

Effective roller coasters in this context are comparable to the HCI concept of trajectories (Benford et al., 2009). As discussed in section 2.5.4, trajectories work through mapping out the intended experience journey of a

participant (canonical trajectory) and mapping the trajectory that a participant takes within the experience (participant trajectory). This provides understanding of the intended journey and how the experience truly plays out. As mentioned within the literature review when discussing trajectories in Section 2.6.1, I use the notion of a canonical and personal trajectory of fear to create an experience that aims to dynamically align the personal to the canonical. For adaptation, it would be insightful to map out a fear trajectory of each experience without adaptation, and map out a fear trajectory of the experience with adaptation. This could provide insight into the intended impact of adaptation on the experience. Additionally, the use of fear trajectories could ensure that adaptation is present within intended fear 'beats' of the experience and doesn't detract from the narrative.

Interactive and Immersive Experiences

Although audience interaction in horror can take many forms, this project focuses on physiological monitoring. As physiological adaptation requires a connection with the audience, it becomes one way of transforming the horror experience into an interactive encounter through active participation. A point raised by Steven is how this may affect immersion: "I suppose what's interesting to me is how it would affect immersion in the story. You are aware that your reactions are being monitored and that those reactions are being used to change the story. Would it limit immersion?". Immersion is important for any media, but especially horror. If an audience isn't immersed in the world portrayed, they may not be frightened or feel emotionally provoked.

For adaptation to work, however, there needs to be an understanding of the audience member. Steven refers to it as a paradox where an adaptive

experience is attempting to get an individual to lose themselves in a more personalised experience, yet they know that what they feel / how they react will affect this experience. This would affect the immersion because if they are too focused on their impact on the experience, they may be less affected by the content, at which point fear responses will be less impactful.

To understand this further, the developed toolkit is applied and tested with an audience. An interview process is then done on audience members to determine whether they feel aware of their physiological interaction with the adaptation during an experience, and how this impacts the experience that they've had. This is detailed in Chapter 7.

Expectations, Rewatchability, and Ownership

This sub-theme covers the audience integration into adaptation. Adaptation opens up many changes to audience considerations beyond the audience journey. The following sub-themes will look at expectations created by adaptive content, the process of understanding what is needed to ensure that the adaptation is repeatable for audience members, and look into what adaptive content means for the ownership of adaptive content.

Talking with the filmmakers, there is the expectation that adaptation, if working correctly, would heighten the experience for viewers. As mentioned by Sean, "One can only assume that if it works well, that it would obviously heighten the viewer's experience". This thought is shared amongst other filmmakers, with the idea that potentially adaptation could be seen as 'the next level' to horror. This may also cause audiences to expect a higher level of horror from adaptive media, but also capable of drawing in more audiences through being able to adapt to an individual's response to fear.

The idea of adaptation can potentially remove expectations from audiences. As mentioned by Richard, "just that knowledge that a film is going to be changing based on something to do with you it's it's straight away removing certain expectations that you might know what's gonna happen". When going to watch a traditional film, an audience is given a general expectation of what the film may be about or include. With adaptive content, the aim is to introduce more variability to what may be seen, reducing those expectations.

With linear 2D cinema, when an audience re-watches a film, they are aware of what to expect, but with adaptation comes the ability to re-watch an experience to see if there is a different outcome to previous viewings. On this topic, Richard raises the question "How do you guarantee that the quality is gonna still be high each time it's watched?". If there is a lack in adaptive content, repeatability of the experience will more or less provide the same experience, so to accommodate this, the adaptive content needs to be constructed in a way that it's possible to get different outcomes based on each viewing.

To ensure repeatability, the toolkit used for adaptive content will need to be varied enough in the content that it uses. This content includes variations in sound, lighting, and visuals as mentioned in Section 5.4.1 above. Variations could include layered content, where different audio cues, lighting intensities, and visual effects are strategically combined to evoke varied emotional responses during multiple viewings. By introducing subtle shifts in these elements, the adaptive content can respond to fear responses in ways that maintain engagement across multiple viewings, whether by amplifying surprise, unsettling the audience in new ways, or shifting toward other emotional tones that keep the horror experience dynamic and unpredictable.

Discussing the elements of adaptation, ownership was mentioned as being impacted. From Sean's perspective, adaptation takes away "the primacy of the storyteller and puts it in the audience member's hands". Creating and directing a film gives ownership to the creator(s), but with adaptation, elements of the film are now intended to be different for each individual based on their response. Richard mentions that this almost creates a sense of ownership for the viewer and their version of the film/experience. If a viewer can create their version of a film, they could then show their version to others, for another audience to see how they saw the film. To be compatible with repeatability, however, this would require a method of recording/storing each individual's experience.

Adaptation opens up the availability of co-ownership between the filmmaker and audience (Ramchurn, Martindale, Wilson and Benford, 2019). It's important, therefore, to maintain a balance where both the filmmaker's vision and the audience's reactions co-create the atmosphere and intensity of the horror.

5.5 Discussion

These interviews with horror filmmakers aimed to understand the existing creative approaches in horror film-making, including their approaches to audience journey, and discuss how adaptation could fit into any pre-existing structures. The focus here is on identifying key elements that could be leveraged for real-time adaptation in horror media.

Across the 7 interviews, many insights were found surrounding the variation in creative processes for horror, as well as the impact of audiences in driving how horror film is created. Adaptation was well received with a lot

of positive reaction to the idea of altering horror in real-time, but with this came some informative considerations as to how adaptation should be designed, and whether this creates a new form of media outside of film itself. The discourse revealed recurring themes in horror creation that also point toward specific stimuli and structural tools that could be used in adaptive horror systems.

The core themes found from thematic analysis are the following:

- Dynamic Storytelling and Creative Flexibility
- Directorial Coordination and Processes
- Managing the Audience's Journey

Each theme provides insight towards an adaptive toolkit, outlining the potential stimuli and mechanisms that could be used within adaptive horror systems.

5.5.1 Flexibility of Horror

While horror is widely associated with a dark, suspenseful tone, the interviews made clear that there is no singular process or rulebook for horror filmmaking. Horror often borrows from other genres, and this blending can be incorporated into adaptive systems. From an adaptive perspective, this opens up flexibility in tone and content, so long as core emotional responses, such as fear, tension, and dread, are consistently reinforced. A key point raised was the idea of horror as a 'fictionalised safe space', where filmmakers can portray their depiction of fear or social expression. Therefore, adaptive horror should prioritise stimuli that evoke tension while allowing

flexibility in themes. For adaptive systems, this suggests that adaptive elements should prioritise maintaining fear rather than strictly sticking to the horror genre.

5.5.2 Audiovisual Stimuli and Fear Triggers

While horror is subjective, certain stimuli were consistently mentioned as effective across broad audiences. These include sound, lighting, and atmosphere. Filmmakers also emphasised the importance of realism and plausibility, where fear fails when the environment becomes too unrealistic. Triggering primal fears was a recurring strategy. These stimuli can be modularised in adaptive systems, allowing real-time tuning based on the viewer's state. Therefore, adaptive horror systems should dynamically manipulate audiovisual elements, particularly sound, lighting, and atmosphere, to maximise fear potential, ensuring changes are grounded in realism and capable of triggering primal emotional responses.

5.5.3 The Use and Subversion of Tropes

Filmmakers were divided on horror tropes, where some saw them as clichés and others relied on them as effective tools. In adaptive experiences, tropes can serve as predictive expectations to be confirmed or subverted in real-time. For example, a hallway view might lead a viewer to expect a jump-scare, which can be triggered or delayed, based on biofeedback. Adaptive systems must retain narrative coherence even when modifying or omitting genre expectations. This is to ensure that the narrative sense is kept.

5.5.4 Modifiers and Fear Trajectories

A core idea that emerged from discussions was that of a 'fear modifier', a mechanism that could increase or reduce fear intensity at specific points. Paired with a mapped fear trajectory, a timeline of the emotional journey, such modifiers could enhance or relax tension in real time. For adaptation, this means that adaptive horror systems should incorporate a fear modifier which alters the audiovisual intensity in key moments based on a viewer's state. This modifier should be mapped to a fear trajectory to ensure adaptation aligns with the emotional pacing of the underlying experience and does not disrupt the narrative flow.

5.5.5 Directorial Constraints and Production Considerations

Budget constraints were a primary concern of filmmakers, particularly in choosing between SFX and VFX. Adaptive systems should favour reusable digital assets that can be easily reconfigured to create varied emotional effects without significantly increasing production costs. Therefore, adaptive stimuli should be digitally driven, allowing for content reuse to reduce budget costs. Subtle digital alterations, such as lighting changes, audio overlays, and environmental tweaks, should be prioritised over large-scale alterations.

5.5.6 Audience Journey and Engagement

Filmmakers made an important point about the emotional rhythm of horror, such as the rise and fall of tension like a rollercoaster. Adaptive horror

can lean into this, allowing for adaptive content to fit into the peaks and troughs for increased effect based on real-time biofeedback. Similar principles have been demonstrated in other personalised narrative works, such as Booke Leave Home, which explored how tailored storytelling could foster deeper audience connection and engagement with otherwise abstract subjects like open data (Concannon et al., 2020). For an adaptive system, this suggests that audiovisual stimuli should be synchronised with the emotional beats of the story, reinforcing the moments of fear or calm to maintain audience engagement. Changes should be timed to support the viewer's changing physiological state.

5.5.7 Summary of the Key Components of the Adaptive Toolkit

The following Table provides a summary of the key components used within the adaptive toolkit:

1.	Adaptive horror should prioritise stimuli that evoke tension while allowing flexibility in themes.
2.	Adaptive horror systems should dynamically manipulate audiovisual elements, particularly sound, lighting, and atmosphere, to maximise fear potential, ensuring changes are grounded in realism and capable of triggering primal emotional responses.
3.	Adaptive systems must retain narrative coherence even when modifying or omitting genre expectations.
4.	Adaptive horror systems should incorporate a fear modifier which alters the audiovisual intensity in key moments based on a viewer's state.
5.	Adaptive stimuli should be digitally driven, allowing for content reuse to reduce budget costs.
6.	Audiovisual stimuli should be synchronised with the emotional beats of the story, reinforcing the moments of fear or calm to maintain audience engagement.

Table 5.4: Key components of the adaptive toolkit codeveloped with horror filmmakers

5.6 Conclusion

These structured interviews contribute to the advancement in adaptive horror by reframing traditional filmmaking into a toolkit of adaptable elements that can be used to design real-time, adaptive experiences. Through these interviews with experienced filmmakers, it became clear that while there is not a single formula for creating fear, certain audiovisual stimuli and narrative techniques can be effective in engaging diverse audiences.

Rather than offering rigid creative guidelines, this research identifies a set of core stimuli and mechanisms, including sound, lighting, environmental manipulation, and narrative structure, that hold potential for adaptive systems. These elements allow horror to remain emotionally focused while responding dynamically to individual viewer responses. Filmmakers showed openness to adaptation, provided it respects the integrity of the emotional journey and supports rather than undermines traditional narrative consistency.

As the boundary between film and interactive media continues to blend, the findings of this study suggest that real-time adaptation using audiovisual stimuli is not only viable but potentially transformative, enabling more controlled and immersive horror experiences. Moving forward, the next step is to explore how these adaptive elements can be applied within an adaptive experience, transferring the theoretical toolkit into practical mechanisms. This is done through the design, development, and evaluation of an adaptive VR horror experience called *A Place for Everyone*. Chapter 6 outlines the design and development of *A Place for Everyone* and Chapter 7 evaluates this process through two studies, one for public evaluation and one for a controlled data set.

Chapter 6

A Place for Everyone - Design, Filming, and Adaptive Implementation

6.1 Introduction

With the increasing prevalence of immersive technologies, such as virtual reality (VR), there are more opportunities to create immersive and emotionally affective experiences than traditional 2D cinema (Ding et al., 2018; Zhang et al., 2023; Shin, 2018). Industry players such as Meta and Apple are pushing immersive viewing as a significant use case for their devices (Cheng et al., 2024; Aros et al., 2024). VR shows particular promise within interactive storytelling; indeed, gaming is a 'first and foremost' application for many VR users; however, there is also an opportunity for a more passive form of interaction, namely adaptation, where user engagement might be enhanced through dynamic responses to an individual's physiological changes. Modifying an experience in response to physiological data is a

well-researched path (Zaib and Yamamura, 2022; de Lima et al., 2020, 2022; Houzangbe et al., 2018); however, experiences are generally experimental or research activities and are created without the active hand of industry practice. As a result, there is a lack of formal design approaches applied within the reporting of such adaptive media.

This chapter explores the co-creation process of designing an adaptive VR horror experience, titled *A Place for Everyone*, between technical researchers and a long-experienced filmmaker, AlbinoMosquito. *A Place for Everyone* is a VR social thriller experience focused on climate change and takes place within a future fictional Nottingham. The purpose of this piece is to provide an adaptive experience that can change visual and audio elements in response to an individual's fear as measured through brain activity. The adaptation system uses fNIRS to measure an inference of an individual's fear response and modify the visuals and audio in real-time to affect the individual's emotional state. I outline the challenges presented through co-creation, including moving from 2D to 3D space, using volumetric capture within a virtual space and the integration of adaptation. These challenges arose because traditional 2D filmmaking practices contain fixed and carefully controlled composition, depth, and audience perspective. A 3D virtual space requires designing for spatial immersion, which breaks many conventions of 2D cinematography. Additionally, using volumetric capture introduced technical and creative difficulties, as translating human performance into 3D demanded careful balance between realism and computational efficiency. Finally, integrating adaptation required rethinking timing, pacing, and atmosphere so that shifts in fear intensity felt coherent within a dynamic, VE, rather than a linear film.

To design an adaptive experience, the HCI trajectories framework (Benford et al., 2009) was applied to establish a fear trajectories framework.

The fear trajectories framework outlines the emotional intensity of fear throughout the experience, both as a 'canonical trajectory' (the intended fear journey) and as 'user trajectories' (the fear journey experienced by the user), utilising adaptation to try to close the gap between these two trajectories. Following a hybrid approach, positioning myself as a creative technologist, embedded collaborator, and empirical researcher, I co-created the experience, very much led by the artist, while gathering detailed notes and interviews about the process, and used this data to reflect on two research questions:

- RQ 3) How could media professionals utilise a toolkit for creating adaptive experiences and engage audiences with that content?
- RQ 4) What are the broader generalisations that can be made about emotionally adaptive experiences?

The research will allow users to have a personalised virtual horror experience, based on a combination of the canonical trajectory, which provides the 'shape' of the fear journey, and their preferences for 'levels' of fear, which provides the upper and lower limits, thereby 'positioning' the trajectory. To do this, I build upon the understanding of fear as an isolated emotion from both current research and from the data collected from my previous study, detailed in Chapter 4. An adaptive fear-based system has also been developed, building upon the thematic analysis results from the horror film maker interviews in Chapter 5 as theorised to determine the effectiveness of the fear model's approach for use within designing fear-based adaptive systems.

6.2 Planning, Designing, and Filming the Experience

The overall planning, designing, and filming took place over just under 1 year from September 2022 to July 2023. The original planning and designs began with me and my industry partner, AlbinoMosquito, which built up over time to include a cast of actors, technicians, artists, and more. Through this process, I supported the technical delivery by establishing new techniques for utilising volumetric capture, as well as approaches for incorporating adaptation into the design and development of a VR experience. It is essential to clarify that this experience is positioned as an adaptive VR experience, rather than an adaptive VR film. Discussion with horror filmmakers identified this approach of adaptive media as film adjacent, and therefore, this artefact is identified as an adaptive VR experience.

6.2.1 Background to AlbinoMosquito

AlbinoMosquito is a film production company that creates adaptive films using physiological data. Dr Richard Ramchurn and Rachel Ramchurn run the company. Previous works include *The Disadvantages of Time Travel* (2015), *The Moment* (2018), and *Before We Disappear* (2023). Each film uses either an EEG scanner or a live video feed to alter the film in unique ways, such as narrative order or visuals and audio. While the films are responsive to physiological data, they are not adaptive per se, as the content is predefined; they all work by dynamically cutting between simultaneous pre-recorded videos. Key themes of these works look into the topic of dystopian futures and the impact of humans on the world. With AlbinoMosquito as director and producer of this work, the overall themes and

technological decisions were led by them, while the means of adaptation were developed by me, including the types of adaptation to include for each scene, when adaptation should be present within the scenes and the implementation of the adaptation.

6.2.2 Initial Story Motivation and Planning

Before being able to create an adaptive system, the experience itself must first be created to understand how an adaptive system can be applied. Therefore, I began with the general idea of an experience that contained key moments of heightened fear, so that when altered, it could provide a unique experience for those who viewed it. Following similar themes to previous works by AlbinoMosquito, we focused on the idea of a dystopian future affected by a climate crisis.

To kick-start this idea, conversations were had with climate researchers, Emily O'Donnell and Meghan Alexander, from the University of Nottingham in March 2022. This discussion aimed to gather information and understanding into the future of the current climate crisis that we face in the real world.

From this discussion, a series of AI-generated images using prompts such as climate change was created to provide a visual understanding of what a potential climate crisis future could look like. This was then taken to audiences at libraries to discuss their thoughts and feelings around the future and how they feel towards climate change. This was carried out from February to March 2023 at St Ann's library, Strelly library, and Nottingham Central library. We then took these thoughts and ideas into practice when working on the planning and development of the VR experience. This

work was funded by Arts Council England, with libraries such as Mansfield Library selected as sites due to their identified need for greater access to creative opportunities in their local communities.

6.2.3 Storyboarding for A Place for Everyone

With the initial narrative of a dystopian future impacted by a climate crisis, we came to the idea of creating an experience that allows a viewer to embody a series of different memories. Each memory would be a different scene that captures a series of stories that provide an interconnected narrative. The narrative follows a group of refugees travelling from the coast of England to Nottingham to seek shelter, highlighting their struggle within society and the twisted world they now live in.

From these concepts, we decided upon 6 memories/scenes to be named 'Refugee', 'Camp', 'Plants', 'Raid', 'Processing', and 'Supper'. Each scene reveals a new insight into the climate crisis world; however, to connect these scenes, we also defined a hub scene. The hub scene acts as a menu and is used for the viewer to choose which memory they wish to view. Viewers can select any unseen scene at any point in the hub, not restricting them to any scene order, but memories are placed in chronological order. This allows viewers to choose their journey through the memories.

6.2.4 Design Choices for Virtual Reality

VR was chosen for this experience to provide an immersive environment that would allow a viewer to better embody an individual when compared to a 2D-based experience. Evidence leading to this design choice comes from the impact VR has on an individual's emotional experience, as mentioned

by Ding et al. (Ding et al., 2018), who demonstrated that cinematic VR, a virtual reality format that uses 360-degree video to provide an immersive and film-like experience, can provoke a stronger emotional experience and physiological reaction than 2D film can. They also show that the design of the VE strongly influences emotional processing.

Working alongside AlbinoMosquito for the creation of a VR experience presents a series of challenges and opportunities for planning and designing. These include moving from 2D to 3D space, digital environments, presentation of actors, and user interaction. From a filming perspective, going beyond 2D film into a 3D space requires awareness of the visual surroundings rather than just the camera's viewpoint. Users within the experience have a 360-degree view of the environment, and therefore, capturing actors and environments within the camera viewpoint alone is not enough.

As VR allows for movement within the scene as well as a 360-degree view, this provides options towards how the experience is to be designed, such as freedom of movement and interaction with objects. As this experience aims to embody different characters through their perspective, lateral movement was intentionally limited; instead, we focus on three-degrees of freedom (rotation) to give the impression of a fixed position. This is equivalent to filming with a 360 camera, in which the viewer can look around, but the viewpoint remains fixed in space. Embodiment of a character requires a prerecording of that character, therefore restricting the viewer to their static perspective. This, however, allowed for simplifications for both filming and computational workload. Filming was simplified as it allowed the physical placement of a VR character that actors could refer to throughout the recording of scenes. Computational workload was simplified as it meant that fewer cameras could be used for recording actors within scenes. More

detail on the computational simplification is provided within section 6.2.6.

Similar to movement, the level of VR interaction was heavily limited within scenes as the viewer encapsulates the body of another through a point of view (POV) perspective. The only interaction available is head rotation. The POV bodies are visible to the viewer, and therefore, any other interaction, such as hands, would disconnect the viewer from the body. One scene, however, the hub, does allow for interaction as at this point the viewer is not embodying another character. The hub scene allows a viewer to choose which scene they wish to view next. Interaction is used here for scene selection by using their hands to touch a virtual memory. The viewer's hands are visible to the player as virtual hands.

The experience was initially designed to be a standalone experience with the Quest 2. After testing, however, it was found that the hardware limitations of the Quest 2 required us to run the experience on the device from a machine of higher specification, an approach usually called PCVR and supported through the Quest Link system. As a sit-down experience, however, tethering the Quest 2 doesn't limit any other interactions or capabilities within the experience.

Using volumetric capture within a VE gave AlbinoMosquito the ability to stage more complex scenes and environments than had been possible in their earlier productions, even with a similar budget. Volumetric capture is a technique that records actors in three dimensions using an array of cameras, producing a digital performance that can be placed directly into a VE. In the case of this project, this process simplified production since the entire shoot could take place in a single capture studio, eliminating the need to travel between physical locations while still enabling the creation of a fully realised production design within the virtual space. Floor plans

of the virtual locations were designed within the physical studio space in advance of filming and iterated upon to understand sight lines and blocking for actors. The blocking of actors facilitated the placement of the volumetric camera setup and lighting fixture positions within the floor planning documents.

6.2.5 Capturing of Actors

One main aim of the experience was to ensure that the actors looked and behaved in a naturalistic way. This refers to their movement, speech, and interactions with each other. Two options of performance capture were available to us: motion and facial capture (mocap), and volumetric capture. motion and facial capture (MOCAP) allows for the capturing of detailed bodily movement, interactions with multiple subjects, and speech through facial cameras and face tracking software.

When considering MOCAP, we had three MOCAP suits available and a single face capture system. We explored what that would mean for workflows for actors and for combining performances in post-production. Additionally, the representation of the characters through a digital model of the actors, which would have to be designed, built and dressed. These challenges posed potential problems of representation of actors and ultimately produced an uncanny quality.

Conversely, Volumetric capture addresses every one of these issues. It is a relatively new approach, with rapidly evolving technologies, which captures a defined 3D volume via a perimeter of cameras. There are various approaches to the reconstructing of this volume, from photogrammetry-based approaches, sometimes supported by depth sensors (as in our sys-

tem), which produce a polygonal 3D model of the contents of the volume (Depthkit, 2024; Puerto et al., 2022; Summan et al., 2015), to voxel-based systems which use a point cloud to assign a colour to each voxel (3d pixel) within the volume (Regenbrecht et al., 2019), to brand new techniques based on light field radiance such as gaussian splatting (Wu et al., 2024; Chen and Wang, 2024). These methods capture any actor's movement, interaction, and speech within the volume in a more direct and realistic view of the actors as they physically are, but it is critical to recognise that this is a 'video' like approach rather than an animation one, meaning it shows what was captured at the time, the person, the costume, the movements etc.

One tradeoff for this flexibility is that none of these things can be trivially changed the way one might change the model with a motion capture animation. While there is some scope for modifying after the event, these are limited mostly to lighting changes and minor skeletal tweaks. The three main limitations of this technology that we observed were: Altering the captures post hoc proved very difficult, such as changing a character's clothes, the capture, at least at a consumer-grade price point is inherently visually glitchy, actors and objects that are occluded by cameras cease to exist in the captures, and the captures require a high computational load to run. Although there are limitations to both forms of capture, volumetric capture was chosen primarily due to its more realistic representation of actors' performance and presence and its comparatively simpler post-production workflow. With that choice, I accept that it does not have the visual clarity of purely animated characters, but has different qualities of visual fidelity, in its 'realness'.

6.2.6 Overcoming limitations of Volumetric Capture

As previously mentioned, limitations of volumetric captures include post-production of captures and a high computational workload. Through testing, it was shown that fewer cameras used for each render required a smaller workload and storage space requirement for the use of the captures. Therefore, AlbinoMosquito and I settled on ensuring that each scene used the fewest number of cameras possible for each capture. The fewest cameras were decided on a trial-and-error approach that tested each scene setup and determined the minimum number of cameras necessary to capture all actors within the scene. As the experience was static, a different approach was used for the setup of the cameras to aid in reducing the camera count. This approach involved placing cameras that captured actors from the viewpoint of the user, as shown in 6.1. However, this presented an issue with calibration, as to set up the 3D space to be captured, cameras are required to be calibrated with each other, which involves the need for overlapping space between cameras.

To overcome this, pairing cameras were used so that calibration could be done. This allowed the calibration to work, but now with the requirement of more cameras within a scene. To overcome this, I developed a program within Unity that would allow the removal of any chosen cameras from a recording. This took the metadata of a volumetric capture as input, calculated which cameras were used, and displayed them to the user. This then allowed the user to remove any cameras not needed and would output a new metadata file that stored this altered capture as a new capture, which could be rendered with the new camera setup. It is worth noting that since filming, this technique has been implemented in an update by Depthkit (the manufacturers of the volumetric capture system we used for *A Place*

for Everyone), but at the time, it was not available.

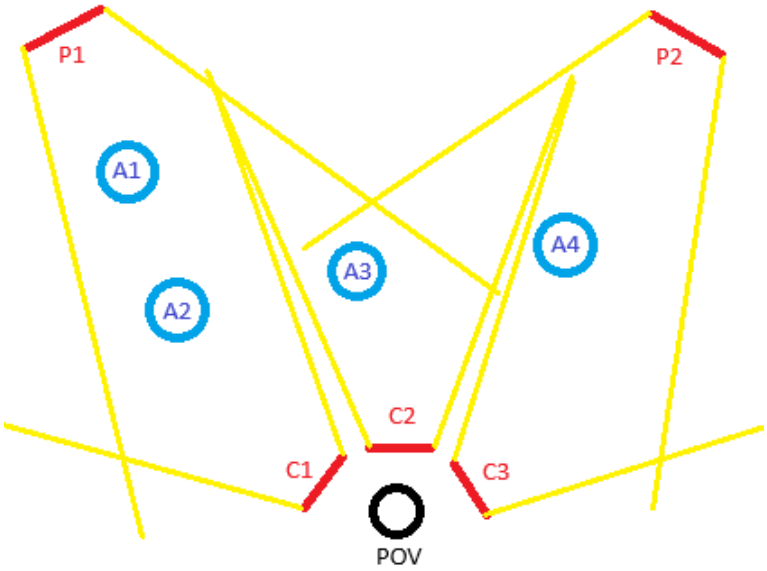


Figure 6.1: An example setup for volumetric capture from the viewpoint of the user. POV refers to the viewpoint of the user. C1, C2, and C3 are the cameras used for capture. P1 and P2 are the cameras used for pairing. A1, A2, A3, and A4 are the actors within the scene.

6.2.7 Visual and Audio Building

For the development of the VE, we worked alongside Sumit Sarkar, a visual artist who has worked on a series of different projects and exhibitions, such as Sevenesque III, a solo exhibition at Z-Arts, Manchester and animator and video mapping for HOAX by Benji Reid. The floor plans of each scene were used by Sumit to create visual concepts, which were used to develop the VEs for the prototype experience. Although the floor plans were limited in space by volumetric capture, the environment surrounding the actors was more flexible and allowed for more freedom of virtual design.

The audio was directed by audio artist Gary Naylor. Gary recorded the audio during filming using ambisonic microphones, which collect audio within a 3D radius. This was used to gather the actor's audio from the position of

the POV by placing the ambisonic microphone where the POV would be in the physical space, allowing for a rich spatial audio production. These audio files were then mastered before being rendered in Unity as spatialised sound. The use of ambisonic capture allows for the rotation of the headset to cause the audio to correctly inverse-rotate, giving the sense of correctly positioned audio sources as opposed to a binaural-capture approach, which one might use if the POV were rotationally static, but which would not allow for this rotation.

As highlighted in the related work, specific audio elements are commonly associated with and used within horror media for various effects. We provided this research to Gary for guidance on the style of music we were looking to include within the experience. This prompted a series of iterations and feedback to create the final pieces of music. For other sound designs, this was more specifically allocated based on the adaptive elements chosen for each scene. A list of sound effects was passed along to Gary to be created and then placed within the experience. This list was taken from each scene's adaptive stages; a scene example can be found in the Authoring Process section.

6.2.8 Adaptation Mechanics in VR

As a core element of the experience, the adaptive aspects needed to be understood to ensure that they would be applicable once the experience was developed. Currently, there is no well-defined framework for creating fear-based adaptation within experiences. Having established an opportunity for fear within the trajectories framework, I discuss how trajectories and fear can develop into a framework in which to build an adaptive experience. I then discuss designing the adaptive system, where the process was split

into two stages: fear levels and adaptive categories.

Development of Fear Trajectories

As the trajectories framework outlines a canonical and participant (viewer) trajectory, the fear trajectories do the same. The canonical fear trajectory outlines the artist's intended emotional journey of fear throughout the experience. The participant fear trajectory represents the actual emotional journey of a viewer's fear throughout the experience. Using this fear trajectory framework, the core aim of adaptation is to ensure that the viewer's fear trajectory is kept in line with the canonical fear trajectory. However, the viewer can define the parameters of that trajectory by choosing the calibration video that matches their preferred fear experience. This is an important step, as it allows the user to dictate what level of fear they would like to feel. While the system only actually measures the presence of fear rather than the intensity of it, we can 1) make some inference from the peak values, and 2) use sustained or dampened fear effects to reduce the amount of fear within a window. The goal is not to change the shape of the canonical trajectory, but rather to allow the user to personalise that overall shape up or down depending on their preferences. Figure 6.2 shows an example of a fear trajectory. Up arrows indicate an activation of the adaptive system, intended to increase fear intensity, while down arrows indicate a reduction and/or removal of adaptation to reduce fear intensity.

I use the fNIRS data to manage this mapping of the viewer's fear trajectory. My previous study on fear in the brain, seen in Chapter 4, found that the left dorsolateral prefrontal cortex had significant activation during fear stimuli compared to calm stimuli. Thus, I use these findings and measure the left dorsolateral prefrontal cortex in real-time; activation in this brain

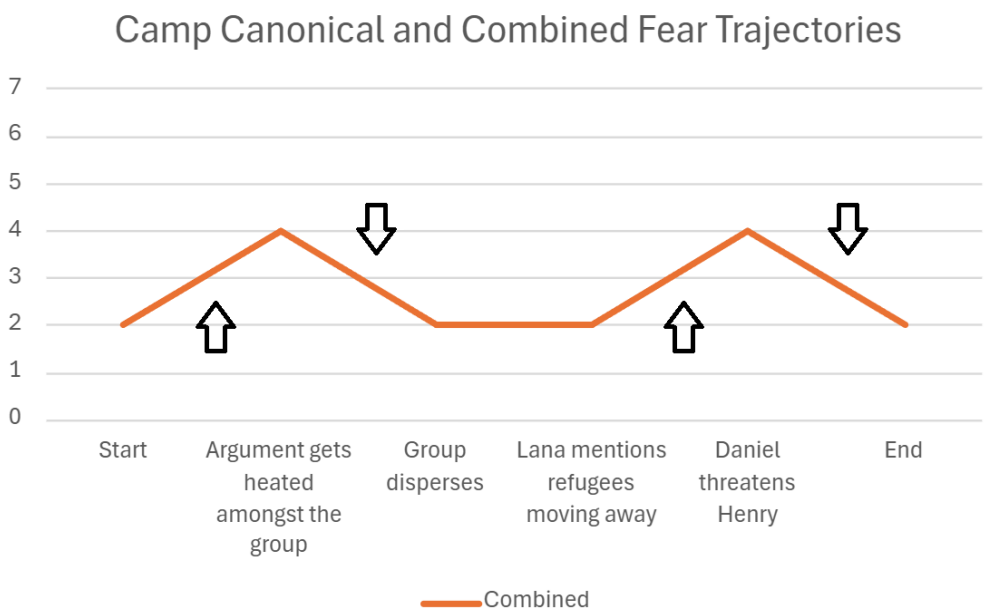


Figure 6.2: An example of a fear trajectory for the scene Camp. Up arrows indicate an activation of adaptation and intended increase in fear intensity, down arrows indicate a reduction and/or removal of adaptation to reduce fear intensity.

region will signify fear for the participant. If a viewer is found to be too fearful, or not fearful enough, an adaptation can trigger a change in the audio and visuals in an attempt to realign them with the intended level of fear for that moment in the experience. Knowing the intended fear level for any given moment requires breaking down each scene into key moments and analysing if they are intended to be fearful or not.

Establishing the Canonical Fear Trajectory

Each scene was split into 6 or 7 key narrative points chosen for the impact they would have on the viewer's experience, which includes the start and end of the scene. To establish a scale of fear for each of these key points, we used a fear scale developed by psychologist James Geer (Geer, 1965), which ranges from a value of 1 to 7. In order of 1 to 7, these values are: *None*, *Very Little*, *A Little*, *Some*, *Much*, *Very Much*, and *Terror*. To apply

this scale to the narrative points within each scene, each key moment was rated for 'intentional' fear depending on previous events and the intensity of dialogue and action present within the moment to determine an appropriate rating for that key moment. Co-Creator Artist's experience in horror film directing was necessary here to decide the appropriate ratings for each key moment.

Once each key narrative point had been established, we began unpacking which of these key moments would contain adaptive elements to increase or decrease the intensity of fear present. This was established as a binary 0 or 1, representing no adaptation for 0, or adaption for 1. Moments that have been specifically designed to be fearful have been set to be adaptive, whilst those intended as more dialogue-driven or relaxed have not been set as adaptive. This approach has been taken so as not to unnecessarily obscure the story with fearful elements. As the adaptation is designed to increase and decrease fear to fit the canonical trajectory of the scene, if a viewer is seen to have too much or too little fear at moments of adaptation, the system can trigger adaptations to realign the viewer with the canonical trajectory. With the scales for fear and active adaptation, a plot of each was made for every scene, including a final plot that combines both scales to produce a scale for which to aim with the adaptive system. This final plot is the canonical fear trajectory for that scene. Each plot can be found within its corresponding scene subsection in Section 6.3.

Adaptation Categories

Having established the key moments for each scene within the experience and areas where adaptation is present, we began establishing categories for adaptation. These categories define which aspects of the experience can be

altered to increase and decrease the fear present. The categories selected are: *colour treatment, music, sound design*, and *environment*, informed by the toolkit designed in Chapter 5. This approach aligns with OBM practices, which conceptualise audiovisual content as modular components to be adjusted to fit the needs of adaptation (Ursu et al., 2020). By treating each adaptive element as an object, the system could flexibly combine or swap assets in real-time while maintaining narrative coherence.

Colour treatment refers to altering the colours within visual objects to provide attention to or draw attention away from these objects. Music refers specifically to the background music playing within each scene. Sound design is the additional sound effects applied to scenes not related to music. Finally, environment refers to altering the 3D objects that make up the environment. For each scene, the alterations have been set out as to what may change upon triggering adaptation. An example is provided in the Authoring Process section.

Adaptation Stages

With the fear levels and categories established for each scene, the adaptation present within a scene at any one time is broken down into stages. These stages increase the fear in the scene as the stages increase, with the aim of a general increase in fear if the viewer has not yet reached their fear limit. Higher stages are additive to previous stages and therefore don't overlap or disrupt them. Stages are created to adapt both the visuals and the audio. To activate a higher stage - given the need to change the visual effects, the viewer hears a short heartbeat followed by a simulated blink so that once the eyes open, the changes will be in effect. At moments when adaptation is no longer present in the scene, the stages are removed

through the same blinking effect that is used to introduce them. Visuals are removed instantly back to the original look in a blink, while audio quickly fades back into the original audio.

Each scene contains 3 stages of adaptation. Each stage introduces a slight alteration to audio and volume and a subtly designed visual. Later stages provide more apparent and intense visual and audio changes. The adaptive elements are different per scene so that they fit directly into the scene itself without detracting from the narrative and intended story of the experience. It's key to make the adaptive system work alongside the experience to provide a unique version of the experience for each viewer.

Changing Adaptation Stages

To determine whether to move to another adaptive stage, the current adaptive stage remains active for a total of 12.5 seconds before a decision is made to transition or stay. The 12.5-second duration was chosen as it balances physiological response timing and practical adaptability: while a peak in oxygenated haemoglobin concentration is typically observed within 4–5 seconds (Bonilauri et al., 2021), a time frame between 10 and 15 seconds ensures reliable aggregation of data while maintaining an engaging and responsive user experience. 12.5 seconds sits in the middle of this time frame and is therefore the chosen duration.

For the adaptive system to transition to a new stage, the participant's brain activity is gathered over a 12.5-second rolling window period. The brain activity measured is then compared to the threshold for the participant, and one of 3 decisions is made. If the measured brain activity is below this threshold, the adaptation system transitions up a stage. If the measured brain activity is higher than the threshold, the adaptation system

transitions down a stage. If the measured brain activity is within ±10% of the threshold, the adaptation system stays at the current stage. Currently, there is no standard for which approach is best for defining a range in a context such as this. A range of 10% allows for some movement within the threshold without being too constricted.

This is a threshold-based approach to the recognition of fear. While the accuracy and depiction of emotional states are limited when using a threshold-based approach, its simplicity enables faster response times and more predictable behaviour, providing suitability for adaptation where rapid feedback is essential. Having already established a method for inferring fear from fNIRS in chapter 4, the use of a threshold provides efficiency for fear recognition in the adaptive system.

6.2.9 Filming

Filming took place over 1 week on a sound stage at the Virtual and Immersive Production Studio in Nottingham. The filming process was unique from the traditional approach of 2D cinema. Where traditional 2D cinema uses film cameras, with different angles and shots to capture actors and the environment, the volumetric capture setup is designed to capture a specific space and everything within that space, with the cinematic language becoming more apparent within the post-production process. This didn't, however, simplify the filming process, as each scene required a different setup for the volumetric capture to ensure that actors were captured efficiently from the perspective of the viewer. Actors were also required to have an understanding of volumetric capture and scene setups to ensure that they were within the scene and clear when interacting with the viewer.

Whilst on set, Richard Ramchurn took on the role of technical director, focusing on camera setup and actor positioning within the scenes. At the same time, Mat Jons worked with the lighting and the actors' dialogue. Gary Naylor managed all audio setup and recording throughout, while I focused on recording the captures, inputting any lighting changes, and assisting with camera setups.

The following sections provide a breakdown of each scene and the volumetric setup. All POV captures are single-camera captures from the top facing downward to emulate a real-life viewpoint.

6.3 Individual Scene Breakdown

The following sections cover a breakdown of each scene, detailing the storyboarding and adaptation design choices.

6.3.1 Refugee

Story Boarding

'Refugee' follows a small group of refugees walking through a derelict city towards what they believe is a refugee camp provided to house those affected by the climate crisis. The characters present are a male (Mike, 40s) whom the viewer embodies, a son (Oliver, 16) and daughter (Demi, 15), and an older woman (Mary, 50s). In front of this group are two women (Lana and Sophia, 30s) with Lana holding an infant (IO, 6 months). There is a discussion between Lana and Sophia about their long journey to where they are, including jokes about the scarcity of food. This is soon drowned

out by talk from the rest of the group deteriorating into an argument between Mike and Demi around the crisis they have ended up in, and how this has affected Demi's life. Along the walk, the refugees pass a billboard of Alistair Cross, the owner of the refugee camp, who is audible describing how the camp is a safe place for those looking for refuge. Another character (Henry, 40s), the leader of the refugees, has also passed, stating that the main refugee group is close to the camp. Figure 6.3 shows a static shot of the Refugee scene.



Figure 6.3: Static Shot of the Refugee Scene

Key Moments and Fear Levels

'Refugee' contains 5 key moments within the scene. These are the conversations between Lana and Sophia at the beginning of the scene, the introduction of the dialogue between the family, the argument between the family, the billboard of Alistair, and the introduction of Henry. Table 6.1 below shows the layout of each key point and the scales provided by the canonical trajectory, the adaptation trajectory, and the combined trajectory.

As shown within the Canonical trajectory in Figure 6.4, the levels of fear

Trajectory	Start	Lana & Sophia	Start of the family chat	Argument in the family	Billboard of Alistair	Henry welcoming the group	End
Canonical	1	1	1	2	3	3	3
Adaptation	0	0	0	1	1	1	1
Combined	1	1	1	3	4	4	4

Table 6.1: Refugee Key Moments

are minimal within this scene, starting from 1 and progressing to 2 over the scene. To accompany this, the adaptation has been chosen to be active from the first scene of increased fear and continue until the end of the scene.

The two key moments at the start of this scene, 'Lana & Sophia' and 'Start of the family chat', both contain a 0 on the fear scale. These scenes are designed as an introduction to the experience, describing the changes the present characters have been through during their travels and why they are travelling to a refugee camp. As the scene progresses into the 'Argument in the family' key moment, the fear increases to 2 to express the distress within the group. This is then further increased to 3 once within the 'Billboard of Alistair' moment, maintaining this for 'Henry welcoming the group'. The last 2 key moments have heightened fear due to their foreboding towards the narrative, and an increased level of fear is provided to reflect this. The adaptation trajectory, as shown in Figure 6.5, follows alongside the canonical trajectory, toggling at moments of increased fear. Adaptation is triggered upon entering the 'Argument in the family' key moment and is maintained throughout the rest of the scene.

Adaptive Categories

The following list describes the adaptive elements to be used within the scene Refugee:

- Colour treatment can be applied to the billboard of Alistair to alter

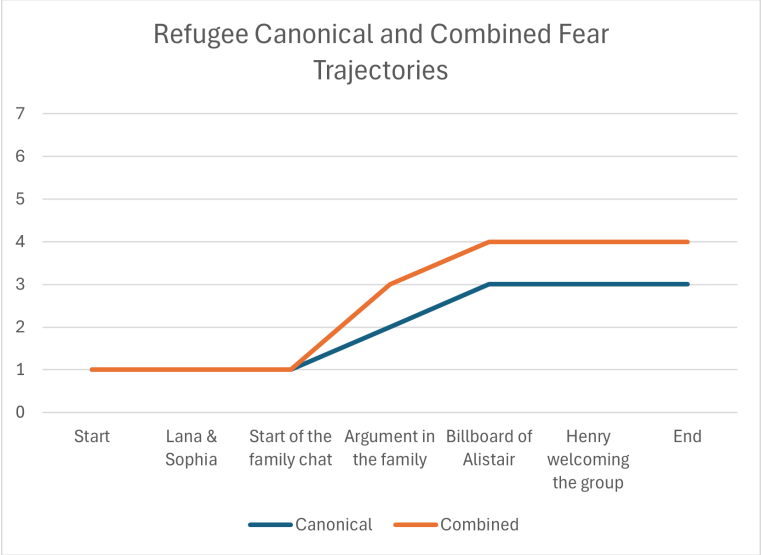


Figure 6.4: Refugee Canonical and Combined Fear Trajectory

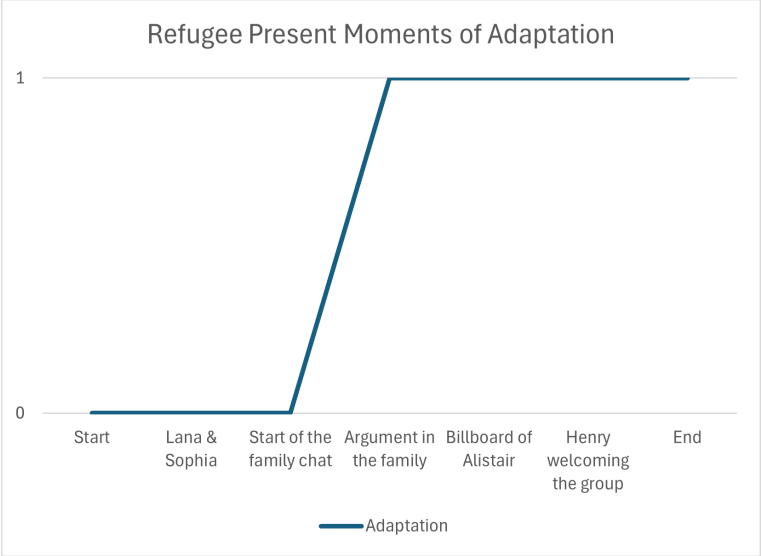


Figure 6.5: Refugee Adaptation Chart

the colour of Alistair's hologram. Colour changing applies a red tone to the existing visual as an element of foreboding towards the evil intent of the character.

- Music cues for altering the music present within the current moment. Cues include effects such as rising tone and sudden sounds. These aim to play on themes of fearful music commonly found in horror scores.

- Sound design can include distant screams, whispers into the ear of the viewer, and noises of machinery, which are found later in the processing scene. The screams are designed to provide a sudden fright to the player. The whispers and machinery are aimed to provide suspense and a feeling of unease as to what is to come.

- Environmental changes can include the sudden appearance of bodies at the side of the road, Silhouettes in building windows, changing the scene from day to night, flickering lights, and the changing of road detritus to human bodies. These environmental changes can be accompanied by the screams and other sound design adaptations to create a greater combined effect.

Adaptive Stages

As adaptation is continuous within this scene once it is triggered, there is only a need for a single version of each stage. Additionally, each stage can build upon the last, maintaining the alterations that any previous stage applied.

Stage 1: Slight introduction of the altered horror music as well as silhouettes in the windows of buildings, turning the scene to night, and the colour treatment of the billboard of Alistair. These subtle effects should create a gradual increase in fear as the viewer walks through the scene. This shouldn't instantly frighten the viewer, but may put those more easily scared into a fearful state.

Stage 2: Further introduction of the altered horror music, replacement of road detritus with human remains and the flickering of lights. There can also be the inclusion of whispers and faint machinery noises. This

stage aims to apply a more apparent increase in fear as there is plenty of debris scattered throughout the scene, with the aim of leaving a majority of viewers within this stage.

Stage 3: Take over from the previous music into the altered horror music, bodies at the side of the road, as well as screams to be heard and an increase in volume of machinery noises. This final stage aims to push the remaining viewers to feel fear, combining all previous stages. This is much more intensive and directed at the viewer.

Filming

This scene was filmed in multiple parts, split into Henry, Alistair, Lana and Sophia, and the rest of the main group. The capture of Alistair was placed on a billboard so could be filmed alone. For Henry, although he interacts with the group as they are walking, he was filmed separately, and the group walking past was simulated to create the effect that he was engaging with the group. As there was no discussion between Lana and Sophia, and the rest of the group, they were filmed separately. Treadmills were used to simulate the walking motion of the characters. The same approach was used for the rest of the group, using treadmills to simulate walking. For both refugee groups, timings were put in place for when they were to interact with the billboard of Alistair and the passing of Henry. This involved one person walking past the group in a motion to attract their attention. To capture the POV, we recorded a loop of an actor walking on a treadmill whilst holding onto a wheelchair. This could then be stitched into the wheelchair present within the scene from the previous capture.

6.3.2 Camp

Story Boarding

'Camp' shows the discourse between 4 refugees as they struggle for resources and survival within the refugee camp. The refugee camp is within a derelict building, cramped with tents, mattresses, and various belongings. The characters present are Henry and Sophia from the refugee scene, as well as another female (Nihira, 30s) and another male (Daniel, 40s). The viewer takes on the POV of a refugee bystander. Daniel approaches Henry, concerned that they are not being treated well and that they are lacking resources. Tension increases among the group as a hopeful conversation from Henry isn't enough to calm the group. After an argument, the group takes a step away, and Lana from 'refugee' enters. Lana expresses that another group has left for training and that the group within the scene will be next. The scene ends with Daniel threatening Henry that if he doesn't do something to fix the situation, then he will. Figure 6.6 shows a static shot of the Camp scene.



Figure 6.6: Static Shot of the Camp Scene

Key Moments and Fear Levels

'Camp' contains 4 key moments within the scene. These are the heated arguments at the beginning of the scene between the characters, the dispersion of the group, Lana mentioning the other refugees having moved away, and Daniel threatening Henry at the end of the scene. Table 6.2 below shows the layout of each key point and the scales provided by the canonical trajectory, the adaptation trajectory, and the combined trajectory.

Trajectory	Start	Argument gets heated amongst the group	Group disperses	Lana mentions refugees moving away	Daniel threatens Henry	End
Canonical	2	3	2	2	3	2
Adaptation	0	1	0	0	1	0
Combined	2	4	2	2	4	2

Table 6.2: Camp Key Moments

The canonical trajectory for 'Camp', Figure 6.7, shows a variation in the fear scale throughout. Upon the first key moment, 'Argument gets heated amongst the group', fear is increased from a scale of 2 to 3, signifying the intensity of the argument. As the group disperses, this intensity drops back to 2 and maintains before the final key moment, 'Daniel threatens Henry', where this then rises up to 3 again. As shown in Figure 6.8, adaptation is activated at the key moments of 'Argument gets heated amongst the group' and 'Daniel threatens Henry' in line with the increase in fear from the canonical trajectory. For the rest of the scene, no adaptation is present.

Adaptation Categories

The following list describes the adaptive elements to be used within the scene Camp:

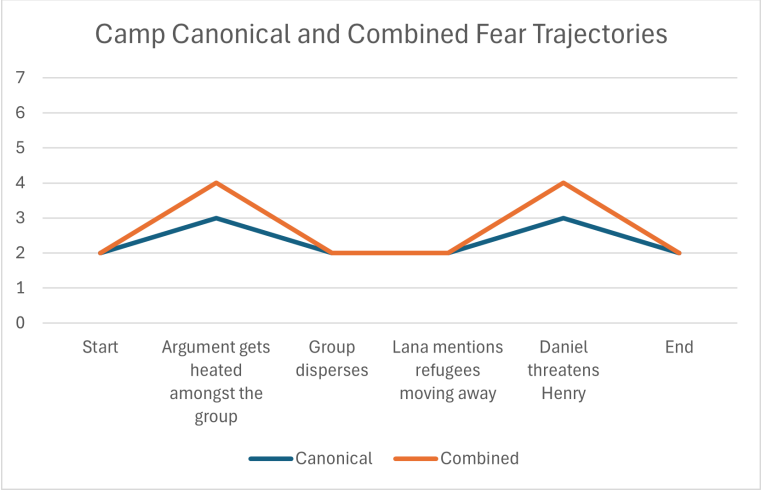


Figure 6.7: Camp Canonical and Combined Fear Trajectory

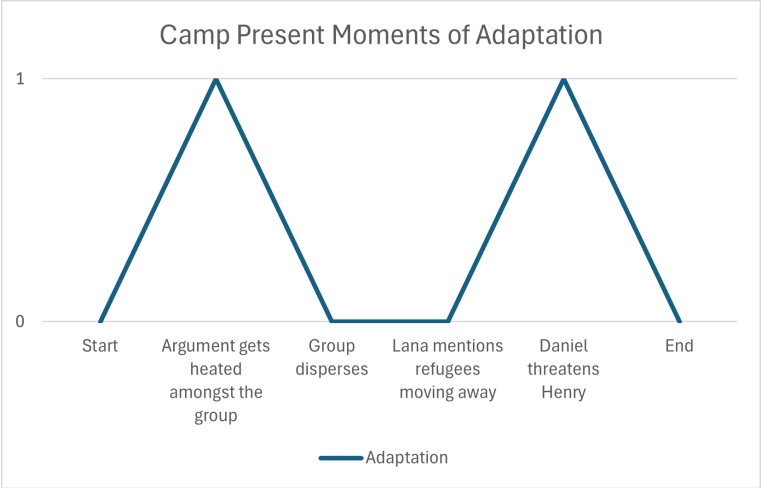


Figure 6.8: Camp Adaptation Chart

- No colour treatment is designed for this scene.
- Music incorporates a rising tone to further express the tension between characters during arguments.
- Sound design includes background screams. This is aimed to incite fear and panic in the viewer.
- Environmental includes altering the visuals of existing background characters in the scene to look more horrific. This was done by adding blood effects and turning them into piles of meat to escalate the level of discomfort.

Adaptive Stages

Adaptation is not continuous throughout this scene; however, with no change in location, the stages won't differ from the first activation of the adaptive system to the second. Each stage builds upon the last, maintaining the alterations that any previous stage applied.

Stage 1: Slight introduction of the altered horror music and the inclusion of whispering sounds for the POV. These slight changes should create a start for increasing fear for the viewers without any direct visual changes.

Stage 2: Further introduction of the altered horror music and the addition of blood-stained textures. Further increase of fear and changes to visuals aim to push more viewers to their threshold of fear. Blood-stained textures are scattered about the camp building and objects within the scene.

Stage 3: Take over from the previous music into the altered horror music, and turn the visual background objects into piles of meat. With the final stage, these more dramatic increases aim to push the last viewers to their fear threshold through direct object changes and more disturbing visuals.

Filming

Filming was split into two parts: one part for the dialogue of the scene and another for Lana's entry into the scene. For the dialogue, this was a single continuous recording. When Lana enters, she appears within the scene, walking in from the side. For filming Lana walking into the scene, we used a treadmill to simulate Lana walking into the scene, which was then stitched into the moment that Lana enters the dialogue capture. Actors were made aware of where certain virtual objects would be, such as tents,

and were required to work around these. There are moments when Lana and Sophia enter/exit a tent, which requires a floor layout of the tent and entrance. To capture the POV, we recorded a loop of an actor dressed in tattered clothing, standing still with their arms crossed to fit them in as a bystander to the dialogue of the scene.

6.3.3 Plants

Story Boarding

'Plants' is set within a greenhouse; the viewer embodies a soldier guarding the location. In front of the POV is a male (Alistair, 50s) and a female (Cleo, 40s). Lead in by a female soldier (Theresa, 18) is Henry. Henry begins by thanking Alistair for his time, before stating that he and the refugees are struggling and are looking for jobs and resources. Alistair appears to listen but provides little comfort on the issue before leading on to discuss a plant growing within the greenhouse called Cuscata. Cuscata presents itself as a yellow vine growing around other plants. Alistair explains that this plant absorbs nutrients from its host plant, ending the conversation ominously by saying, "Even a parasite has its uses". Henry is led out of the greenhouse, and the scene ends. Figure 6.9 shows a static shot of the Plants scene.

Key Moments and Fear Levels

'Plants' contains 4 key moments within the scene. These are the entry of Henry into the scene, the initial discussion between Alistair and Henry regarding living conditions, the movement toward the other table containing a unique plant, and the mention from Alistair that "even parasites have



Figure 6.9: Static Shot of the Plants Scene

their uses". Table 6.3 below shows the layout of each key point and the scales provided by the canonical trajectory, the adaptation trajectory, and the combined trajectory.

Trajectory	Start	Entry of Henry	Initial discussion of plants	Moving over to other table	Alistair talks about parasites	End
Canonical	2	2	2	3	3	3
Adaptation	0	0	0	1	1	1
Combined	2	2	2	4	4	4

Table 6.3: Plants Key Moments

The 'Plants' canonical trajectory in Figure 6.10 is similar to that of Refugee, with a low fear scale of 2 from the start, rising to 3 at the key moment of 'Moving over to other table' and continuing at the same fear scale. This key moment signifies the start of foreboding dialogue as well as the dialogue twisting from the needs of the refugees towards the purpose of the refugee camp and Alistair's ideas. Adaptation is present upon the increase of fear within this scene and is kept active till the end of the scene, as shown in Figure 6.11.

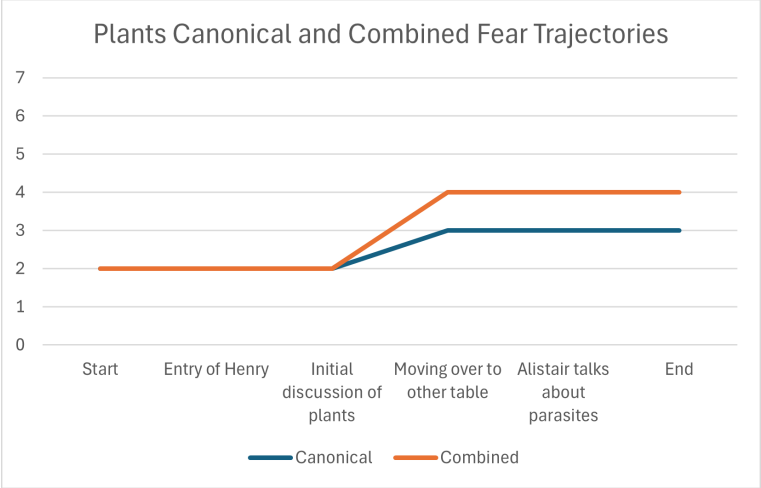


Figure 6.10: Plants Canonical and Combined Fear Trajectory

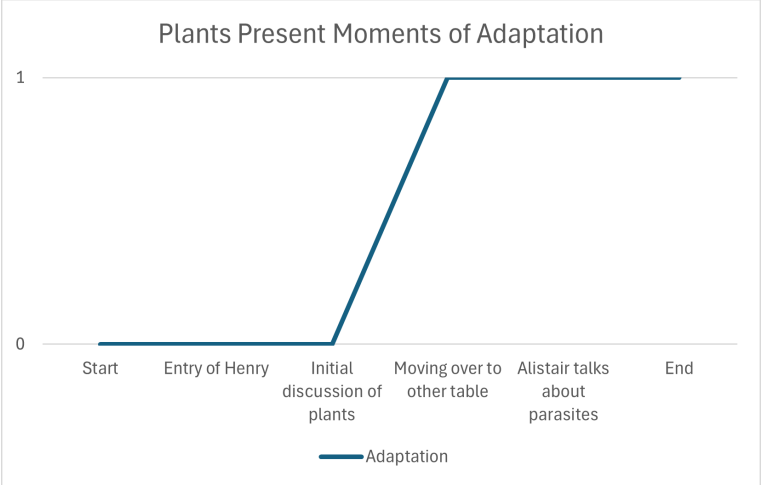


Figure 6.11: Plants Adaptation Chart

Adaptation Categories

The following list describes the adaptive elements to be used within the scene Plants:

- Colour treatment is used in this scene to alter the green from all of the plants to red. Not only does this draw attention to the plants, but it also removes the natural green and provides a darker, more sinister tone.
- Music contains sequences with altered tone. This aims to increase

suspense.

- Sound design includes background screams. This is aimed to incite fear and panic in the viewer.
- Environmental changes include changing the scene to night, flickering lights, human figures positioned within the flickering lights, turning the rain red to represent blood, changing the sky to red to emulate the blood rain and bloodied textures. This aims to play into the struggle of resources available by detracting from the life of the environment and turning to a much darker theme.

Adaptive Stages

As adaptation is continuous within this scene once it is triggered, there is only a need for a single version of each stage. Additionally, each stage builds upon the last, maintaining the alterations that any previous stage applied.

Stage 1: Slight introduction of the altered horror music, the colour change of the plants from green to red, and faint, distant screams. The music is the main focus of fear, whilst the plant colour change aims to incite foreboding for later stages, where plants are changed to weeds. The screams are provided to add unease.

Stage 2: Further introduction of the altered horror music, the colour change of rain and the sky to red, and flickering lights. This builds upon the discolouration of the plants with a more fearful environment, in effect. Manipulation of the lighting is aimed at reflecting the undertone of danger in the scene and inducing a sense of unease in the audience.

Stage 3: Take over from the previous music into the altered horror music, application of blood textures, and human figures positioned within the flickering lights. This is a much more dramatic effect for blood than previously used to escalate the fear within the scene. Also, the addition of figures within the lights adds the effect of an uncomfortable and unknown presence.

Filming

As there are no additional dialogues, character entries, or equipment limitations, filming for this scene required one volumetric camera setup. To film the POV scene, the cameras were set up so that they were pointing outwards from the position of the POV. 4 cameras were chosen to ensure that any characters moving across the scene, such as Henry on entry, are captured and don't simply appear. To capture the POV we recorded a loop of an actor dressed as a soldier holding a gun. They inspect the gun on occasion but stand still, acting as a guard on standby.

6.3.4 Raid

Story Boarding

'Raid' takes place within a tent inside the refugee camp. Present within the scene are Lana and Sophia as the viewer embodies a baby (IO, 6 months). The scene opens with Lana talking to us before Sophia enters the tent. The two characters discuss life before the climate crisis and how their lives used to be. They also discuss their relationship and affection for each other. After some time, a door to the building opens up as the voice of soldiers enters, commanding the refugees to go for retraining, with all

following actions only seen through silhouettes on the tent. A heated argument between the soldiers and refugees leads to the soldiers opening fire on the group. Refugees run around looking for places to hide before we see Sophia's silhouette crawl in front of the tent, before she is executed. More gunfire follows, with bullets hitting and killing Lana before the scene closes. Figure 6.12 shows a static shot of the Raid scene.

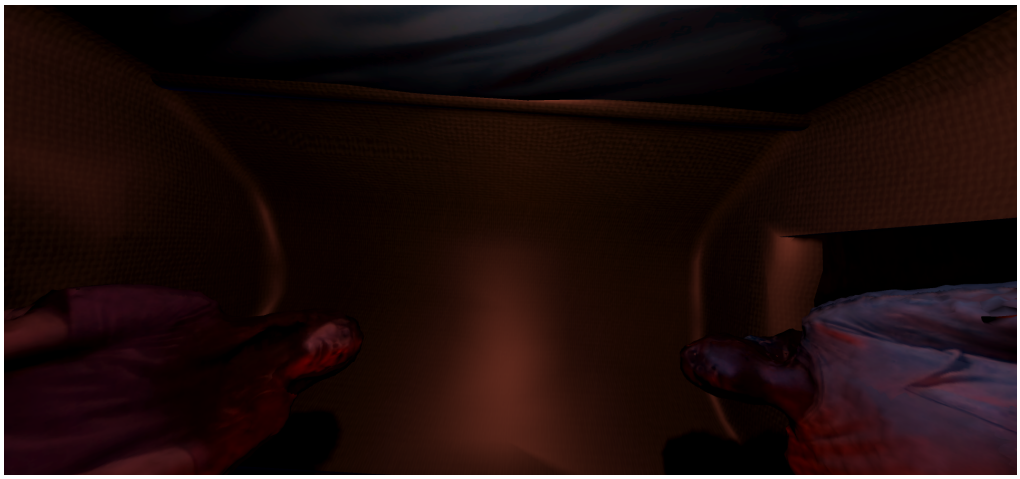


Figure 6.12: Static Shot of the Raid Scene

Key Moments and Fear Levels

'Raid' contains 5 key moments within the scene. These are Sophia and Lana talking at the start of the scene, the building door to the refugee camp opening, shots being fired within the camp, Sophia dying, and gunfire at the end of the scene. Table 6.4 below shows the layout of each key point and the scales provided by the canonical trajectory, the adaptation trajectory, and the combined trajectory.

Trajectory	Start	Sophia and Lana talking	Door opens	Shots fired	Sophia dies	Gunfire	End
Canonical	1	1	3	4	5	6	6
Adaptation	0	0	1	1	1	1	1
Combined	1	1	4	5	6	7	7

Table 6.4: Raid Key Moments

The canonical trajectory for Raid, Figure 6.13, increases throughout the scene. The scene begins at a fear scale of 1 before increasing to 3 at the key moment of 'Door opens', this is then increased to 4 at 'Shots fired', 5 at 'Sophia dies' and then 6 at 'Gunfire'. Each of these key moments is designed to further intensify the scene, causing this gradual increase over time. As such, adaptation is present at every key moment beyond 'Sophia and Lana talking' as seen in Figure 6.14.

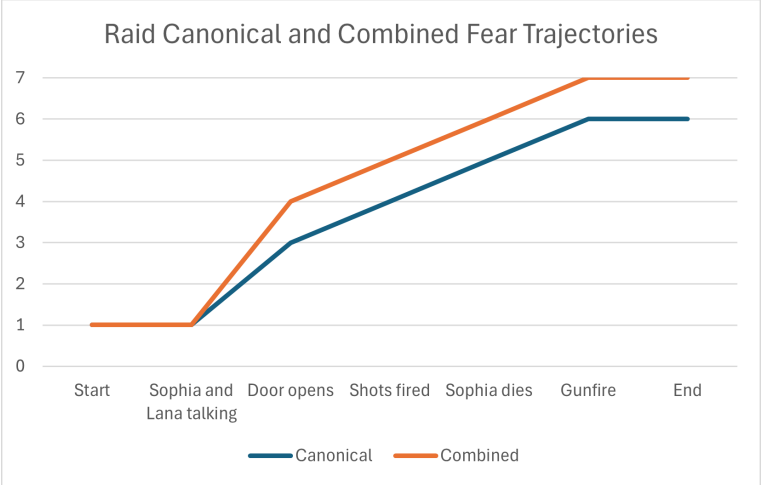


Figure 6.13: Raid Canonical and Combined Fear Trajectory

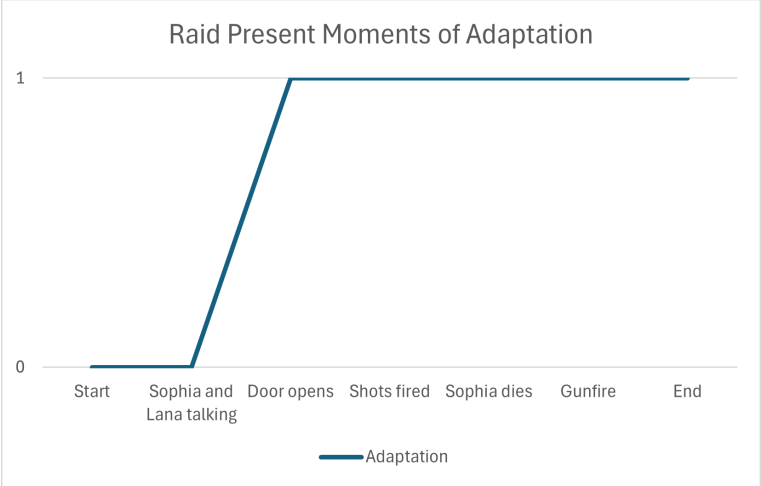


Figure 6.14: Raid Adaptation Chart

Adaptation Categories

The following list describes the adaptive elements to be used within the scene Raid:

- No colour treatment is designed for this scene.
- Music increases the intensity through various techniques, such as rising tone. As the scene intensity increases with each key moment, the music aims to do the same to provide a higher impact of tension and terror.
- Sound design alters the screams heard within the scene, adding more intensity to these screams and the amount heard.
- Environmental adds blood effects. This aims to provide more gore and fright throughout the existing fear.

Adaptive Stages

As adaptation is continuous within this scene once it is triggered, there is only a need for a single version of each stage. Additionally, each stage builds upon the last, maintaining the alterations that any previous stage applied.

Stage 1: Slight introduction of the altered horror music, blood textures on the tent and bullet shots through the tent. subtle changes introduce the fear, whilst blood on the tent provides foreboding for the scene.

Stage 2: Further introduction of the altered horror music and an increased amount of screams, more gunshots and slashing noises. With limitations

within the scene, this stage does not contain many alterations, but it aims to push more viewers to their fear threshold.

Stage 3: Take over from the previous music into the altered horror music and bloody figures watching the viewer from a distance. The final stage should provide a final level of fright to the viewers that pushes the remaining viewers to their fear threshold. The addition of bloody figures watching the viewer aims to provide a sudden visual change to frighten the viewer.

Filming

Filming for 'Raid' was unique from the other scenes due to the POV being of a baby. This required the cameras to be facing up from the ground to capture the actors above. The scene was shot in one recording as there were no additional interactions. To capture the POV of the baby, we did a single-camera capture facing down at a baby on the floor.

6.3.5 Processing

Story Boarding

'Processing' begins with the POV strapped to a chair on a processing line. In front of them is Henry, also strapped to a chair. The processing line moves forward as the characters move through a dimly lit tunnel before emerging into a white room containing a worker (Simon, 40s). The worker signals through a radio that he believes he has found who Alistair Cross was looking for. Henry swears at the worker, asking why he's in the situation, before the worker hits Henry across the face. The worker then turns to the POV and tasers them for looking in his direction. Alistair then walks in to

talk with Henry, explaining that we are a part of the process, that those who have been in the camp for a long time deserve food and that even parasites, us, have their uses. Alistair nods to the worker before Henry and the POV begin moving along the processing line again. The scene moves to the abattoir, containing machinery such as saws. Another worker prepares a bolt gun as Henry pleads for his life. Henry is shot in the head by the worker before they move towards the POV, and the scene ends. Figure 6.15 shows a static shot of the Processing scene.

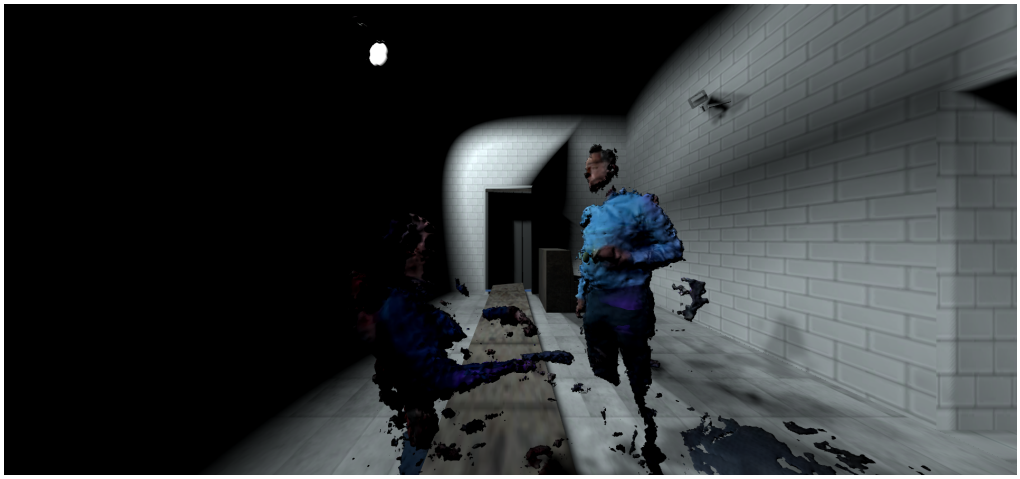


Figure 6.15: Static Shot of the Processing Scene

Key Moments and Fear Levels

'Processing' contains 5 key moments within the scene. These are Henry and the POV being strapped to a chair, the attack from the worker in the first room, Alistair entering the scene, moving to the second room, and being killed in the second room. Table 6.5 below shows the layout of each key point and the scales provided by the canonical trajectory, the adaptation trajectory, and the combined trajectory.

This scene is designed to be the most fear-intensive, chronologically following 'Raid', which ends at a fear scale of 6. As seen in Figure 6.16, this

Trajectory	Start	Henry and POV strapped to a chair	Henry and POV attacked in the first room	Alistair comes in	Moving to 2nd room	Killed in 2nd room	End
Canonical	4	4	5	4	5	6	6
Adaptation	1	1	1	0	1	1	1
Combined	5	5	6	4	6	7	7

Table 6.5: Processing Key Moments

scene starts at a fear scale of 4, increasing to 5 at the key moment 'Henry and POV attacked in the first room' before dropping back to 4 at 'Alistair comes in'. The fear scale then rises to 5 again at 'Moving to 2nd room', continuing to 6 at 'Killed in 2nd room'. As this scene is designed to be the most fearful, adaptation is active from the start of the scene. At the key moment 'Alistair comes in', adaptation is toggled off, before activating again for 'Moving to 2nd room' and staying active. This can be seen in Figure 6.17.

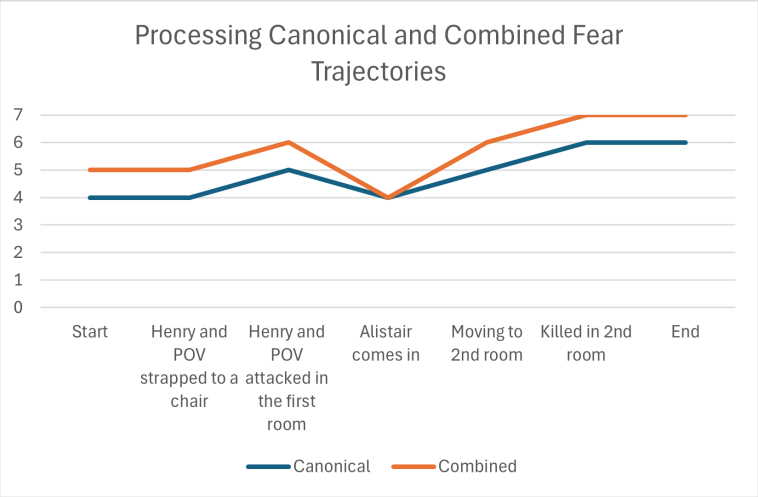


Figure 6.16: Processing Canonical and Combined Fear Trajectory

Adaptation Categories

The following list describes the adaptive elements to be used within the scene Processing:

- No colour treatment is used within this scene. This is due to the

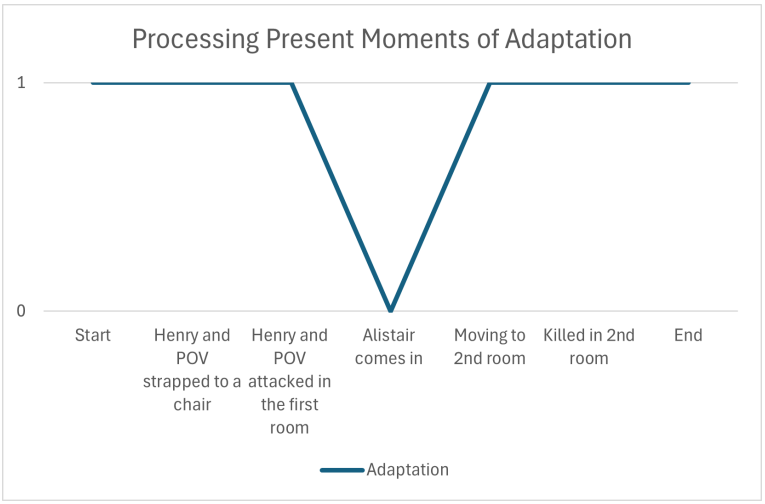


Figure 6.17: Processing Adaptation Chart

already changing environment, and the use of colour treatment may distract from other elements of fear.

- Music increases in intensity as the scene progresses. This accompanies the increasing intensity of the events and climax as the scene reaches the death of the characters. This aims to push more terror as the intensity increases.

- Sound design includes a combination of machine noises and screams. The use of both provides sounds that provide backing to the music's intensity and dread for what is to come within the scene.

- Environmental changes include flickering lights, changing lighting colour to red, appearance of eyes in darkness, shadowy figures and bloodied textures. This is to reduce visibility of the surroundings, an approach commonly used in horror to increase fear through reduced visibility. Additionally, it applies the feeling of being watched to the viewer.

Adaptive Stages

Adaptation is not continuous within this scene. Additionally, this scene moves location and therefore the stages can be separated into two activations. The first activation contains the stages for the first activation of the adaptive system, while the second activation contains the stages for the second activation. Each stage builds upon the last, maintaining the alterations that any previous stage applied within its own set.

Activation 1, Stage 1: Slight introduction of the altered horror music and changing of the lighting to red. The lighting change within the restricted view aims to build tension for what is to happen.

Activation 1, Stage 2: Further introduction of the altered horror music and eyes hidden in the darkness that face the viewer. The lighting also now flickers. Flickering lights and hidden eyes aim to create discomfort of being watched and reduce lighting.

Activation 1, Stage 3: Take over from previous music into the altered horror music, machinery noises, screams, and bloodied textures on the walls. The final stage introduces more horrifying sounds and creepier textures for when they can be seen.

Activation 2, Stage 1: Slight introduction of the altered horror music and eyes hidden in the darkness that face the viewer. The use of returning to hidden eyes aims to create more discomfort and dread for what is coming up.

Activation 2, Stage 2: Further introduction of the altered horror music, added screams, complete reduction in lighting except for on the worker capture, blood rain and bloodied textures. Although the scene is dark, the

lighting changes focus on the worker who is about to kill the characters. The use of blood rain fits the disturbing ambience of the scene

Activation 2, Stage 3: Take over from previous music into the altered horror music, flickering lights with the appearance of dismembered figures, and an increase in machinery noises. The use of flickering lights and moving figures aims to provide a feeling of danger and distress as the scene comes to an end.

Filming

'Processing' was the most complex scene for filming. As the scene involves virtual movement as well as multiple character entries, the scene is split into three recordings. The first recording involves Henry and the POV moving along a conveyor belt. Lighting was done manually through the physical rotation of standing lights to emulate the characters passing by static lights. The second recording is of Henry having a discourse with a worker and Alistair. This recording involved three cameras to capture the three moving actors within the scene. The third recording takes place within the killing room. Here, a similar setup is used as the second recording with three cameras to capture the two moving actors. For the POVs within this scene, three POVs were recorded. The first POV recording is set up the same as the first recording of Henry, using rotating lights to simulate movement. The second POV is within the white room, with the POV responding to a direct interaction from another actor from a different capture. The third recording is of the POV in the killing room to capture the different lighting.

6.3.6 Supper

Story Boarding

'Supper' takes place within a dining room as part of a middle-class house. The table is set for 4 people with 2 characters present, Dominic (Male, 15) and Theresa. In the background is a framed portrait of Alistair. Theresa is watching fights between refugees whilst Dominic is in the POV. There is a short dialogue between Dominic and Theresa before their mum, Liz (Female, 40s), enters holding food and interrupts the dialogue to mention that Dominic has good news about a job. Theresa then begins to tease Dominic about what this could be, causing a small argument between the two characters. Before long, the father, Simon, enters and asks Dominic about the new job. Dialogue is exchanged between all 4 characters until Dominic asks if the group could end up like the refugees. The rest of the family shows no remorse and that they are where they belong. The characters take a glance at the Alistair poster before opening a pot lid to see a human head inside. The characters begin serving the food, and the scene ends. Figure 6.18 shows a static shot of the Supper scene.



Figure 6.18: Static Shot of the Supper Scene

Key Moments and Fear Levels

'Supper' contains 5 key moments within the scene. These are the discussions between the POV and the sister, the mum entering the room mentioning good news, the sister teasing the POV character, the dad entering the scene, and the eating of human meat at the end. Table 6.6 below shows the layout of each key point and the scales provided by the canonical trajectory, the adaptation trajectory, and the combined trajectory.

Trajectory	Start	Discussion between the POV and his sister	Mum comes in to mention the good news about POV's new job	Sister teasing POV and discourse	Dad comes in	Eating human meat	End
Canonical	1	1	1	2	1	3	3
Adaptation	0	0	0	1	0	1	1
Combined	1	1	1	3	1	4	4

Table 6.6: Supper Key Moments

The final scene, 'Supper', contains variations in fear scale as seen in Figure 6.19. The scene starts at 1 before escalating to 2 at 'Sister teasing POV and discourse', the scale retracts back to 1 at 'Dad comes in' before rising to 3 at 'Eating human meat'. The discourse between the sister aims to provide tension, whilst the eating of human meat is aimed to provide discomfort and disgust, therefore both increasing the fear scale to different degrees. Adaptation reflects these fears, which increase by activating at the same key moments that the fear scale increases, as shown in Figure 6.20.

Adaptation Categories

The following list describes the adaptive elements to be used within the scene Supper:

- No colour treatment is used within this scene.

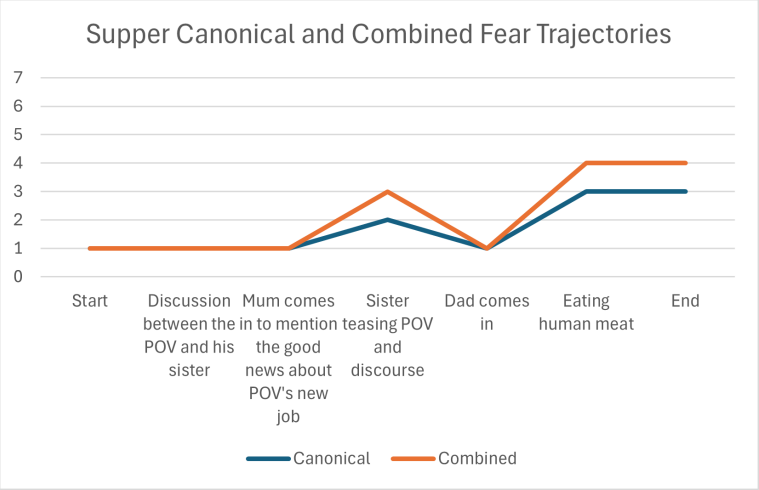


Figure 6.19: Supper Canonical and Combined Fear Trajectory

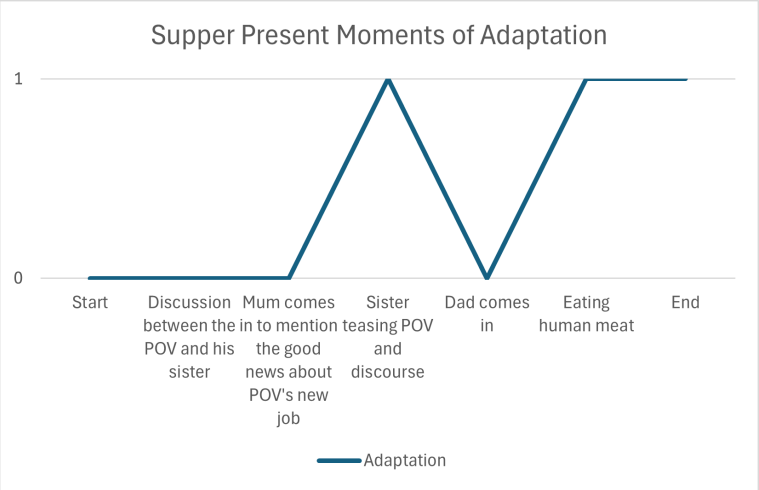


Figure 6.20: Supper Adaptation Chart

- Music heightens in noise intensity to increase the tension of key moments.

- Sound design includes the sounds of what the sister is watching within the scene, including sounds of screams and violence, as well as blender noises of bones. This is to bring discomfort to the viewer and provide elements of gore prior to more disturbing events.

- Environmental includes altering the poster of Alistair, placing human body parts on plates, and blood on the walls. Each of these changes aims to play into the disturbing nature of the scene by drawing on

the actions of the previous scenes.

Adaptive Stages

Adaptation is not continuous throughout this scene; however, with no change in location, the stages won't differ from the first activation of the adaptive system to the second. Each stage builds upon the last, maintaining the alterations that any previous stage applied.

Stage 1: Slight introduction of the altered horror music as well as blender noises, and the sounds from what the sister is watching at the start of the scene. Both additions happen at the start of the scene, and are therefore required for stage 1; otherwise, they could be missed if they were part of a later stage.

Stage 2: Further introduction of the altered horror music, altering the poster of Alistair and the faces on the walls. This is irrespective of actions in the scene, so it can fit well as part of a later stage. This also draws a lot of attention to the surroundings through much more disturbing and creepy visuals.

Stage 3: Take over from the previous music into the altered horror music, human body parts on the table, and added screams. This final stage shows a lot more gore and disturbance around the centre of the scene, drawing attention to the previous actions of the characters.

Filming

'Supper' was filmed with 1 recording. Although characters enter and exit the scene, the focus is on the setup of the dinner table. Three cameras are

used to capture the scene and all 3 actors that surround the table. The POV was filmed with the character generally behaving in a somewhat reclusive manner to give the effect of feeling uncomfortable with the scenario that they are in.

6.3.7 The Hub

The hub's initial design was a refugee camp, immediately immersing the viewer into the dystopian environment. The memories in this scenario would act more as real-time events, with the hub visually altering as each scene is viewed to reflect what had happened within the scene. This, however, was changed to a museum of the future, where each scene is a memory from the past. This design choice was made to provide a safe place distant from the chaos of the refugee experience, but that still maintained immersion. The museum is surrounded by a variety of different exhibitions which reference the memories. The memories themselves are designed as microchips that the viewer can pinch to select. Each microchip also has a placard in front to display who the embodied character will be, their date of birth, date of death, and recording date. This allows the viewer to understand the memory order and gives some detail to each POV. This version of the hub scene won't contain any visual alterations, but instead provides audio detailing the memory the viewer had just experienced.

The audio is altered based on the average fear shown by the viewer. A baseline average is provided for each viewer while they are in the hub. Using this average, if their fear for a scene has been above the average, they get a voice-over with increased intensity upon returning to the hub. If the average is below this baseline, then they get a relaxed version of the voice-over. Finally, if their average stays within a small range from the

baseline, they get a neutral voice-over. Figure 6.21 shows a static shot of the Hub scene.

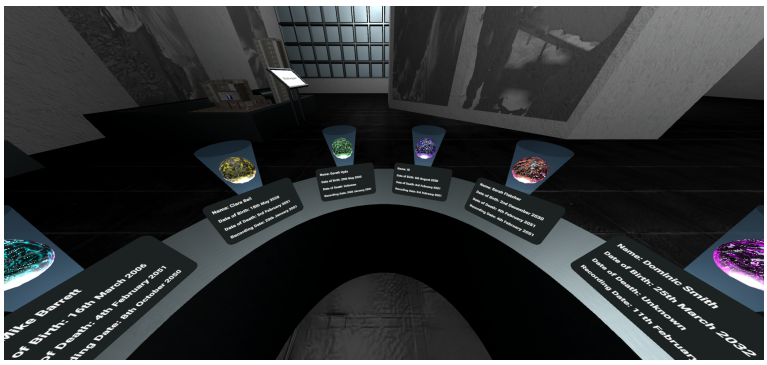


Figure 6.21: Static Shot of the Hub Scene

6.4 Implementation Post Filming

With filming wrapped up, development began to bring the recordings into the VE. The DepthKit software used to capture the recordings was compatible with Unity, allowing them to be imported and ready to use. This set Unity as the game engine with which to develop the experience.

6.4.1 Visual Building

For the development of the VE, I worked alongside Sumit. Sumit developed the initial concept designs for each scene. When filming, AlbinoMosquito developed blueprints of each scene, which were used to direct the actors and then later used to design the digital scenes. The initial blueprints of each scene can be seen below:

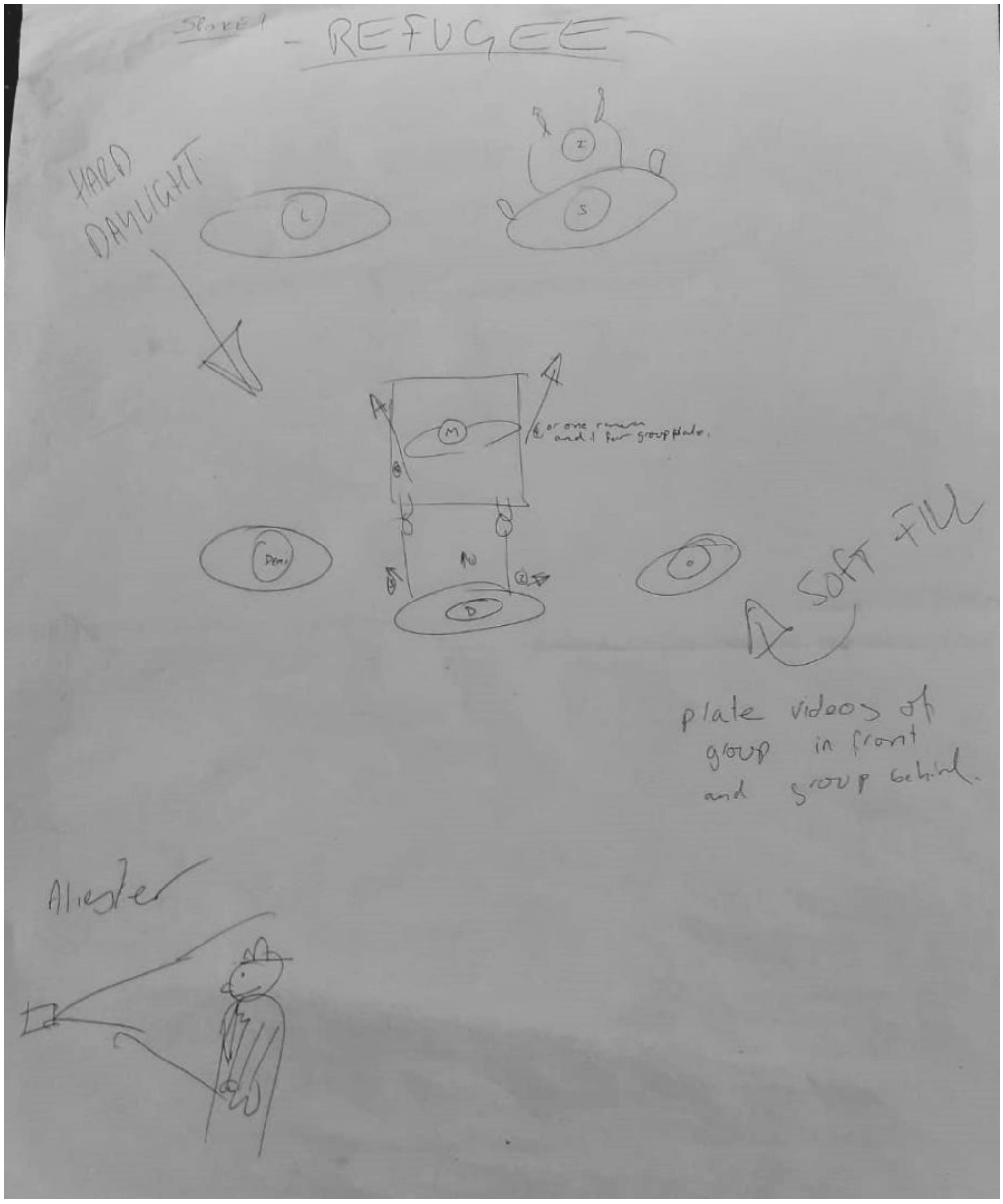


Figure 6.22: Hand drawn blueprints for the scene Refugee

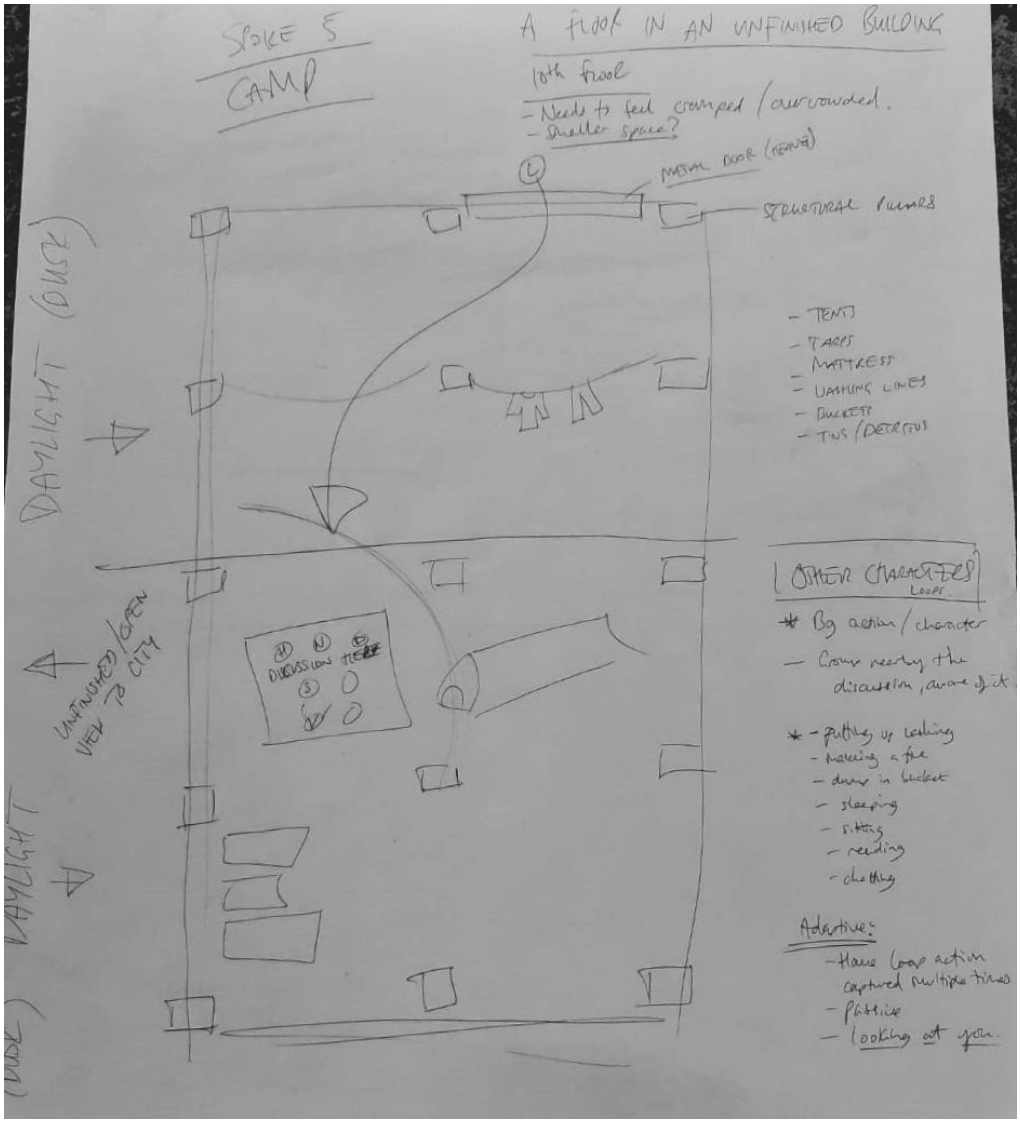


Figure 6.23: Hand drawn blueprints for the scene Camp

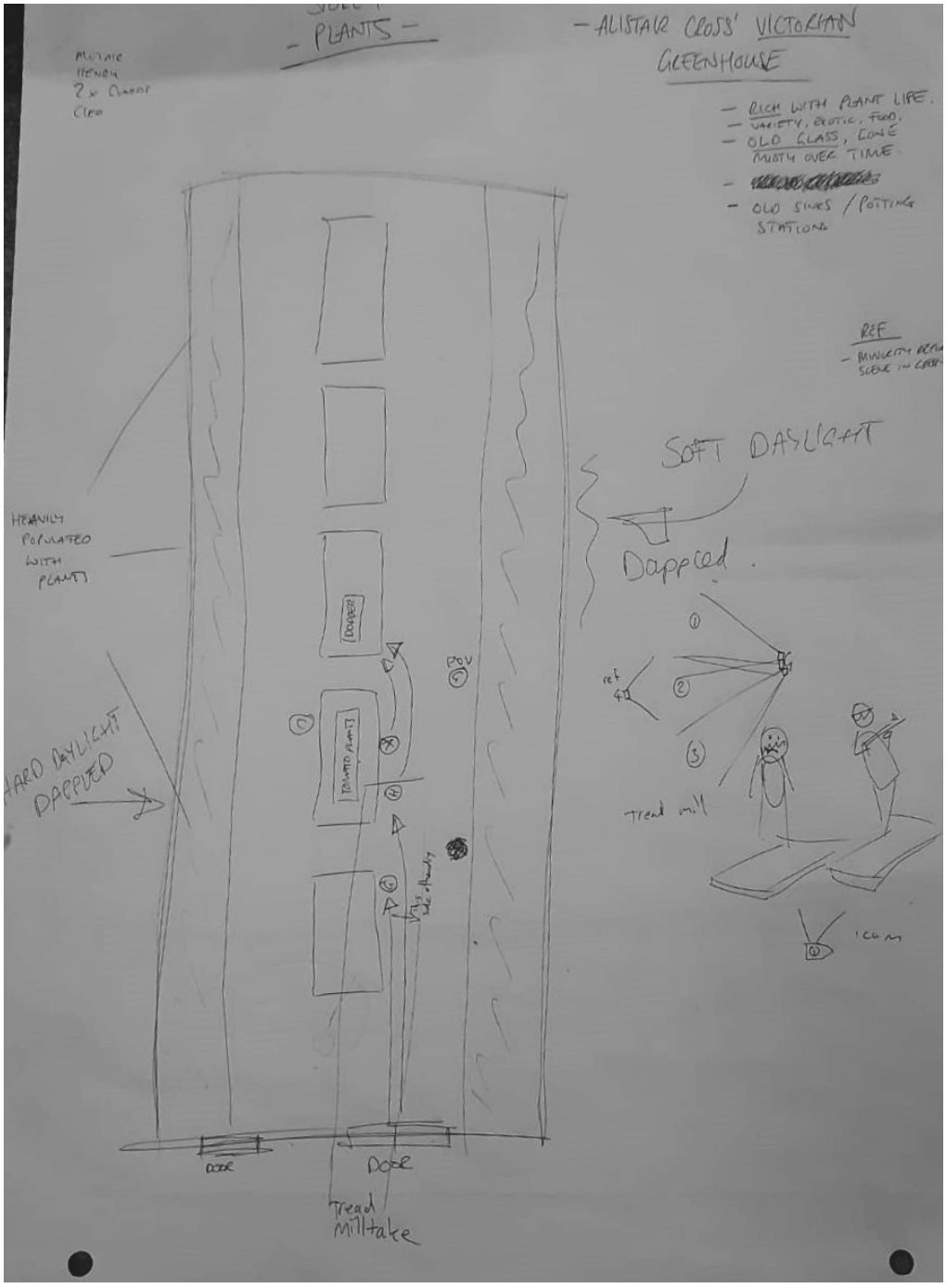


Figure 6.24: Hand drawn blueprints for the scene Plants

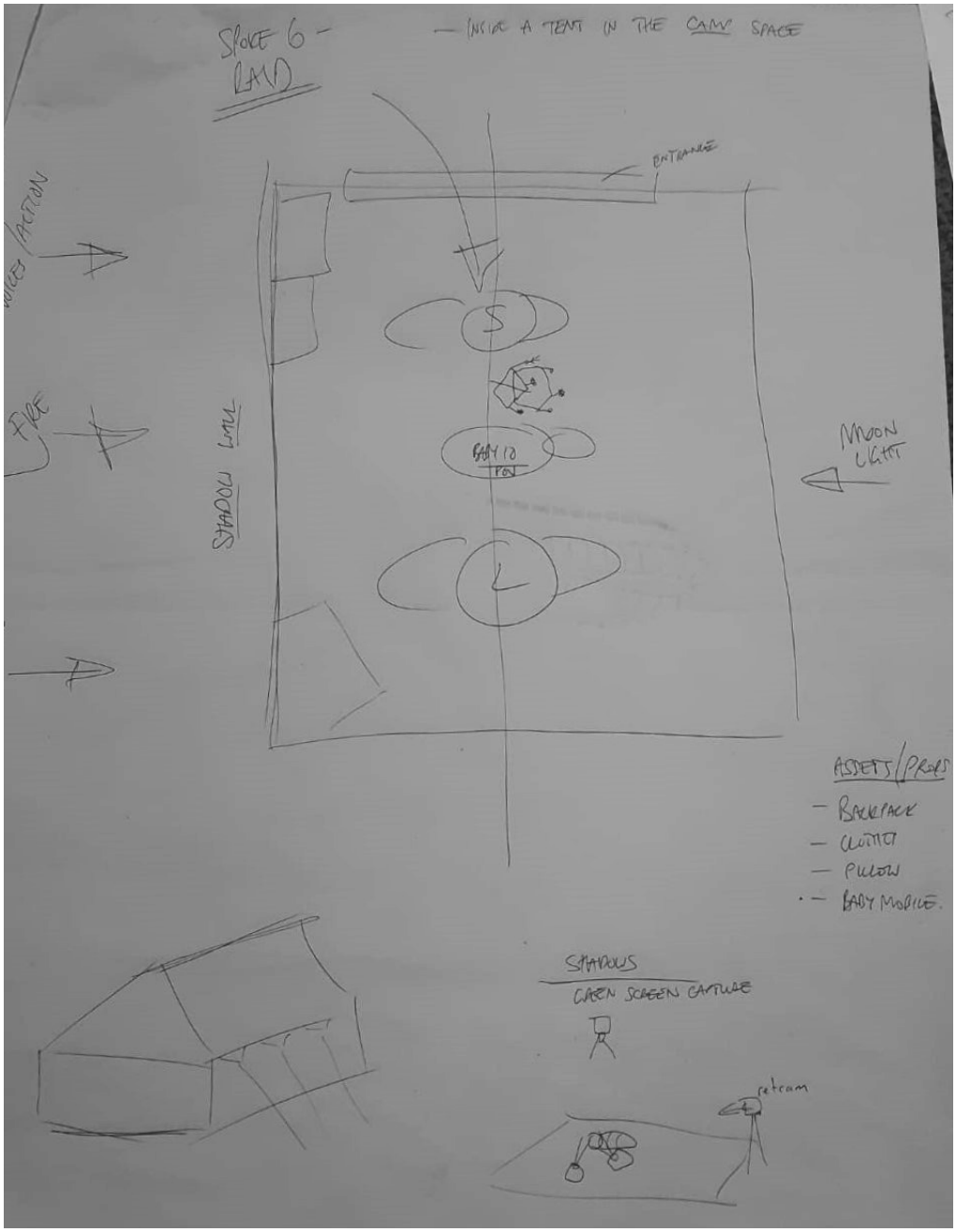


Figure 6.25: Hand drawn blueprints for the scene Raid

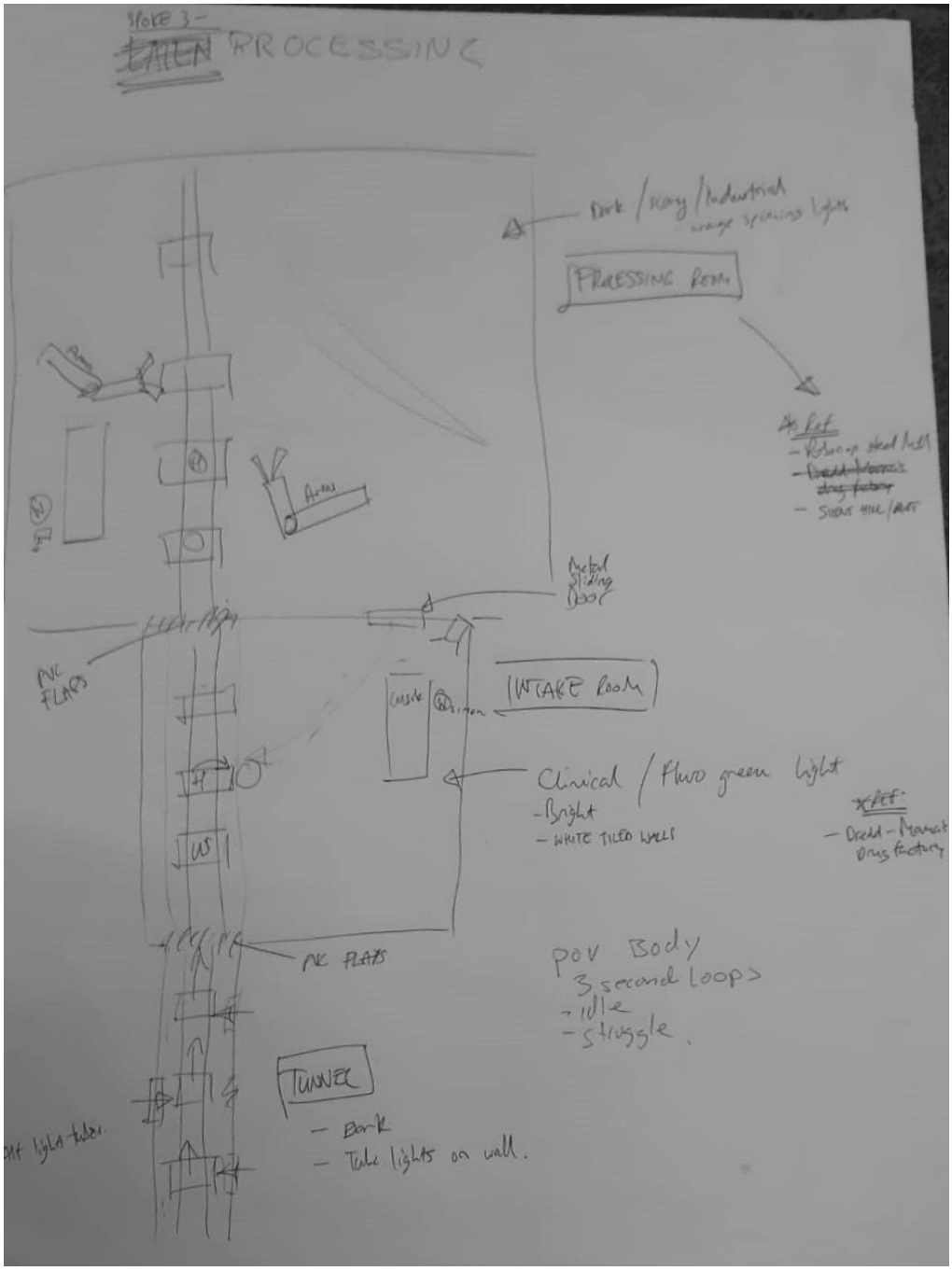


Figure 6.26: Hand drawn blueprints for the scene Processing

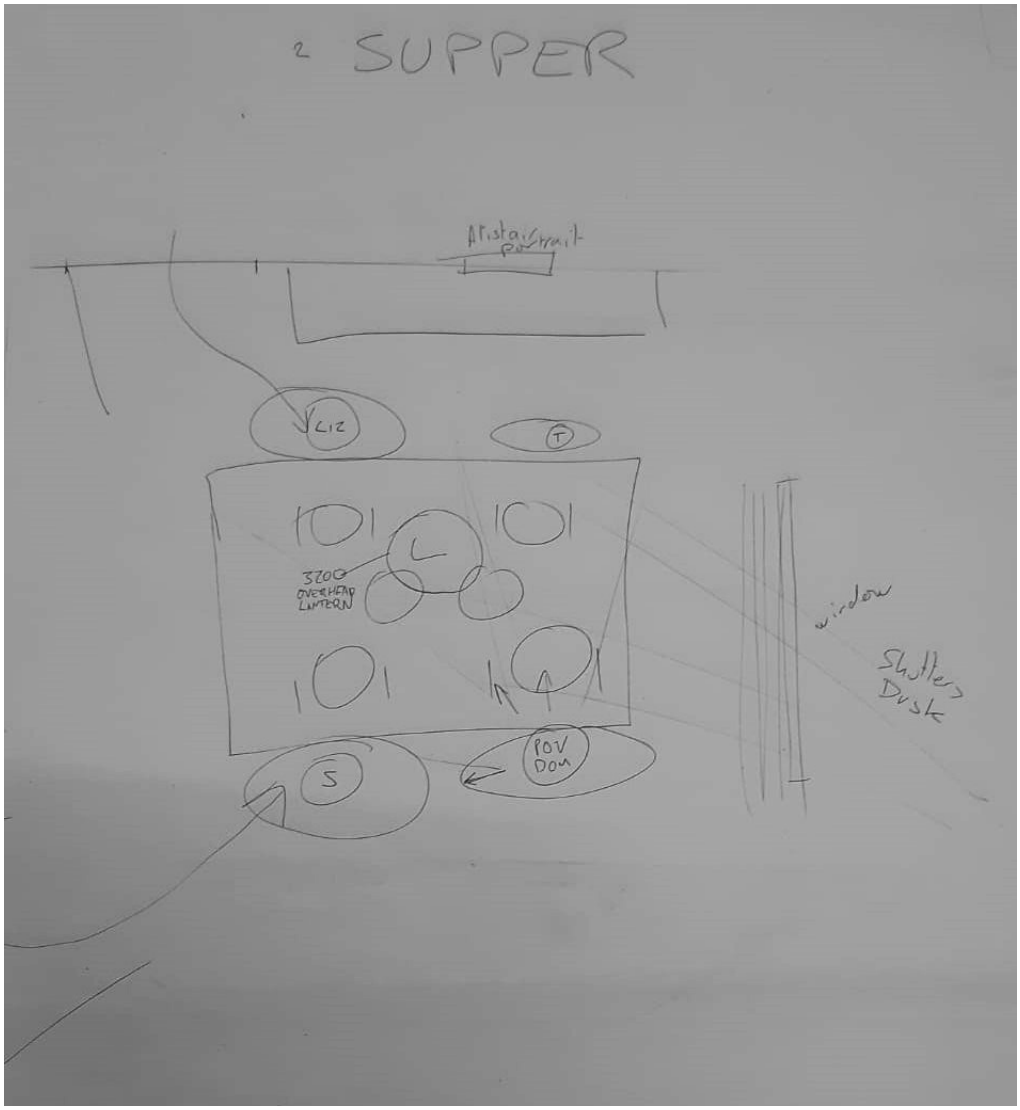


Figure 6.27: Hand drawn blueprints for the scene Supper

Each blueprint details the general shape and look of each scene, whilst guiding the placement of actors. Recording the actors with volumetric capture meant there was little flexibility with the positioning. The environment surrounding the actors, however, was more flexible and allowed for more freedom of virtual design. These blueprints were passed to Sumit to create concepts, which were used for the original development build of the experience. Although the visuals provided a good conceptualisation of the experience, for the final build, AlbinoMosquito and I found the experience lacking in meaningful visuals. Therefore, I redesigned the experience's visuals and built an interconnected world that visually joined each scene together as opposed to the current visuals that simply provided standalone scenes. These interconnected scenes are designed to take place in a virtual world loosely resembling Radford Boulevard, Nottingham. The choice of this location was a design choice from AlbinoMosquito, fitting the narrative of the story. A cross-comparison of the Refugee scene with the conceptual visuals and updated visuals can be found below:

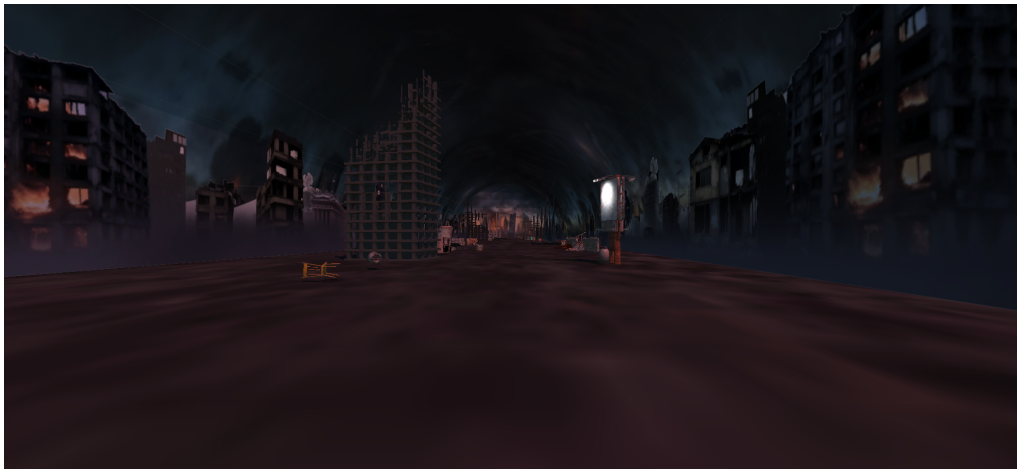


Figure 6.28: The old visuals from the scene Refugee



Figure 6.29: The new visuals from the scene Refugee

6.4.2 Audio

Audio was managed by Gary Naylor. Gary recorded all audio during filming using ambisonic microphones, which collect audio within a 3D radius. This was used to gather the actor's audio from the position of the POV by placing the ambisonic microphone where the POV would be. These audio files were then processed before being placed within Unity and set to ambisonic to ensure they worked as 3D audio.

The music for this was also provided by Gary and informed by my research. As highlighted within section 2.5.2, specific audio elements are commonly associated and used within horror media for a variety of effects. I spoke with Gary and provided the research I had conducted with him for guidance on the style of music I was looking to include within the experience. This prompted a series of iterations and feedback to create the final pieces of music. As for sound design, this was more specifically allocated based on the adaptive elements chosen for each scene. A list of sound effects was passed along to Gary to be created and then placed within the experience. This list was taken from each scene's adaptive stages.

6.5 Reflection on Co-creating A Place for Everyone

The interdisciplinary collaboration between AlbinoMosquito and me as a researcher allowed for a smooth design and development process. The artist's expertise in crafting emotional and narrative elements worked cohesively with our focus on integrating adaptive technologies into VR. This process allowed both artistic and technological considerations to shape the experience, ensuring that creative decisions informed technical implementation and vice versa.

Transitioning from 2D to VR presented a learning curve, requiring collaboration to align the creative vision with technical feasibility. Moving to VR required a shift in perspective, including the considerations for 360-degree environments, the presentation of actors, and the ways users interact within the space. To manage these challenges, we restricted user movement and interactions, focusing on embodiment within the virtual space. For embodiment to be effective, all scenes were recorded from a character's perspective.

Combining volumetric video capture with VR presented technical limitations in the project. Original designs had hoped for this to be a standalone experience; however, the high computational workload required to play back the captures removed this possibility. On top of this, we had to ensure that all captures used as few cameras as possible to allow multiple captures to be present within one scene. Although the ability to remove cameras after the fact of filming is now available, our implementation of this workflow was pivotal within the design and filming process to minimise computational workload. Volumetric capture was essential to the development of the adaptive system, allowing the actors to seamlessly exist within

an adapting environment. Overall, reducing the complexity of volumetric capture equipment and opening up to a virtual space allowed us to develop a project at a greater visual scale while minimising production costs.

Key findings highlight the importance of the co-creation process when addressing challenges, such as moving from 2D to 3D environments, implementing immersive technologies into the workflow, and balancing between artistic vision and technical feasibility.

6.6 Adaptive System Development and Integration

6.6.1 Introduction

This section covers the creation of the adaptive system to be applied to *A Place for Everyone*. The adaptive system is designed to obtain data from the Octamon wireless fNIRS system from Artinis Medical Systems (Artinis Medical Systems, 2018*b*), pass the online data to a Python script for processing, and then send it to Unity (Unity, 2025) where the processed data can be applied to the experience to adapt the visual and audio elements. This pipeline makes use of existing scripts and packages to provide the brain data processing. A functional version of *A Place for Everyone*, which used this adaptive system, was initially tested on the public before performing a deeper dive into the physiological data through a controlled lab experiment. As outlined in the previous section on the development of *A Place for Everyone* 6.2.8, the adaptive elements and stages are defined; this adaptive system will incorporate them into the experience.

6.6.2 Streaming fNIRS Data to Unity

To retrieve fNIRS data, the same method is applied as in the study to understand a fear response shown in Chapter 4. To measure brain activity changes, the Octamon wireless fNIRS system from Artinis Medical Systems (Artinis Medical Systems, 2018*b*) is used. The real-time data is recorded using the Oxysoft software provided by Artinis Medical Systems (Artinis Medical Systems, 2019). To access and use this data, the connection with the Octamon device and Unity must first be established. This is done through a lab streaming layer (LSL), an open-source framework designed to stream data from one device to another. Oxysoft provides streaming of LSL data already, so no implementation is needed there. Equally, a package already exists for Unity called LSL4Unity (Fleck, 2021). This package provides the foundations for Unity to listen for LSL streams and read in the streamed data by specifying a stream name, using an inlet to obtain the LSL data, and finally storing the data in a buffer. This LSL data, however, is raw fNIRS data that has not been processed and therefore is currently unusable. To be able to use this data in practice, once again through the same approach as Chapter 4, it needs to be preprocessed, filtering the data and removing any movement artefacts to clean the data ready to be processed. With clean data, it can now be processed and applied to the experience to infer the current fear state of the viewer by observing the left dorsolateral prefrontal cortex. It is then cleaned and processed data that needed to be brought into Unity to be able to adapt the experience; however neither the preprocessing nor the processing procedures exist within Unity, so I would require an alternative approach.

Preprocessing and Processing of fNIRS Data in Real-Time

As Unity doesn't contain any inbuilt preprocessing or processing methods for fNIRS data, a Python script developed by Benerradi (Benerradi, 2023) provides preprocessing and processing of live fNIRS data through an LSL stream. The preprocessing done within this script includes motion and frequency filtering through TDDR and bandpass, respectively. These are defined in section 2.4.1. For a band-pass filter, the online frequency filter values have been shown to work at a 0.01 Hz high-pass filter and a 0.5 Hz low-pass filter (Chen et al., 2024; Rieke et al., 2020). The TDDR method is imported from the MNE Python toolbox.

Once preprocessing is done, the same Python script is then used to collect three values and examine them for their use as a threshold from the brain data concerning the micromolar (μM) value: the peak value, the average value of the peaks obtained every second, and the average micromolar value. These three values are collected to understand the applicability of each, with an understanding of a potential threshold for participants. As the aim of the brain data is to produce a threshold, peaks are gathered to know the height of their brain activity, as a peak value refers to the highest point of oxygenated haemoglobin measured within the brain activity. By gathering the peak value, the highest point an individual reached can be seen; however, the issue with this value is that it is highly susceptible to noise. Even with preprocessing, movement could cause a value to go higher, rendering that peak invalid for use, as a participant's threshold would be too high. Averaging all micromolar values produces a more controlled value, much less affected by noise; however, high values will still skew the data. The main issue with this average, however, is that although it does provide a generalised overview of brain activity, a generalised look

at the brain activity does not provide insight into key moments of fear. These key moments may cause someone to feel too much fear, which may go unnoticed through an average of all micromolar values. Therefore, to counter the noise of a single peak value and the generalisation of all micromolar values, an average peak micromolar value is taken. This average peak micromolar value provides insight into key moments of fear whilst ensuring that noisy data is reduced. With this, the system can provide a more accurate representation of an individual's threshold and ensure that adaptation is correctly responding to the participant.

Once the script has calculated the average peak value, it then passes this value back to Unity, where the value is used to evaluate either an increase or a decrease towards the inferred fear state of the viewer. To ensure that an individual is not pushed continuously for a fearful response, a brief initiation into their fear response must be configured first to understand their threshold to fear. This threshold provided a baseline of the participant's typical haemodynamic response to fearful stimuli. During the main adaptive experience, the system compared incoming fNIRS signals to this baseline. When activation rose above the individual's threshold, the system inferred that the participant was experiencing fear and limited adaptation to maintain intensity without exceeding that level. In this way, the threshold acted as a safeguard, ensuring that adaptation responded dynamically to each participant while avoiding overstimulation. The Python scripts developed for 'A Place for Everyone' can be found here (Berger, 2025). Figure 6.30 provides a flow diagram of this process, showing how data is collected from the Octamon brain scanner and passed to the adaptive system in Unity.

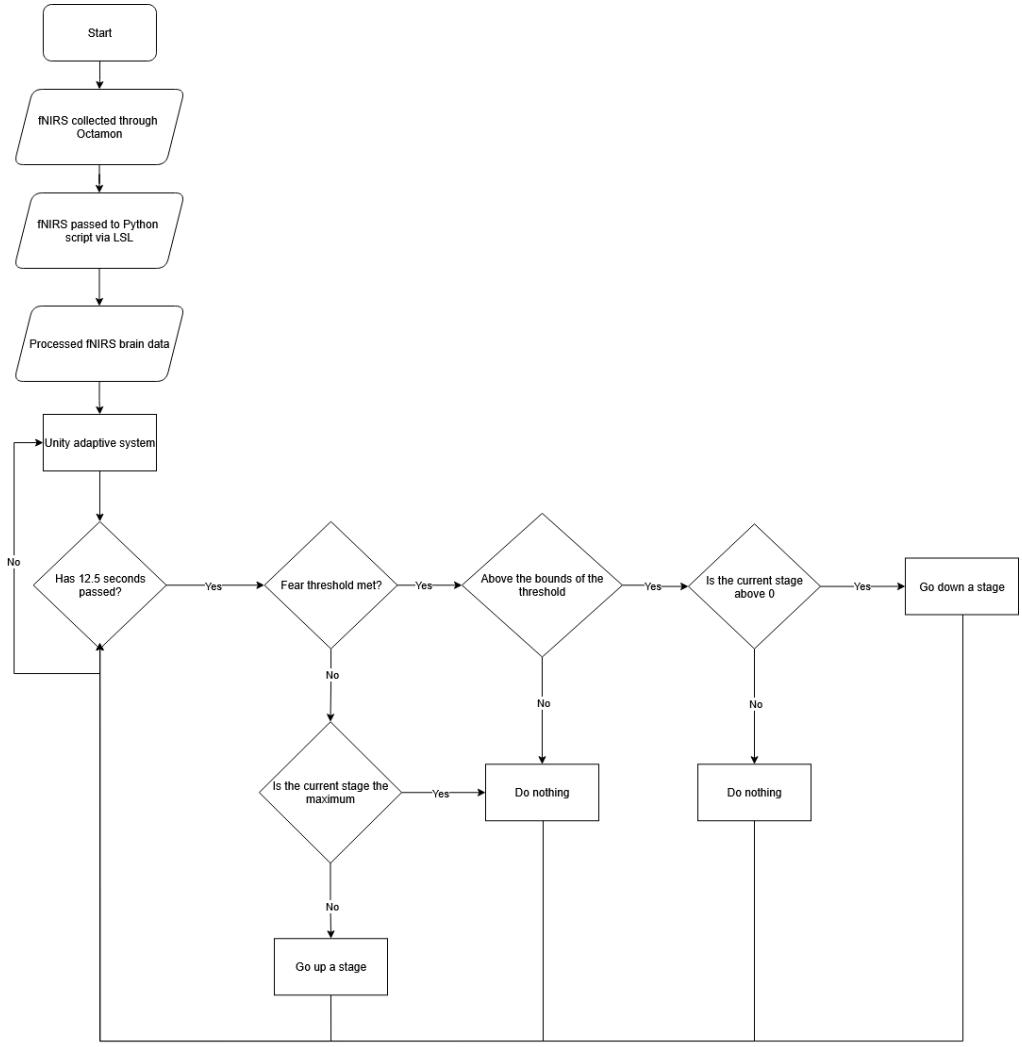


Figure 6.30: A flow chart representing the flow of fNIRS data from the Octamon brain scanner to the Unity adaptive system within *A Place for Everyone*.

Viewer Calibration

For calibration of the viewer's threshold to fear, following a threshold-based approach, each viewer will engage with a calibration activity to observe an onset of fear processing in response to fearful stimuli. This will involve the viewer watching 4 horror videos in VR whilst measuring their brain activity in real-time to gather a range of average peak micromolar values. The average peak micromolar value refers to the peak value of micromolar concentration every second. This is then averaged out throughout the

stimuli. The stimuli are presented as short 30-second 360-degree videos in VR. The viewer will also provide feedback in the form of a Likert scale after each stimulus as to how fearful they found it. This will be in the range of 1 to 5, with 1 identifying little to no fear and 5 identifying a high amount of fear.

The fear stimuli to be used will be similar to those used for the previous study 4 on fear processing in the brain. This consisted of VR horror videos which include low to no lighting, unsettling environments, inhuman creatures, objects used to jump-scare participants, and unnerving sound effects. The nature and design of these are different to the adaptive experience but are designed as generic horror clips that aim to elicit a fearful reaction. As these were found to provide significant results previously, they are used again for calibration.

The order of the horror videos will be randomised and repeated for each individual. There will be 3 repetitions of each stimulus, totalling 12 videos for calibration. After each video, there is a short rest period of 30 seconds to allow a reset of their haemodynamic response. Repetitions are taken to accommodate any potential technical issues as well as errors from noisy data. One potential effect of this is a reduced impact from the horror videos through repetition; however, this cannot be avoided, as the same stimuli must be used.

The threshold will be calculated through understanding the average subjective rating of each horror video and the average micromolar peaks. The expected results will show the highest average peak micromolar value for the highest rated fearful stimulus. This data can be skewed, however, based on noise such as movement artefacts, which may not show higher peak micromolar values for the higher rated fear. The script developed for

analysing the fNIRS data in real-time will contain noise filters to mitigate this, where possible, as mentioned above.

Participants will be able to choose which horror video best represents the level of fear they wish to maintain throughout the experience. Once a video is chosen, the average peak micromolar value for that video is taken and set within the adaptive experience. A singular value, however, will cause constant fluctuations in either being above or below this threshold; therefore, a range is introduced to allow the system to settle on a fear stage for the participant. Currently, there is no standard for which approach is best for defining a range in a context such as this. Therefore, for testing, the range will be initially set at 10%. This means that once the participant's individual threshold is established from the calibration task, the adaptive system monitors their ongoing fNIRS signals and compares them against this threshold ±10%. If activation rises above this range, the system infers a heightened fear response and triggers the next stage of adaptation, increasing the adaptive audiovisual stimuli. Conversely, if activation falls below the lower bound, the system reduces these adaptive effects. If activation is within this bound, no changes occur within the system. In this way, the calibration data directly informs the adaptive system's decision-making, ensuring that the modulation of fear is tailored to each participant's baseline response.

6.6.3 Testing of A Place for Everyone

With the adaptive system integrated into the experience, the experience can now be tested. As mentioned, *A Place for Everyone* underwent two separate studies for evaluation. The first to be discussed is the InSitu study (7.2, a qualitative, exploratory, lightweight review of the public experience.

The second is a controlled lab study (7.3) following a mixed-methods and experimental within-subject design. By conducting two studies, I hope to examine the public perspective on the adaptive experience and take a deep dive into the physiological reactivity in relation to the adaptation.

Chapter 7

A Place for Everyone - Evaluation

7.1 Introduction

This chapter presents two studies that evaluate the adaptive VR horror experience, *A Place for Everyone*. Each study addresses different aspects of the research questions outlined in Chapter 1.

The first study (7.2) evaluates the experience in situ at public film festivals following performance-led research (Benford et al., 2013). This lightweight qualitative study explores how audiences encounter the adaptive system in an ecologically valid setting, and contributes particularly to RQ 3 by providing insights into the public reception of adaptation and its impact on immersion and fear.

The second study (7.3) evaluates the system in a controlled laboratory setting. Here, a mixed-methods experimental approach was used to measure both physiological and self-reported responses. This study extends

the findings of the performance-led study by providing empirical data that helps validate the adaptive system's effect on fear modulation, immersion, and involvement, contribution to both RQ 3 and RQ 4.

Together, these studies form a comprehensive evaluation of *A Place for Everyone*, balancing ecological and empirical validity, grounding the adaptive toolkit in both real-world practice and measurable outcomes.

7.2 Study 3a: Evaluation of A Place For Everyone: In the Wild

7.2.1 Introduction

With a working adaptive experience prototype *A Place for Everyone*, the first approach was to evaluate the effect of the adaptive system on public audiences. To do so, the experience was presented in various public venues, including cinemas, universities, and film festivals, to encourage members of the public to try the experience and provide feedback through post-experience interviews. 18 people watched the experience, with 17 of these participating in a post-experience interview. The following section outlines the study with which *A Place for Everyone* was examined and reports on the findings through thematic analysis. This study feeds into RQ3: How could media professionals utilise a toolkit for creating adaptive experiences and engage audiences with that content? From this, I hypothesise the following:

- The adaptive system in 'A Place for Everyone' increases the audience's experience of fear, with participants reporting greater immer-

sion, fear, and emotional responsiveness tied to the adaptive changes.

To validate the hypothesis, participants were interviewed after watching *A Place for Everyone* to assess their thoughts on the experience, adaptation, and future of adaptive systems.

7.2.2 Methodology

This follows a performance-led research in the wild approach (Benford et al., 2013) to understand the impact of *A Place for Everyone* within an in-situ environment through the public. A qualitative, exploratory, lightweight review of the public experience with *A Place for Everyone* was conducted to gather real-world insights into adaptive systems. Every scene within the experience was set as adaptive. Participation was done in person at a series of public venues and events. These were:

- Northumbria University, Newcastle, as part of the Horror Studies Research Group
- Star and Shadow cinema, Newcastle
- Salford University, Manchester, as part of the Storytellers + Machines 2024 Conference
- Folkestone International Film Festival, Folkestone
- Riverside Film Festival, Castelgrande, Italy
- Nottingham Film Festival, Nottingham

For recruitment, venues were asked to advertise on social media platforms before the event, providing full details on the experience and the need for

data collection. Upon arrival, participants were shown details of the experience, including notification of a post-experience interview, and could sign up to participate by booking a specific time slot. Participants were taken through a narrative that involves violence, death, and strong language. As such, it was limited to an audience of 18 and above. No rests were scheduled as part of the study, but the experience does contain moments of rest through the hub scene, allowing participants to stop and rest if necessary. After viewing the experience, participants were then reminded of the interview process and asked if they still wished to do so. If they still wished to take part in the interview, they were asked to fill in an ethics form to confirm participation. Participants could take a break between the experience and the interview to allow time to rest.

This study involved the calibration phase as detailed within the documentation of the adaptive experience in Section 6.6.2. The only data collected and stored from this study were the participant demographics and subjective feedback through the post-experience interview. Questions can be found in the Appendix (C.3). Interviews took roughly 10 - 20 minutes per participant. No physiological data were stored, and the only physiological measure used was the fNIRS brain scanner. No brain activity was stored for this; it was only collected and used in real time as it was read from the brain scanner.

Technology Setup

Following a similar setup to the previous fear reactivity study mentioned in Section 4.2.3, the Oculus Quest 3 VR headset was used to display the experience to participants. To measure brain activity, the Octamon wireless fNIRS system from Artinis Medical Systems was used (Artinis Medical

Systems, 2018*b*).

Participants

Ethical approval was granted by the Research Ethics Committee at the University of Nottingham. Seventeen (n = 17) participants took part in the study from the public. Demographics include age, gender, and ethnicity. On average, the age of participants was 44. 41% of participants were male and 59% were female. For ethnicity, 88% of participants were white, 47% of participants were British, and 6% of participants reported other for ethnicity. Additionally, during the interviews, participants were asked if they were consumers of horror. 8 participants said yes, 8 participants said no, and 1 participant said that they used to be a consumer of horror before COVID.

Self-reported Data

Participants were interviewed after the experience, focusing on their experience with *A Place for Everyone*. This aims to understand the horror and adaptive elements and their impacts, as well as critical thinking surrounding potential uses of a system that can make alterations in response to an individual's brain activity. A full list of questions can be found in the appendix (C.3).

7.2.3 Thematic Analysis for Post-experience Interview

To analyse the interview data, Braun and Clarke's thematic analysis (Victoria and Braun, 2014) was employed. With a total of $n = 17$ transcripts, 53 codes were generated. These were refined down to 35 codes before being compiled into 4 themes. The themes are:

- Awareness and Engagement with Adaptation
- Adaptation as an Emotional Amplifier
- Narrative Disruption and Integration
- Embodiment and Realism

Before discussing the themes, of the 17 participants who watched the experience, 12 participants, 71%, said that they would describe the experience as a horror experience. Of the 5 participants who said they didn't feel it was a horror experience, they generally found it unsettling or interesting, but overall, not scary. 2 of the participants who didn't feel it was a horror experience were consumers of horror.

Awareness and Engagement with Adaptation

Awareness and engagement with adaptation covers participants who noticed, interpreted, reflected on, and attempted to understand or influence the adaptive system. When discussing adaptation, 10 participants reported noticing the adaptations, while 10 participants also stated that they had forgotten about the brain scanner and its involvement in adaptation. This shows an overlap of participants, specifically 7, who noticed adaptation,

but at times forgot about the brain scanner and the adaptive system. For those who noticed, participants picked up on lighting and colour changes, with one participant saying, "I thought that the use of red was effective and in sort of that sort of a sense of foreboding and then something's gonna happen." Some participants looked to the volumetric captures and narrative for adaptive elements, believing that the adaptive system caused the narrative to be scarier or the captures to appear more in focus. Although adaptation was expressed to participants ahead of watching the experience, the actual implementation of adaptation was not described to stop participants from focusing too much on the adaptive elements. For some participants, this caused them to either not notice adaptation or seek adaptation through changes other than audiovisual stimuli. For example, one participant said, "sort of how close up things were to me, I noticed they kind of progressed as the like each of the memories kind of went on." Other notes on adaptation refer to adaptation being clever in its effect on lighting, and for some participants, reflecting anxiety for them.

Adaptation as an Emotional Amplifier

Adaptation as an emotional amplifier covers how the adaptation shaped emotional intensity, fear, unease, and emotional overload. 14 participants, 82%, said they found adaptation to increase the level of fear that they experienced. For those who found adaptation to improve the experience, feedback included "That [adaptation] kind of added to that experience of horror" and "[Adaptation] definitely added to how I interpreted everything, which I think just made me more engaged". 3 participants said that adaptation didn't increase the fear in the experience for them; however, 2 of these participants mentioned that they did find it interesting and engaging. Additionally, 2 of the participants who stated that adaptation did not

affect their fear levels also said that they are not a consumer of horror, nor did they find the experience to be horror. The other participant, however, said that they did find the experience to be horror and are a consumer of horror. 13 participants found the experience to be effective as a horror experience as it made them feel unsettled, provided fear through realism, and combined the use of VR to capture their surroundings. For those who didn't find this to be a horror experience, some found it uncomfortable, interesting, and engaging, but lacking in fear for them. One participant found that they felt adaptation pushed them too far in some cases. They said, "I think particularly in the processing work, I could feel myself trying to get away from what was happening and trying to move away from it and things like that and feeling disorientated". Although the participant didn't stop the experience, potentially allowing a participant to manually change the fear in the experience could help maintain the fear. It is also possible that the calibration threshold chosen by this participant caused them to feel more fear than they expected. 2 participants also found the adaptation to be of the horror genre, but not the narrative. This shows that adaptation did increase the horror for these participants as intended, but potentially the narrative itself needed more.

Narrative Disruption and Integration

Narrative disruption and integration covers the way adaptation either enhances or adversely affects narrative immersion and believability. Some participants found the adaptation added to the narrative. One participant's reflection of this was as follows, "Is this, like, flashbacks, You know, So I was like, is this like, the character is hearing something that worries them, and then they're back to kind of reality when it goes back to normal?". Here, the participant refers to the blinking effect built into adap-

tation to introduce audiovisual stimuli. They found the blinking effect to create two narratives, one of fiction (adaptation) and one of reality (no adaptation). Using adaptation to not change the narrative but add to the narrative provides a unique way of adapting experiences whilst maintaining the filmmaker's intentions. Some participants attributed changes in adaptation to be a cause of the narrative rather than the adaptive system. It could be argued that adaptation is adding to the narrative, but conversely, it could be questioned if adaptation is instead changing the narrative.

How adaptation affects the narrative was a key part of the process of the adaptive system. The aim was to provide the same narrative and alter the horror elements to induce more fear. Overall, adaptation was successful based on the responses of participants; most participants found that adaptation increased the fear that they experienced. It does seem for some participants, however, that adaptation in fact altered their sense of the narrative as well. Reflecting on this, potentially the implementation of adaptation could be timed differently, so as not to interfere with the narrative, or different adaptations could be introduced that heighten the fear of existing objects present in the scene. The aim of this would be to increase the fear of existing objects, rather than to add new fearful stimuli. 1 participant found the narrative to be too real, whilst another found it to be unrealistic. This outlines the key subjectivity of experiences and horror. When creating horror and experiences, audiences are likely to create their own interpretation and thoughts, leading to conflicting views. This leads back to the trajectories framework, where the participant trajectory aims to visualise this difference in view. Actions can then be taken to adjust and attempt to bring the participant back to the canonical trajectory. For the adaptive system, its design directly attempts to address this by understanding a participant's fear trajectory and bringing them to the intended,

canonical fear trajectory of the current scene.

Embodiment and Realism

Embodiment and realism covers how the experience connected to the participants through POV, realism, and adaptation. Participants found the POV perspectives and character embodiment to add to the experience, noting the POV as clever, fear-inducing, and attention-grabbing. For one participant, the POV perspective is what allowed them to categorise the experience as horror, "if you're embodying someone, you're in the experience, you feel very passive". Discussing volumetric capture, one participant found it removed immersion due to the flickering effect as part of the technology. Others, however, found it to add to the horror due to its low fidelity. This shows another case of subjectivity in how participants interpret the visuals in front of them.

Some participants related to a feeling of realism within the experience that contributed to their fear; "it's realistically scary rather than, you know, typical horror things that you come across". Others mentioned atmosphere contributing to the horror; "The atmospheric sort of fit within the genre conventions of horror, but then also as it progressed, as sort of I see in traditional like in horror, the danger level increases". Notably, one participant mentioned how VR had a strong impact on their impression of the experience; "I think the VR aspects of it actually contributes for me as to why it's horrific because if you're embodying someone, you're in the experience, you feel very passive."

Finally, when discussing the future uses of adaptation, participants had varied responses on how an adaptive system could be used. Mentions included emotion regulation in medical research, such as PTSD, adaptation

of music to better fit an individual's mood, or to assist in learning. For negative applications, participants tended towards manipulation through emotional control and misuse of brain activity data for targeted advertising. Understanding future uses of this technology opens direction for where this research can go beyond *A Place for Everyone*. Participants found that this research could benefit the fields of medicine and education. Negative applications open discussion of the ethics of this work and future uses. This will be covered in detail in the discussion chapter (8).

7.2.4 Looking Towards a Deeper Data Analysis

By addressing challenges in adaptation, this study lays the groundwork for future research and development in immersive media design. Initial results indicate that the adaptation effectively enhances the fear response in participants. Moving forward, the next step for this research was to perform a deeper dive into the physiological effects of this experience within a controlled environment.

7.3 Study 3b: Evaluation of A Place for Everyone: Controlled Lab Study

7.3.1 Introduction

Having developed *A Place for Everyone*, the following section details a comparative study that was conducted to compare the impact of adaptation against non-adaptation. Comparing participant experience with adaptation and non-adaptation aims to provide insight into the impact adapta-

tion has on the experience, including impacts on emotional intensity and engagement. This study feeds into RQ3: How could media professionals utilise a toolkit for creating adaptive experiences and engage audiences with that content? From this, I hypothesise the following:

- The use of adaptation in a horror experience, as opposed to a non-adaptive horror experience, can create a more fearful and engaging experience.

This hypothesis is based on existing literature discussed within the literature review section 2.7.1, where the use of adaptation in games increased engagement (Houzangbe et al., 2018) and adaptation in horror increased the fear experienced (Demarque and Lima, 2013). To assess participant responses to adaptation and non-adaptation, participants are not made aware of adaptation in this study. This is to reduce potential bias in response to the adaptive or non-adaptive content, such as participants focusing on trying to manipulate adaptive scenes.

7.3.2 Methodology

The study follows a mixed-methods and experimental within-subject design within a controlled environment. The study is split into two sections: Calibration and *A Place for Everyone*. Calibration, as detailed in Section 6.6.2, is used to find the threshold of fear for the participant. This is to ensure that the adaptive system correctly adapts in response to the participant. With calibration completed, the participant then watches *A Place for Everyone*, detailed in Section 6.3. Each participant watched all 6 scenes of the experience, with scenes varying between being adaptive and non-adaptive.

When inside the experience, there is a possibility of motion sickness and disorientation. The following steps were taken to mitigate this:

- The participant may pause or stop the experience and remove the head-mounted display at any time
- I am near the participant to assist them if required
- A bucket will be within the room in case a participant feels unwell
- There will be no movement other than head orientation due to the participant being seated

To mitigate potential stress and anxiety, participants were given the right to withdraw at any time within the study. A key component of this study is that participants are not told that the experience is adaptive.

Study Conditions: Calibration

To assess the effectiveness of calibration in inducing fear, the process consists of two conditions:

- Rest condition: the participant is presented with a white view with a black plus positioned in the centre of their view. The participant is asked to rest for 30 seconds.
- Horror condition: the participant is presented with one of four possible horror videos, each of which lasts for 30 seconds. These horror videos are:
  - Girl running (G)
  - Jump scare (J)

- Bedroom (B)
- Chainsaw (C).

The process of calibration is similar to that of the previous study on physiological reactivity to fear, detailed in chapter 4. Calibration starts with a rest condition, where participants rest for 30 seconds, before starting a horror condition, where a horror clip plays for 30 seconds. The four horror videos were chosen specifically due to the style of the stimuli used. The four horror clips are as follows:

- G: consists of a humanoid child-like creature running and laughing around the participant before screaming and making a crashing sound at the side of the room. This focuses on sustained visual fear.
- J: contains a long corridor with the participant in a door frame looking out, the music intensifies before the participant is turned around and jump scared by a masked character behind them. This focuses on suspense leading into a jump scare.
- B: the participant is lying on a bed looking out across a bedroom, in the corner of the room, a chest lid slowly opens to reveal a creature hiding inside, the chest lid then closes again after some time. This focuses on the suspense of being watched without outright scare.
- C: a surgical style room with the participant in the centre, chainsaw noises can be heard nearby cutting through bodies, accompanied by screams. This focuses on audio.

The order of each horror clip is randomised to enforce counterbalancing. Once each horror clip is viewed, the process is repeated 2 more times,

totalling 12 horror clips for calibration. Repetitions are taken to accommodate any potential technical issues as well as errors from noisy data. One potential effect of this is a reduced impact from the horror videos through repetition; however, this cannot be avoided, as the same stimuli must be used.

Study Conditions: A Place for Everyone

To analyse the effect of adaptation, the 6 scenes for *A Place for Everyone* will alternate across 3 different conditions:

1. low fear condition (C1): this condition will consist of no adaptation, and scenes under this condition will be maintained at the lowest stage of fear possible.

2. high fear condition (C2): this condition will consist of adaptation only at the initial activation of adaptation, at which point scenes under this condition will be maintained at the highest stage of fear possible.

3. adaptive condition (C3): this condition will consist of live adaptation allowing scenes to adapt in response to fNIRS data

With 3 conditions and 6 scenes, each condition will be applied to 2 scenes across 6 variations through randomised block counterbalancing. 6 variations are chosen as fewer variations may introduce more bias through untested condition combinations, whilst more variations create more complexity and demand a higher sample size. The following variations are as follows:

Table 7.1: Condition Assignments Per Scene Across 6 Variations

Variation	**Scene 1**	**Scene 2**	**Scene 3**	**Scene 4**	**Scene 5**	**Scene 6**
1	C1	C2	C3	C1	C2	C3
2	C1	C3	C2	C1	C3	C2
3	C2	C1	C3	C2	C1	C3
4	C2	C3	C1	C2	C3	C1
5	C3	C1	C2	C3	C1	C2
6	C3	C2	C1	C3	C2	C1

Each variation contains every condition twice, with no two conditions adjacent, and no repeated variations. Additionally, across all variations, each scene goes through each condition twice. This is done to minimise potential fatigue effects, reduce bias of learning effects caused by two sequential conditions of the same type, and ensure counterbalancing for the 3 conditions. When assigning variations, every 6 participants will be randomly assigned one of the 6 variations, ensuring each participant has a different variation. It is important to ensure that the number of participants is a factor of 6 so that there is an equal participant count for each variation.

Technology Setup

Following a similar setup to the previous fear reactivity study mentioned in Section 4.2.3, the Oculus Quest 3 VR headset was used to display the experience to participants. To measure brain activity, the Octamon wireless fNIRS system from Artinis Medical Systems was used (Artinis Medical Systems, 2018*b*). This device collected changes in HbO and HbR levels in the brain. For measuring GSR data, the Shimmer3 GSR+ Unit from Shimmer was used (Shimmer, 2025). This device collected changes in the electrical conductivity of the skin.

Participants

Ethical approval was granted by the Research Ethics Committee at the University of Nottingham. Twenty-four (n = 24) participants were recruited from the University of Nottingham as well as the public. Demographics consisted of 12 males, 11 females, and 1 Non-binary. Participants consisted of an average age of 26.8, ranging between 18 to 53, spread amongst 12 ethnic groups.

Study Procedure

Before being placed in VR, participants were asked about their prior experience with VR. Understanding a participant's familiarity with VR helps determine if they are aware of what to expect and can be further informed if necessary. The Octamon is then placed correctly on the participant's prefrontal cortex, the GSR is placed on the middle phalanx of the index and middle fingers of the participant's non-dominant hand, and the HMD is positioned comfortably. They are then presented with an introductory set of screens. These screens show participants the following:

- How to recentre the VR if they appear in the wrong place within the VE
- Background information for the experience, detailing the date, situation, and general narrative of *A Place for Everyone*
- Details on how to select memories from the Hub scene
- Information for the calibration process (rest, condition, feedback)

Once the participant has completed these screens, they are then introduced

to the calibration rest screen view and are ready to begin the experience. Whilst within the experience, real-world interaction with participants is kept to a minimum where possible. Only during the feedback state could conversation happen if required. If a participant has issues or wishes to withdraw, they are reminded that they can reach out at any point to stop the study, keeping participant safety as the highest priority. When ready, the participant rests for 30 seconds before the first horror video condition is shown. This will be a random horror video from one of the 4 horror videos. The fNIRS data, specifically from D2 - S8 as established from the results of Chapter 4, is streamed to Unity to be collected per video. GSR data is also collected per video. Once watched, they will provide feedback on their level of fear throughout that video on a scale of 1 (low) to 7 (high). They are then taken back to the rest screen to repeat the process. This process repeats a total of 12 times, 3 times per video. Once this is completed, the participant is asked which horror video best represents a good level of horror for them in line with what they would want from a horror film. For the selected video, the average of the fNIRS data for that video is taken and used as the calibration threshold for *A Place for Everyone*. The participant is now ready to begin watching the experience.

For *A Place for Everyone*, the order of conditions, low fear, high fear, and adaptation, is chosen based on the next variation (e.g. if the previous participant was variation 4, this participant will be variation 5). The calibration threshold is set for the adaptive scenes. The participant is initially asked to rest for 30 seconds before the first scene of the experience starts. This is repeated for all 6 scenes for the experience. Throughout each scene, fNIRS and GSR data are collected. For the adaptive scenes, fNIRS data is also applied to inform the adaptive system. After each scene, participants are asked a series of questions relating to presence and fill in a fear trajec-

tory mapping. After all the viewings are completed, participants fill in a presence questionnaire and are interviewed to engage with their thoughts on the experience.

Collected Data

Self-reported Data For calibration, participants were asked to rate their fear after viewing each horror clip, on a scale of 1 - 7, following a fear scale developed by psychologist James Geer (Geer, 1965) covered in Section 6.2.8. Once all horror clips had been seen, participants were then asked which clip best represents a level of horror they are comfortable with.

For *A Place for Everyone*, subjective feedback was gathered after each scene through a fear trajectory mapping followed by a series of 3 questions. The fear trajectory mapping asks the participant to draw a continuous line depicting their level of fear on a scale of 1 - 7 (y-axis) throughout the key moments of the scene (x-axis) they just watched. An example of this can be found in Figure 7.1.

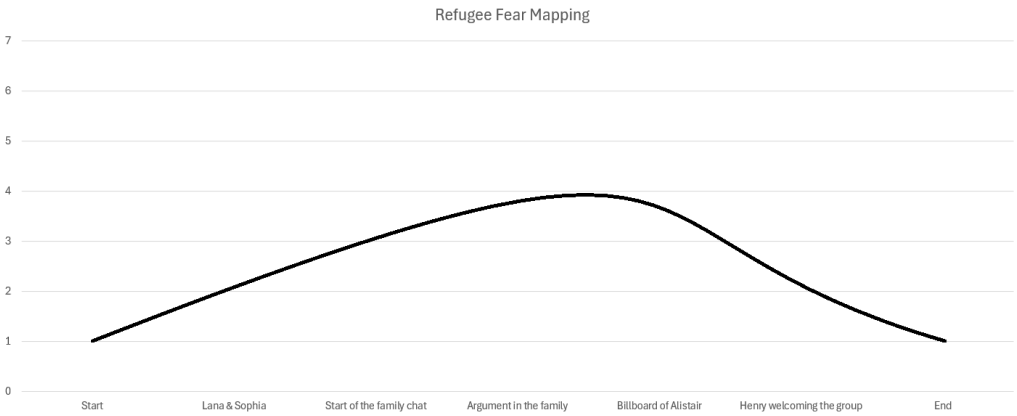


Figure 7.1: An example of what the participant fear trajectory mapping may look like for the scene Refugee. This is not an actual participant mapping

The 3 questions asked of participants were as follows:

- How involved were you in the scene?
- How much did the visual aspects immerse you?
- How scared did you feel?

These questions aimed to understand how involvement, immersion, and fear may differ among the three conditions. Participants also complete a presence questionnaire based on Witmer and Singer's Presence Questionnaire (Witmer and Singer, 1998). The post-experience interview aims to engage a participant with their thoughts on the experience as a horror experience, the use of adaptation, including revealing that what they saw was an adaptive experience, and questions on critical thinking surrounding the future of adaptive systems. A full list of questions can be found in the appendix (D.3).

Physiological Data Collection fNIRS data and GSR data were collected throughout both calibration and *A Place for Everyone*. Similar to the fear reactivity study (4.2.6), the Octamon was placed on each participant's frontal cortex, approximately over the forehead, just above the eyebrows. Data capture was done through all channels. Although I had previously identified a specific channel in my results of the fear reactivity study (4.3.2), which is D2-S8 (detector 2, light source 8) corresponding to the left DLPFC, all channels were collected for evaluation. For the adaptive system however, only data from D2-S8 is used. As for GSR, the electrodes were placed on the middle phalanx of the index and middle fingers of the participant's non-dominant hand. This was done to reduce potential noise through movement. Participants were asked to avoid any sudden movements where possible and to rest the non-dominant hand in a comfortable position.

Through collecting both types of data, we aim to find potential for future cooperation between the two physiological measures for use within adaptation. Although the current system uses only fNIRS, GSR could provide a more robust calculation of the emotional state of the viewer if combined with fNIRS. GSR is also a well-established physiological measure for detecting arousal, a component known for being increased during a fear response, so it can assist with understanding the effectiveness of fear throughout the experiment. By comparing the physiological responses alongside subjective feedback with the conditions in both calibration and *A Place for Everyone*, I aim to understand whether changes in fear can be detected through both fNIRS and GSR, if these changes are correctly altering the adaptive experience, and how those changes affected the experience for the participant. The rationale for collecting both fNIRS and GSR was to determine whether adaptation was effectively inducing measurable changes in fear processing and arousal. These measures complement the self-reported data, which more directly capture whether participants felt immersed or distracted by the adaptive changes. Together, these datasets allow us to evaluate both the physiological impact of adaptation and the participant's subjective experience.

Physiological Data Processing

For analysis of the GSR data, the data is first preprocessed through a Butterworth low-pass filter at 0.5Hz, to reduce noise, (Butterworth, 1930), before applying z-score normalisation (Costadopoulos et al., 2019) to standardise the data, allowing for comparison amongst participant data. The data was then separated into calibration data and *A Place for Everyone* data before being further segmented into each condition: rest and horror for calibration, low fear, high fear, and adaptive conditions for *A Place*

for Everyone. Feature extraction was then done on the segmented data to retrieve mean GSR, peak GSR, and skin conductance response (SCR) count.

For fNIRS, the method for preprocessing is the same as the previous fear reactivity study 4.2.7. The analysis follows a similar method to that of Pöhlmann et al. (Pöhlmann et al., 2023), who used the same device and device setup. To analyse the fNIRS data, NIRS Toolbox was used (Santosa et al., 2018). Initially data was down-sampled from 10Hz to 4Hz before being converted to optical density changes. Beer-Lambert law was used to convert the signals into HbO and HbR estimates (Strangman et al., 2003), preparing the data for analysis. The toolbox employs the AR-IRLS method to address motion artefacts and physiological noise, supplemented by the use of short separation channels.

To analyse the calibration data, approach continues to follow that of the fear reactivity study 4.2.7, where the GLM was used in conjunction with a BoxCar function, which estimates the hemodynamic response in separation of the systemic physiological interference, cleaning noise in the data (von Lühmann et al., 2020). By using the boxcar function, the focus was on simply identifying whether or not there was a response to the stimuli, rather than its precise timing (Landowska et al., 2018). Group analysis was also performed using a mixed effect model (Tak and Ye, 2014), which combines the use of a fixed effect model and random effect model, with the following formula: $beta{-}1{+}cond{+}(1|subject)$. False discovery rate (FDR) correction was also applied with a significance level of $q \leq 0.05$. Only channels showing a significant negative correlation between haemoglobin species - HbO and HbR, were considered significant (Cui et al., 2010). Contrast analysis was then applied between each condition to observe the differences.

To analyse the *A Place for Everyone* data, BAA was used instead as the average condition length of the data greatly exceeded the typical condition length used for GLM (60 seconds). The block average data was then compared among each condition to evaluate the differences in data caused by each condition.

7.3.3 Results: Calibration

To report the results of the data, the analysis is split into two categories: Calibration and *A Place for Everyone*. The aims of analysis within calibration are to verify the use of the horror clips in eliciting a fear response, both through self-reported data and physiological data. The analysis for *A Place for Everyone* aims to evaluate the efficacy of adaptation within the experience, specifically the impact of adapting audiovisual stimuli to induce fear.

For analysis of the calibration data, each method of analysis compares data across all 24 participants. All participants experienced all conditions the same number of times following a within-subjects design, allowing for direct comparison between participants.

Self-reported Data

Analysis of the self-reported data for calibration consists of comparing the fear ratings of each participant, per calibration horror video. Table 7.2 shows the mean, median, range, and standard deviation of the average ratings across all 24 participants.

All ratings of the horror clips are between 1 and 3, placing them on a fear

Table 7.2: Descriptive Statistics of Self-reported Calibration Data for Each Condition

Condition	Mean	Median	Range	Std Dev
G	2.83	2.50	1 – 6.33	1.38
J	2.67	2.67	1 – 5.00	1.19
C	1.88	1.50	1 – 4.00	1.02
B	1.60	1.33	1 – 3.67	0.71

scale of *None*, *Very Little*, and *A Little* following Geer's fear scale (Geer, 1965). Some participants rated certain videos higher; however, the highest average rating for the G video was 6.33. Overall, G produced the highest fear rating, followed by J, C, and B, respectively. The data is visualised in the boxplots in Figure 7.2.

Amongst the 4 videos, for the final choice of video to be used as the calibration video, 46% of participants chose G (n = 11), 38% chose J (n = 9), 8% chose B (n = 2), and 8% chose C (n = 2). Comparing this to the statistics of each condition, participants tended to choose the video that they rated highest, but this was not the case for all participants, as some chose a lower-rated video, such as participant 9, who rated G as the most fearful, but chose J for their final choice.

Performing Wilcoxon signed-rank tests on the data did produce significance in the data as shown in table 7.3. Wilcoxon signed-rank tests were used due to the use of non-normal data and non-continuous data between two paired groups.

Comparing all conditions, both G and J are significantly higher than the other two horror clips. Comparison of G against J and B against C produced no significant difference.

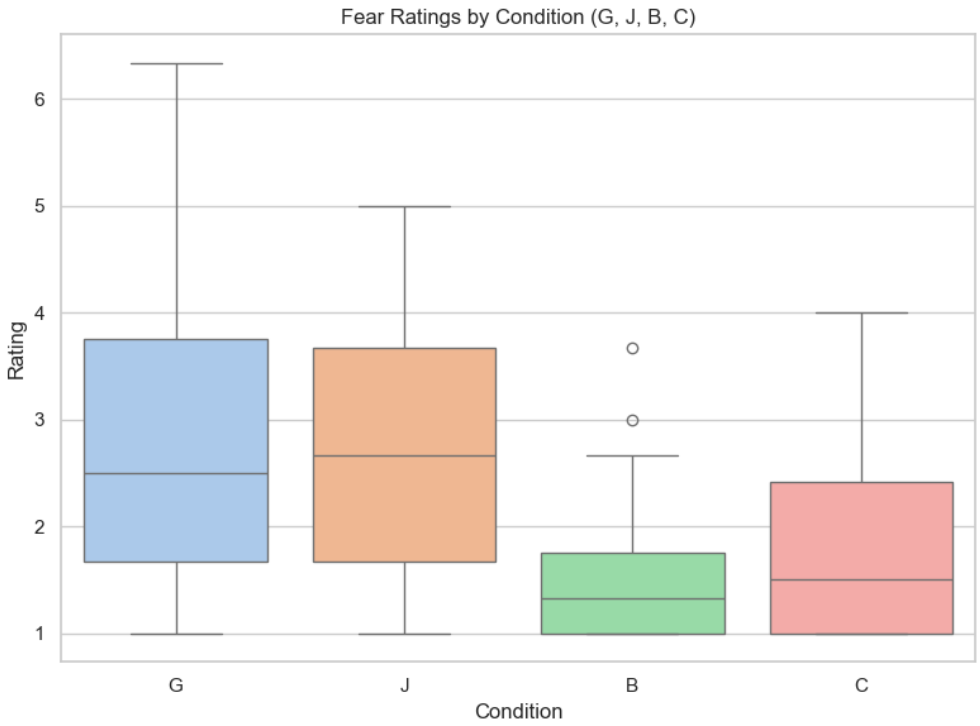


Figure 7.2: Boxplot of Subjective Fear Ratings per Condition. The conditions are: Girl running (G), jump scare (J), bedroom (B), and chainsaw (C)

Table 7.3: Pairwise Comparisons of Self-reported Calibration Data Between Videos Using Wilcoxon Signed-Rank Tests

Comparison	Mean 1	Mean 2	Diff	W	p-value	Sig.	Effect Size	Interpretation
J vs B	2.67	1.60	+1.07	4	0.040	Yes	1.01	J significantly higher
J vs C	2.67	1.88	+0.79	10.5	0.040	Yes	0.971	J significantly higher
G vs B	2.83	1.60	+1.24	15.5	0.040	Yes	0.921	G significantly higher
G vs C	2.83	1.88	+0.96	37	0.040	Yes	0.759	G significantly higher
B vs C	1.60	1.88	-0.28	37	0.060	No	0.419	No significant difference
G vs J	2.83	2.67	+0.17	66.5	0.060	No	0.358	No significant difference

Galvanic Skin Response

GSR results for calibration compared mean GSR, peak GSR, and SCR count through repeated measures ANOVA. Repeated measures ANOVA was chosen due to each participant experiencing all conditions. Before conducting this analysis, however, the mean GSR, peak GSR, and average SCR count were calculated per condition over all participants. The results of this can be seen in table 7.4.

Condition	Mean GSR	Peak GSR	Avg SCRs	Total SCRs	GSR Variability
Rest	0.3370	0.5796	1.31	376	0.1133
J	0.4195	0.8183	2.60	187	0.1713
G	0.4409	0.9024	3.07	221	0.2372
C	0.3309	0.7083	2.64	190	0.1807
B	0.3686	0.5976	1.81	130	0.1165

Table 7.4: GSR metrics across different conditions.

The GSR metrics show that G contains the highest values for all categories, generally followed by J, C, and then B. This is the same order as the subjective fear rating rankings. To analyse the data further, one-way ANOVA was used for the mean GSR, peak GSR, and SCR count as all participants went under the same conditions with multiple groups for comparison. The results of the comparisons can be seen in Table 7.5

GSR Metric	Significant	Key Findings (t, p_{corr})
Mean GSR	No	No significant differences between conditions
Peak GSR	Not After Correction	G > Rest (t = 2.80, p_{corr} = 0.0607) [trend]
SCR Count	Yes	C > Rest (t = 2.91, p_{corr} = 0.0414) G > Rest (t = 3.45, p_{corr} = 0.0086)

Table 7.5: Summary of statistical results comparing GSR metrics across conditions Rest, B, C, J, G. p-values are Holm-corrected.

Mean GSR produced no significance across conditions. Peak GSR produced no significant results after correction but showed a trend between G and *Rest* with a higher peak GSR for G compared to *Rest*. SCR count produced two significant results between conditions, including between G and Rest and C and Rest. For both sets of results, the horror condition was significantly higher than the Rest condition. Running the Pearson correlation test, no significance was found between mean GSR, peak GSR, or SCR count compared to subjective ratings per condition.

Overall, the GSR results show some significance during calibration, mostly for the G condition when compared to the Rest condition. This aligns with the subjective ratings that placed G as the highest rated fear condition on average.

Functional Near-Infrared Spectroscopy

Results of the fNIRS data were analysed through GLM before applying a mixed effects model with the formula: $beta \sim -1 + cond + (1|subject)$. The results provide no significance towards the hypothesis of this study. Some channels showed significance for either HbO or HbR, but no channels showed significance overall. This includes D2-S8, the channel used to gather fear-related data as established from the previous fear reactivity study discussed in Chapter 4. Similarly, comparing the beta values of D2 S8 for HbO and HbR against the subjective ratings yielded no significant results through the Spearman rank correlation analysis. Spearman's rank correlation was used as the self-reported data is not continuous.

7.3.4 Results: A Place for Everyone

For analysis of *A Place for Everyone*, data is split into conditions per scene. As not all participants experienced the same conditions for each scene, the analysis must be split to compare how each condition affected participant data per scene. This follows a mixed design, as the 6 Scenes are within-subjects, whilst the 3 conditions are between-subjects. This changes the count of participants per group to 8 (n = 8), as follows: the 6 variations shown in table 7.1, each condition was studied 2 times per scene for every 6 participants. As 24 participants took part in the study, this produced a total of 4 full iterations of the variations, causing each condition to be studied 8 times total per scene.

Self-reported Data

Self-reported data were analysed by comparing the mean, median, and range per question, per scene, per condition. This can be seen in table 7.6. The questions asked of participants were:

- How involved were you in the scene? (Involvement)
- How much did the visual aspects immerse you? (Immersion)
- How scared did you feel? (Fear)

Scene	Condition	Involvement			Immersion			Fear		
		Mean	Median	Range	Mean	Median	Range	Mean	Median	Range
Refugee	Low Fear	3.88	4.00	3–5	3.50	4.00	1–6	2.00	1.50	1–4
	High Fear	4.38	5.00	2–7	4.75	4.50	4–6	1.75	1.50	1–4
	Adaptation	4.63	5.00	2–6	4.88	4.50	4–7	2.25	2.00	1–5
Camp	Low Fear	3.75	4.00	1–7	3.38	3.00	2–5	2.13	2.00	1–4
	High Fear	4.00	4.50	1–6	4.88	5.00	3–7	2.00	2.00	1–4
	Adaptation	3.50	3.50	2–5	3.13	3.00	1–6	1.25	1.00	1–2
Plants	Low Fear	5.25	5.00	3–7	5.50	6.00	4–7	2.38	1.00	1–5
	High Fear	3.13	3.00	2–5	3.38	4.00	1–5	1.88	2.00	1–3
	Adaptation	4.88	4.50	4–6	4.50	5.00	2–5	1.88	2.00	1–3
Raid	Low Fear	4.63	5.00	2–6	3.63	4.00	1–5	3.38	3.00	1–6
	High Fear	5.63	6.00	3–7	5.63	6.00	3–7	2.88	2.50	1–5
	Adaptation	5.50	6.00	4–7	5.63	5.50	4–7	3.50	3.50	2–5
Processing	Low Fear	5.38	5.00	4–7	5.00	5.00	4–6	3.75	4.00	2–5
	High Fear	5.88	6.00	4–7	5.38	5.50	4–7	3.88	3.50	2–6
	Adaptation	5.25	5.50	2–7	4.88	5.50	1–7	2.88	2.50	1–5
Supper	Low Fear	5.50	6.00	3–7	5.25	5.00	4–7	2.50	2.50	1–4
	High Fear	4.25	4.50	2–7	4.00	4.00	1–7	2.75	2.00	1–6
	Adaptation	5.38	5.00	3–7	4.75	5.00	4–6	3.38	3.50	1–5

Table 7.6: Descriptive Statistics For Post-scene Subjective Questions by Scene and Condition

The statistics show that *Processing* generally rates highest for involvement and fear, especially in the *High Fear* and *Low Fear* conditions. *Plants* has the highest involvement and immersion in the *Low Fear* condition. Raid shows the highest immersion ratings for *High Fear* and *Adaptation* and the joint highest fear rating, alongside *Supper*, for the *Adaptation* condition. Refugee has the highest involvement and immersion in the *Adaptation* condition. Notably, the fear ratings across the scenes and conditions are

generally higher than those for the calibration videos, suggesting that the experience provided a higher sense of fear for participants than calibration.

Having established a descriptive analysis of the self-reported data, Mann-Whitney U tests were run to compare results across the 3 questions per scene per condition. Mann-Whitney U tests were chosen due to the use of non-normally distributed data, with small sample sizes (N = 8), and non-continuous data between two different groups. The results can be seen in table 7.7.

Measure	**Scene**	**Comparison**	**p-value**	**Mean1**	**Mean2**	**Higher Mean**
Involvement	Plants	Low Fear vs High Fear	0.0062	5.25	3.12	Low Fear
Involvement	Plants	High Fear vs Adaptation	0.0124	3.12	4.88	Adaptation
Immersion	Camp	Low Fear vs High Fear	0.0230	3.38	4.88	High Fear
Immersion	Plants	Low Fear vs High Fear	0.0065	5.50	3.38	Low Fear
Immersion	Plants	High Fear vs Adaptation	0.0341	3.38	4.50	Adaptation
Immersion	Raid	Low Fear vs High Fear	0.0120	3.62	5.62	High Fear
Immersion	Raid	Low Fear vs Adaptation	0.0071	3.62	5.62	Adaptation

Table 7.7: Significant Mann–Whitney U Test Results ($p < 0.05$) for Self-reported Ratings comparing two conditions at a time per scene

Results of the Mann-Whitney U tests showed no significant results for fear ratings when comparing two conditions per scene. For involvement, *Low Fear* and *Adaptation* were significantly higher rated than *High Fear* in the *Plants* scene. For immersion, *High Fear* was significantly higher than *Low Fear* for the *Camp* scene. In the *Plants* scene, *Low Fear* and *Adaptation* were significantly higher than *High Fear* in immersion. Finally, *Adaptation* and *High Fear* were significantly higher for immersion than *Low Fear* for the *Raid* scene. Overall, the *Adaptation* condition was generally rated well for immersion and involvement, especially when compared to *High Fear*.

The presence questionnaire results (full question list in the appendix D.4) are visualised in figure 7.3. The results show that participants adjusted quickly to the environment, with sound cues being effective alongside visuals and immersion. Issues are presented in movement (Q3), examining

objects from multiple viewpoints (Q7), and close examination of objects (Q9). These issues are likely related to the restricted movement of participants, as although some scenes involved forced movement, the participant could not move around the scene, only rotate their head to examine the VE.

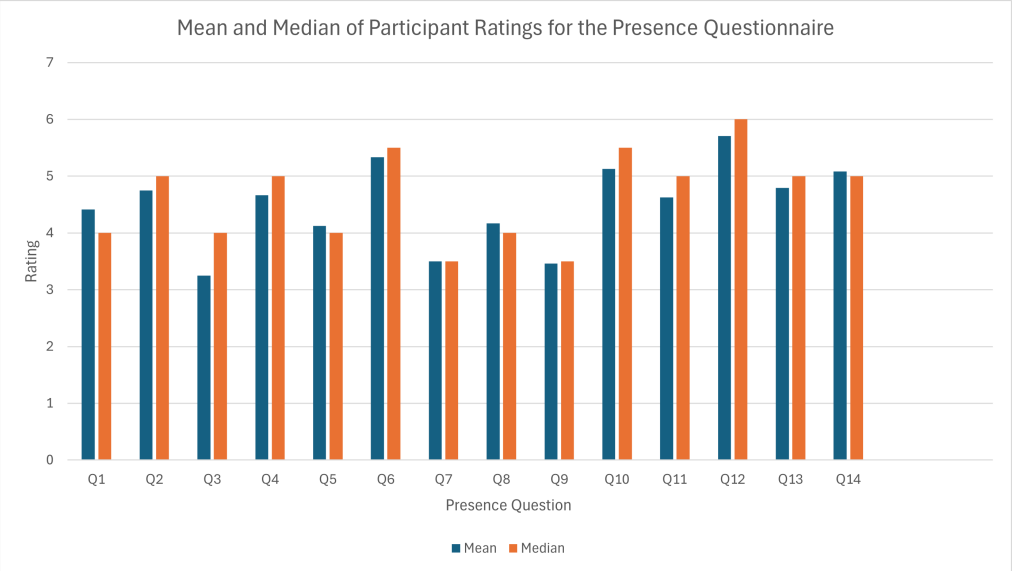


Figure 7.3: Mean and median results for the participant presence questionnaire

Finally, the participant trajectories were analysed through a digitisation process. This involved taking all participant trajectories and noting the y value alongside each key moment and storing this value per trajectory. This process of digitisation simplifies the graphs for comparison, but does remove the participant nuance within the graphs themselves. Advantages of this are that it is much easier to standardise and average the data across participants, as well as run statistical analyses on the data. The disadvantages, however, are the loss of data through smoothing out the data. I argue that the approach taken still provides enough detailed insight to evaluate the participant trajectories. The figures 7.4 7.5, 7.6, 7.7, 7.8, and 7.9 show the trajectories for each condition, where conditions have been averaged over participants.

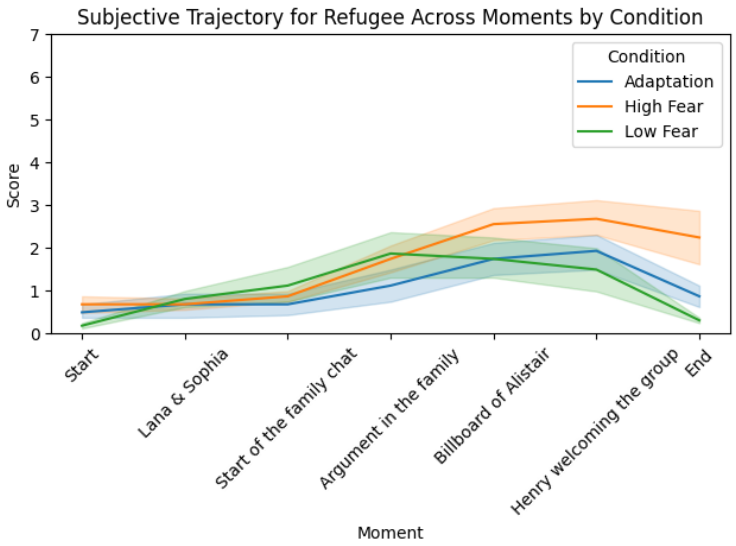


Figure 7.4: Mapping of the Refugee participant trajectories combining adaptation, high fear, and low fear participants to visualise the averages of each condition

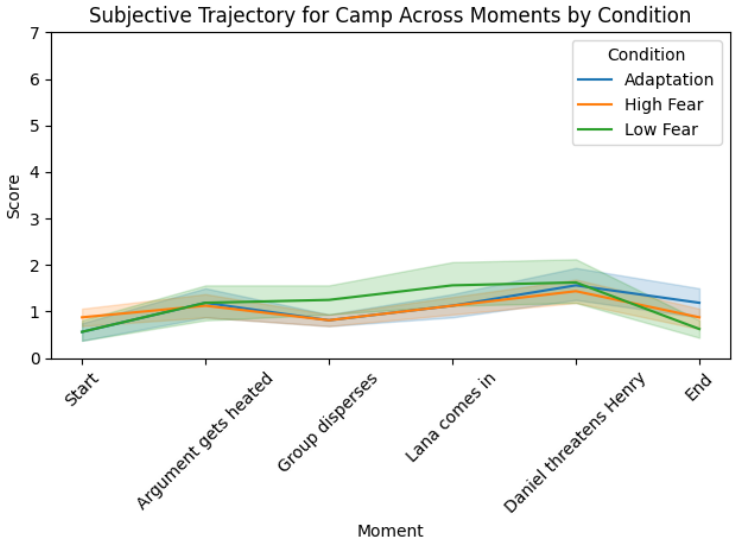


Figure 7.5: Mapping of the Camp participant trajectories combining adaptation, high fear, and low fear participants to visualise the averages of each condition

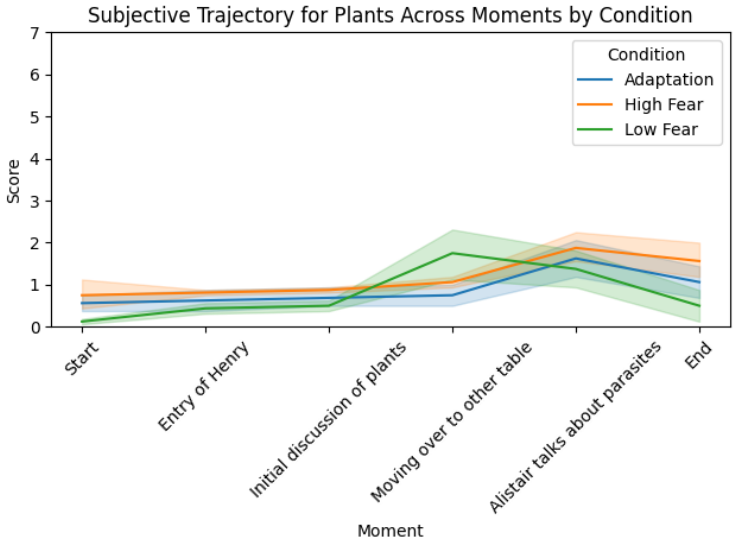


Figure 7.6: Mapping of the Plants participant trajectories combining adaptation, high fear, and low fear participants to visualise the averages of each condition

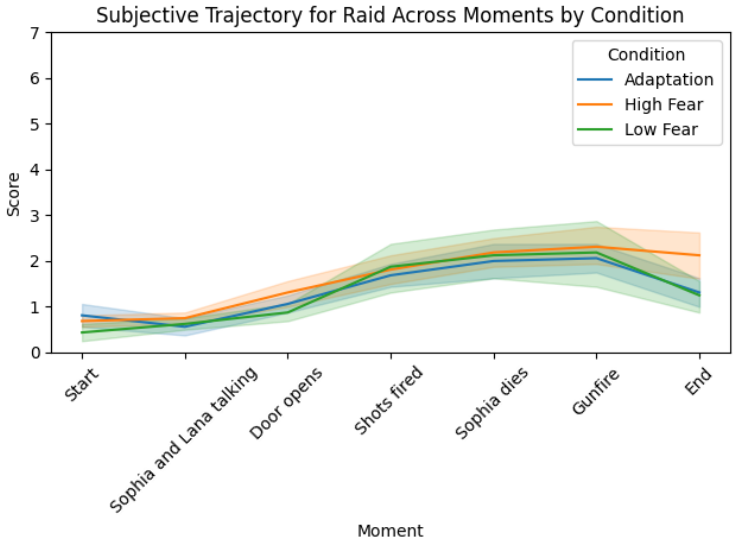


Figure 7.7: Mapping of the Raid participant trajectories combining adaptation, high fear, and low fear participants to visualise the averages of each condition

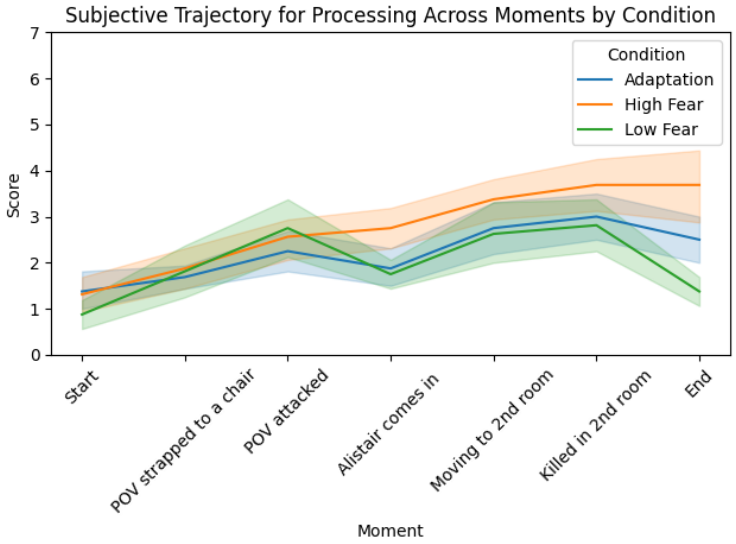


Figure 7.8: Mapping of the Processing participant trajectories combining adaptation, high fear, and low fear participants to visualise the averages of each condition

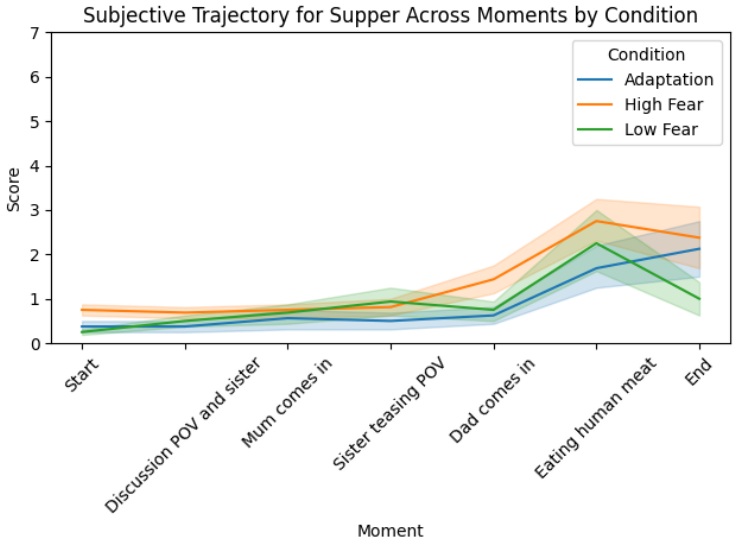
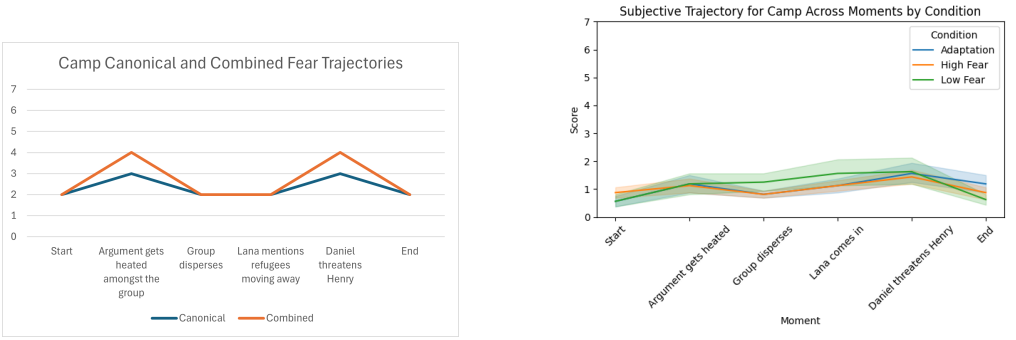


Figure 7.9: Mapping of the Supper participant trajectories combining adaptation, high fear, and low fear participants to visualise the averages of each condition

Interestingly, comparing the participant trajectories to the intended trajectories of the scenes as defined by me and AlbinoMosquito, there are similarities between all trajectories. As shown in figures 6.4, 6.7, 6.10, 6.13, 6.16, and 6.19, each trajectory follows a similar mapping to the par-

ticipant trajectories showing that generally participants followed the same trajectories as planned for the experience. Figure 7.10 shows a comparison of the *Camp* scene, showing the original planned trajectory and the participant trajectories per condition. As shown, the overall shape of the lines is very similar; the only difference is the reduced overall fear for the participant's trajectory.



(a) (b)

Figure 7.10: Comparison of planned fear trajectory (left) and participant trajectories per condition (right) for the scene Camp

Running Mann-Whitney U tests provided some significant results when comparing the key moments across conditions, two conditions at a time. Mann-Whitney U tests were chosen as the data were discrete and not normally distributed. The significant results can be seen in table 7.8.

Category	**Moment**	**Comparison**	**u-value**	**p-value**
Refugee	Henry welcoming the group	Adaptation vs High Fear	U = 11.000	p = 0.028
	End	Adaptation vs High Fear	U = 7.500	p = 0.007
Plants	End	Adaptation vs High Fear	U = 11.500	p = 0.030
Processing	End	Adaptation vs High Fear	U = 13.000	p = 0.048
Supper	Start	Adaptation vs High Fear	U = 10.000	p = 0.017

Table 7.8: Summary of significant Mann-Whitney U test results comparing key moments across conditions, two at a time

The significant results indicate significant differences between key moments in the *Adaptive* and *High Fear* conditions. In all cases, *High Fear* is significantly higher, showing that in cases of *High Fear*, participants plotted those key moments significantly higher than for *Adaptation*. This could

be due to the max level of fear for *High Fear* scenes as opposed to the potentially fluctuating fear of *Adaptation* scenes.

Galvanic Skin Response

GSR results for *A Place for Everyone* were analysed through unpaired t-tests using mean GSR, peak GSR, and SCR count. Unpaired t-tests were used to compare two separate groups of participants under different experimental conditions. Before calculating these results, the mean GSR, peak GSR, and SCR count were calculated per condition, per scene.

Table 7.9: GSR Mean, Peak, and SCR Count by Scene and Condition

Scene Name	Condition	Mean GSR	Peak GSR	SCR Count	GSR Variability
Refugee	Low Fear	0.273	2.184	69.125	0.781
Refugee	High Fear	0.184	1.680	23.125	0.554
Refugee	Adaptation	0.365	2.447	46.875	0.765
Camp	Low Fear	-0.029	1.728	22.750	0.748
Camp	High Fear	0.155	2.082	36.375	0.677
Camp	Adaptation	0.267	1.810	37.625	0.531
Plants	Low Fear	-0.224	1.756	19.875	0.603
Plants	High Fear	-0.060	1.932	40.625	0.747
Plants	Adaptation	-0.064	1.973	19.125	0.639
Raid	Low Fear	-0.440	1.785	49.125	0.802
Raid	High Fear	-0.108	1.697	8.750	0.600
Raid	Adaptation	-0.198	2.321	39.125	0.725
Processing	Low Fear	0.171	2.291	18.500	0.743
Processing	High Fear	-0.109	1.724	24.625	0.705
Processing	Adaptation	0.307	2.134	29.750	0.651
Supper	Low Fear	0.083	1.013	8.250	0.357
Supper	High Fear	-0.242	0.651	11.625	0.311
Supper	Adaptation	-0.185	0.806	4.375	0.507

Breaking this down by scene provides the following results:

- Refugee: *Adaptation* shows the highest results for mean and peak GSR; *Low Fear* shows the highest result for SCR count. This suggests that *Adaptation* evokes a strong, sustained arousal with moderate phasic response.
- Camp: *Adaptation* shows the highest results for mean GSR and SCR

count; *High Fear* shoes the highest result for peak GSR. This suggests that *Adaptation* may enhance both tonic and phasic responses.

- Plants: All conditions have a negative mean GSR; *Adaptation* has the highest result for peak GSR; *High Fear* has the highest result for SCR count. This suggests that *Adaptation* had minimal impact in this scene.

- Raid: All conditions have a negative mean GSR; *Adaptation* has the highest result for peak GSR; *Low Fear* has the highest result for SCR count. This suggests that *Adaptation* increases phasic arousal even in low-tonic scenes.

- Processing: *Adaptation* has the highest results for mean GSR and SCR count; *Low Fear* has the highest result for peak GSR. This suggests *Adaptation* has a stronger overall engagement than other conditions

- Supper: *Low Fear* has the highest results for mean and peak GSR; *High Fear* has the highest result for SCR count. This suggests *Adaptation* is the least responsive condition for this scene.

Overall, across the scenes, *Adaptation* shows a high mean GSR compared to the other conditions, with a varied SCR count. This indicates that *Adaptation* has sustained arousal across scenes, evoking a balanced phasic response.

Continuing analysis with the mean, peak GSR alongside SCR count, unpaired t-tests with Cohen's d were conducted to establish the significance and size of effect of the GSR metrics when compared per condition, per scene. Unpaired t-tests were used as the data were normally distributed. The table 7.10 shows the results.

Table 7.10: Mean GSR, Peak GSR, and SCR Count unpaired t-tests per condition, per scene with Large Effect Sizes (Cohen's $d \geq 0.8$ or Cohen's $d \leq -0.8$) and/or significance $P < 0.05$

Scene	**Measure**	**Comparison**	t	p	d
Refugee	SCR Count	Low Fear vs High Fear	2.36	0.0495	**1.18**
Refugee	SCR Count	High Fear vs Adaptation	-1.61	0.1511	**-0.80**
Raid	Mean GSR	Low Fear vs High Fear	-1.76	0.1106	**-0.88**
Raid	SCR Count	Low Fear vs High Fear	1.64	0.1441	**0.82**
Plants	Peak GSR	Low Fear vs High Fear	-1.72	0.1157	**-0.86**

The results show only one significant result, which is that the SCR count of *Low Fear* was significantly higher than *High Fear*. Expected results would be that *High Fear* had a higher SCR count; however, this result could be due to the low number of data points per group (n = 8). Other results were not significant, but some did contain a large effect size, notably the SCR count of *Adaptation* was higher than the *High Fear* condition. Other results also show that on some occasions, mean or peak GSR was higher for *High Fear* than *Low Fear*, but for SCR count in *Raid*, *Low Fear* had a higher result than *High Fear*.

Finally, the same GSR metrics were compared against the self-reported data using Spearman rank correlation tests. Spearman's rank correlation was used as the data is not continuous for self-reported data. The tests compared each GSR metric against each self-reported question rating per condition, per scene. The significant results can be seen in Table 7.11.

Table 7.11: Significant Spearman's correlations ($p < 0.05$) comparing Mean GSR, Peak GSR, and SCR Count against self-reported ratings per condition, per scene

Scene	**Condition**	**Measure**	**Question**	ρ**,** p
Camp	Low_Fear	SCR_Count	Immersion	$\rho = -0.810$, $p = 0.0149$
Plants	Adaptation	SCR_Count	Immersion	$\rho = -0.781$, $p = 0.0223$
Raid	Low_Fear	Mean_GSR	Involvement	$\rho = 0.773$, $p = 0.0244$
Supper	Adaptation	Peak_GSR	Immersion	$\rho = -0.913$, $p = 0.0015$

The results indicate that for *Camp Plants* and *Supper*, there was a neg-

ative correlation between physiological arousal, such as SCR count and peak GSR, and visual immersion for the *Low Fear* and *Adaptive* conditions. This indicates that in these conditions, participants who were more physiologically aroused felt less visually immersed. This could suggest that the heightened personal state of a participant may distract them from visual engagement. For *Raid*, there was a positive correlation between mean GSR and scene involvement in the *Low Fear* condition. This could suggest that a heightened physiological arousal may enhance engagement due to the narrative or emotional structure of the scene.

Functional Near-Infrared Spectroscopy

Analysing the brain activity data involved using BAA to evaluate the data before comparing the HbO and HbR, individually, of each condition per scene. BAA was used to compare the block averages between conditions in the same scene. The condition lengths also exceeded the typical length of 60s used for GLM. Evaluation was done through calculating the peak HbO, peak HbR, area under the curve (AUC) for HbO, and AUC for HbR for each condition in each scene. Unpaired t-tests were then run to compare all conditions, two at a time, per scene to determine significance. Only one result was significant, which was AUC for HbO within channel D2-S8 for *Refugee* comparing *Low Fear* against *High Fear* with the results $p = 0.0266$ ($t = -2.48$). This shows that the AUC for HbO in *Low Fear* was significantly lower than for *High Fear*. A similar result was found for GSR within the same scene, comparing the same conditions shown in Table 7.10. Unexpectedly, in the Refugee scene, the SCR count was significantly higher in the *Low Fear* condition compared to the *High Fear* condition. This difference in result for the same scene may reflect different processing strategies in participants. Participants in the *High Fear* condition may

have engaged in more sustained cognitive or emotional regulation, while those in *Low Fear* remained more reactive to moment-to-moment scene elements.

Finally, Spearman rank correlation analysis was run to compare peak HbO, peak HbR, AUC for HbO, and AUC for HbR against each self-reported question rating. Spearman's rank correlation was used as the data is not continuous for self-reported data. The significant results can be found in Table 7.12

Table 7.12: Significant Spearman's correlations ($p < 0.05$) comparing AUC and Peak HbO/HbR against self-reported ratings per condition, per scene

Scene	**Condition**	**Measure**	**Variable**	**r**	**p**
Camp	Low Fear	Peak HbO	Immersion	-0.767	0.031
Plants	High Fear	Peak HbO	Fear	0.743	0.043
Plants	High Fear	Peak HbO	Involvement	0.741	0.045
Supper	High Fear	Peak HbO	Fear	0.774	0.029
Refugee	Low Fear	Peak HbR	Immersion	0.774	0.029
Plants	Adaptation	Peak HbR	Immersion	-0.764	0.036
Raid	High Fear	Peak HbR	Immersion	0.778	0.031
Processing	High Fear	Peak HbR	Fear	-0.812	0.019
Supper	Adaptation	Peak HbR	Fear	-0.849	0.012
Camp	High Fear	AUC HbO	Fear	0.801	0.023
Processing	Low Fear	AUC HbO	Fear	-0.772	0.038
Processing	High Fear	AUC HbO	Fear	-0.764	0.035
Refugee	Adaptation	AUC HbO	Involvement	0.753	0.033
Refugee	Low Fear	AUC HbR	Immersion	0.774	0.029
Camp	High Fear	AUC HbR	Fear	0.901	0.005
Plants	Adaptation	AUC HbR	Immersion	-0.764	0.036
Plants	Adaptation	AUC HbR	Involvement	-0.848	0.021
Raid	Adaptation	AUC HbR	Involvement	0.743	0.043
Processing	High Fear	AUC HbR	Fear	-0.764	0.035

The results show that for almost all significant *Adaptation* conditions, there is a positive correlation for HbO and a negative correlation for HbR, showing that the *Adaptation* condition increased prefrontal activity about *Immersion* and *Involvement*. *Raid* measured with AUC for HbR showed a positive correlation for *Adaptation*, meaning that for this specific scene,

the higher the value of *Involvement*, the higher the AUC for HbR, meaning less cognitive activity. Participants who reported feeling more fear during the *Supper* scene tended to have lower Peak HbR responses. With a strong negative correlation like this, it might suggest that higher activation (lower HbR) is associated with higher self-reported fear.

For *High Fear*, generally, when compared to *Fear*, there is a positive correlation with HbO and a negative correlation with HbR, indicating that as fear ratings increase, HbO increases and HbR decreases. As for *Involvement* and *Immersion*, there is one result showing a positive correlation for HbO and *Involvement* and one result showing a positive correlation for HbR and *Immersion*.

Finally, for *Low Fear*, all conditions show a negative correlation for HbO and a positive correlation for HbR, showing that for the variables *Immersion* and *Fear*, as brain activity increased, the ratings of each variable decreased.

Thematic Analysis for Post-experience Interview

Braun and Clarke's thematic analysis (Victoria and Braun, 2014) was employed to analyse the post-experience interview data from the participants. With a total of $n = 24$ transcriptions, 56 codes were generated. These were refined down to 29 codes before being compiled into 3 themes. The themes are:

- Emotional and Sensory Impact of Adaptation
- Awareness and Interpretation of the Experience Adaptive System
- Future Use of Adaptive Media

Before delving into the themes, participants were asked a few questions that provided more context to their overall feelings towards *A Place for Everyone*. When asked if participants thought of the experience as a horror experience, overall the responses were mixed, with 13 participants saying it was a horror experience and 11 saying it was not. Those who found it not to be a horror experience found the experience to be more towards a thriller, whilst not providing as much fear as they would expect from a horror, such as jump scares. When asked if the experience was effective as a horror, more participants agreed that the horror was effective, with 16 participants saying it was effective, and 8 participants saying it was not.

Although some participants didn't find the experience to be horror overall, they found the elements that were horror to be effective. 16 participants said they were consumers of horror, whilst 8 did not. When asked whether the adaptation increased the fear that the participant experienced, 21 participants said yes, 3 said no. Those who said no wanted the experience to go further than it did, pushing the participant to feel more fear. When asked if participants felt aware of the brain activity being used for more than data collection, 19 participants said no, whilst 5 said yes. Those who said yes tended to develop some relation between the audiovisual changes and the sensors. Finally, participants were asked if they would want to know about adaptation before taking part in an adaptive experience. 15 said no, whilst 6 said yes, those who said yes said they would find the experience more interesting or control/know the response of the adaptation. Those who said no said they feel it would take away from the experience and create a distraction from the experience.

The emotional and sensory impact of adaptation covers how adaptation influenced the fear of the participant, as well as the key moments and immersive effects of the experience. As previously mentioned, 21 participants

found the adaptation to increase the fear that they felt within the experience, which is a large majority of the participant count. In response to being asked if adaptation increased their fear, one participant put "[Adaptation] definitely made it creepier because now you mention those moments, those are the moments that stick out to me as like, oh, I remember that feeling creepier". 13 participants felt that adaptation reflected their fear level, with one participant saying "I think it could have been scarier, but I'm quite glad it wasn't. So I guess, yeah, I guess it reflected my fear level on what I would want from a horror film would be that fear level". This hits the aims of calibration, where participants can choose the level of fear they want in response to the four horror videos.

The adaptive experience never took them beyond their fear level. Some participants referred to the audio being a significant factor for adaptation, where the audio increased participants' fear. This result is expected since, as found in previous research (Liang et al., 2023), audio evokes more emotional arousal than visual. An interesting note on the adaptation of visuals is references to zombies within the first scene *Refugee*. In the first level of adaptation within this scene, human figures are placed around the street inside houses and on top of buildings, rotating along the y-axis to maintain focus on the user. The aim of this is to provide a sense of unease and dread within the participant as they walk along the street. However, the impact of this visual change, for some participants, was the introduction of zombies. As one participant said, "there was kind of like an eerie vibe as you're walking down the street and you're sort of looking around you and you can see zombies in the windows as you're interacting with the group". For one participant, this even affected their view of the experience as a whole, as, when referring to fear in the scene *Raid*, they said "the scene where the zombies attacked because I first started off with the lady in front

of my face".

Some participants mentioned the adaptation increased focus, excitement, and attention, whilst also building expectation. The use of adaptation is to increase fear, but the use of audiovisual changes maintains an ever-changing experience, which participants found engaging. When looking at key moments and more fearful scenes of the experience, participants leaned heavily towards the final three scenes of the experience (Raid, Processing, and Supper). These scenes are designed to be more fearfully intense than the other scenes, and this is reflected in participant responses. Participants note the more action involved in the scenes, such as gunshots in *Raid*, being strapped to the chair in *Processing*, and the face on the table in *Supper*. Some participants did note that they also found the first scene, *Refugee*, to be fearful due to being hesitant about what to expect from the experience.

Awareness and interpretation of the experience and adaptive system covers how participants overall perceived the experience, their perception of adaptation before being told of its use, and the involvement of calibration towards the experience. Overall, participants enjoyed the experience, with notions towards an impressive visual environment, good audio quality, an interesting and immersive experience, as well as being fun and enjoying the use of VR. When discussing the genre of the experience, one participant referred to the experience as being like a documentary, whilst another said it was horror themed, and even one participant found parts of the experience to be funny, "I don't know the last bit when they open the meal and it's human-made. It's funny". This varied reaction to horror likely stems from the subjective nature of horror.

As previously mentioned, 13 participants found the experience to be of the horror genre, while 11 found it to be of another genre. For some,

this experience induced fear, yet for others, they found it to be lacking in tropes such as jump scares and gore. This is a challenge of the genre when creating for wider audiences, but it is also a potential future scope of adaptation in incorporating more fear tropes to attract and provide fear for wider audiences. Looking back at the adaptive system, some participants were able to notice parts of the adaptation before it was explained to them after the experience.

Participants picked up on the changes in lighting, colours, intensity of the audio, and the placement of bodies or figures. Some went as far as to connect the narrative to adaptation. Within the narrative, during the *Plants* scene, the character Alistair discusses parasites and their uses, referring at the time to the plants, but signifying to the audience an undertone of danger towards the refugees. Some participants then associated the adaptive changes to parasites in the head of the characters that they embodied, "I'm assuming there's a parasite in people's bloodstreams or something which is affecting like sanity". This leans into the effect of adaptation on participants without their knowledge of it happening. The use of adaptation may have more effect narratively than the intent of altering the fear that they experience.

Finally, looking at the use of the calibration videos and the choices participants made, participants were split on whether the calibration video they chose during the calibration phase was the same level of fear as the fear they experienced in *A Place for Everyone*. 10 participants chose the same fear level as the video they chose, whilst 11 chose a different video. Many participants who opted for a different video chose either the C or B video based on the use of suspense and audio present within those videos. As previously mentioned, some participants found the audio impactful in adaptation, and the C video focuses on audio, "[C] was more intense for me

in comparison with the other three because of the sound and how intense it was". When referring to the B video, one participant said "yeah, the suspense and the build up rather than having that jump scare". This ties in with the other participant comments of a lack of jump scares, associating more towards the more suspenseful calibration videos than G and J, which aim more towards quick fear through jump scares.

Future use of adaptive media covers the discussion with participants around what they believe an adaptive system could be used for beyond *A Place for Everyone*. When asked about the positive applications of adaptive systems, participants tended towards adaptation of emotions, likely due to the concept of adaptation within *A Place for Everyone*. This included games and films, mostly adapting to fear but also sadness and happiness. Other uses included adapting the difficulty of games, education, and training to aid with learning, as well as using adaptation to assist with exposure therapy by slowly increasing the fear of a patient. When looking towards the use of adaptation for negative applications, a majority of participants leaned towards emotional control and manipulation by understanding a person's emotional state and changing or worsening that state. For example, one participant said, "When you have like an adaptive experience, it can be just used to either scare people or to manipulate people, so perhaps impact on their decisions or something like that". Another use was the use of torture, similar to the use of emotional manipulation, or the misuse of personal data, such as brain data, being accessible beyond a person's control and being used against them.

Interestingly, some participants noted a limitation of adaptation through control of choices. As an adaptation, at least in the case of *A Place for Everyone*, controls the fear level of the experience, some participants noted that this could impact discussion of the experience with others, as they

experienced different things. Similarly, one participant noted the use of controlling emotion to cause negative impacts in the long term. The participant says, "Sometimes the fun of watching a horror film is actually being really scared. I think if things are always adapted to suit your level of needs, you're never going outside your level of need or comfortable". This raises an interesting point about how much control should adaptation have over an experience and whether participants should have control over the amount of adaptation present in an experience.

7.3.5 Discussion

Having collected a large data set with which to analyse *A Place for everyone*, the results show a lot of insight into the hybrid approach taken with the experience, the use of an adaptive system, as well as the future of adaptive experiences. Within this section, I break down the discussion to cover the success of *A Place for Everyone*, the results of the physiological approach taken to adaptation, as well as the future applications that adaptation may have.

The Success of A Place for Everyone

First and foremost, the responses from participants towards the experience were positive. Participants commented on the immersion, engagement, and storytelling as well as the quality of the virtual environment and audio. One core insight of the experience is the similarity between the participant trajectories of fear and the predefined fear trajectories for each scene. As discussed in the results section 7.3.4, all participant trajectories followed a similar shape to the planned fear trajectories of each scene, expressing that

the participants did follow the intended fear trajectory for each scene. The main difference is the intensity of fear, which was lower for the participant trajectories.

It could be argued that, due to averaging over 8 participants per condition, the subjective nature of fear caused a lower average for each condition. The subjective feedback for *A Place for Everyone* had an overall positive impact on the audience, and the experience itself was shown to be a success in relation to audience feedback. When asked if the experience was horror, however, participants were mixed in their response. Those who found the experience not to be horror wished for more tropes, such as jump scares. This leans into the subjectivity of fear, as some participants felt scared, and potentially adding jump scares may have been too much for them. To solve this, adaptation could add further stages to provide for those participants seeking more horror. This does, however, open up to the question of how far adaptation should go. I cover this when looking at the future use of adaptation later in the discussion (7.3.5).

Looking towards the use of the adaptive system overall, participants found it to increase the fear that they experienced when it adapted a scene, highlighting a success in the primary goal of the system. Audio was overall seen as more effective than the visuals; however, that didn't change the impact of the visuals, as some adaptive visuals, specifically the human figures in *Refugee*, changed the narrative of the experience for some participants to focus on zombies. Similarly, the mention of parasites within the *Plants* scene caused some participants to believe the adaptive changes and blinking effect were caused by parasites within the character they had embodied. Although these impacts were for a minority of participants, the use of adaptation for audiovisual stimuli can have a strong effect on the overall narrative of the experience. These impacts were not intended, but

can lean into the unique interpersonal experience of adaptation and how different audiences may interpret the content.

The hypothesis of this study was: the use of adaptation in a horror experience, as opposed to a non-adaptive horror experience, can create a more fearful and engaging experience. Looking at the subjective results, there are indications for some scenes that this is true. For *Refugee* and *Raid*, *Low Fear* ratings are on average lower than *High Fear* and *Adaptation*. For *Plants* and *Supper*, *Low Fear* ratings are overall higher than *High Fear* and *Adaptation*. The impact of *Adaptation* on *Immersion*, *Involvement*, and *Fear* depends on the scene, implying that the use of adaptation and the original statement of the hypothesis goes deeper than simply saying that adaptation will improve fear and engagement.

Examining the scenes where *Low Fear* was overall more impactful, in *Plants* and *Supper*, the participant embodies a character on the side of the antagonist (*Plants* is a guard, *Supper* is the son of a processing worker). On the other hand, for the scenes where *Low Fear* was less impactful, the participant embodies more susceptible characters (*Refugee* is a dad walking through an empty street with his family, *Raid* is a baby in a tent). The embodiment of characters may influence the effect that adaptation has on the scene, with more susceptible characters providing more *Involvement*, *Immersion*, and/or *Fear* when in adaptive conditions. The other scenes *Camp* and *Processing* appear mixed in results with *Adaptation* generally being lowest, followed by *Low Fear* and then *High Fear*. Although *Adaptation* and *High Fear* produced mixed responses against the *Low Fear* condition, there is evidence that adaptation has a positive impact on *Involvement*, *Immersion*, and *Fear*. More responses would be required to examine this further, as each condition has a total of 8 participants per scene.

The Use of fNIRS and GSR For Adaptation

The physiological analysis of the calibration and experience showed signs of significant results. The calibration video most consistently chosen, G, was also the video rated highest for fear, with GSR showing a significantly higher SCR count for G compared to *Rest*. Unfortunately, for calibration, fNIRS showed no significant results. As previously found in Chapter 4, the left DLPFC showed significant activation for fear. The lack of significance in the data could be due to no opposing condition to fear, as the *Fear* condition was only compared to *Rest* and not *Calm*, where the previous study found significance. Although fear ratings were generally below three, the significance in SCR count shows that G and C were successful in eliciting high arousal responses, likely in response to the fear experienced, providing evidence that these calibration videos were fearful.

The results for *A Place for Everyone* also showed significance, notably in fNIRS. Looking at the significant GSR results, there is not much significance between conditions, but there is a large effect size for SCR count where *Adaptation* was higher than *High Fear* in the scene *Refugee*. The small number of significant results likely reflects the lower-than-expected fear ratings for participants. This is not to say that fear ratings were low overall, but that the expected fear ratings per scene were lower than intended, once again reflecting the mixture of results when discussing the experience as being within the horror genre. The results for fNIRS showed one significant result where the AUC for HbO in the left DLPFC was significantly higher for *High Fear* than *Low Fear* in the scene *Refugee*.

The opposite results were observed in the GSR data, where *Low Fear* was significantly higher than *High Fear* in the scene *Refugee*. It is possible that this contention in results is due to participants in the *High Fear* condition

engaging in more sustained cognitive or emotional regulation, while those in *Low Fear* were more reactive to moment-to-moment scene elements. Other significant results were found between fNIRS and subjective ratings, where general increases to HbO in the left DLPFC in *Adaptation* increased *Immersion* and *Involvement*. Additionally, increases in HbO in the left DLPFC for *High Fear* mostly increased the rating of *Fear*. Using the results from the previous study on fear in Chapter 4, this indicates an increase in fear in participants improved *Immersion*, *Involvement*, and *Fear* ratings. The potentially low number of significant results is possibly due to the low subjective ratings of fear, combined with a mix of participants rating the experience as horror or not. If participants were less scared overall, there is likely less physiological response to differ between conditions.

The combined use of GSR and fNIRS shows potential for providing a deeper understanding of fear in a participant. For GSR, results with large effect sizes showed detection of increased SCR count, mean GSR, and peak GSR for *High Fear* and *Adaptation*. Additionally, the significant fNIRS result shows an increase for HbO in *High Fear* compared to *Low Fear*. The contrasting results for *Refugee*, however, show how the physiological measures can provide different results, indicating the potential complexity of an adaptive system that uses both. It is possible that combining GSR and fNIRS could allow for a more fine-tuned experience, but requires a deeper understanding of the effects of GSR and fNIRS in response to fear stimuli. I suggest that further data collection is needed to provide more results, as the current sample size per condition is eight.

Comparing these results to other adaptation-related studies, one study found adaptive horror-based audio to increase fear (Demarque and Lima, 2013) through auditory hallucinations. The results showed that users found auditory hallucinations to increase the fear of an experience. The results

from *A Place for Everyone* indicate a similar response. Although audio was not analysed specifically, participants found audio to be a contributing factor in the effect of audio on the fear experienced. This is likely represented within the physiological data, possibly most notably within the C calibration video, as this video focuses on audio-based fear and GSR showed that it had a significantly higher SCR count than *Rest*.

It is possibly also a contributing factor within the physiological responses measured in *A Place for Everyone*, indicated by the overall increase of fear ratings in response to increased HbO in the *High Fear* condition. Another study used heart rate variability to manipulate gameplay in a VR horror game (Houzangbe et al., 2018), which provided an increase in interest and engagement from participants. For fNIRS results in the *Adaptation* condition, most significant results showed that increased left DLPFC activity related to increased *Immersion* and *Engagement*. Examining GSR, these indicate that an increase in arousal in *Adaptation* had a negative effect on *Immersion* in two scenes, suggesting that a higher personal state in those scenes distracted participants from engagement. There is some support for *Adaptation* improving *Immersion*, *Involvement*, and *Fear*, but it is more susceptible to individual scenes.

The Future of Adaptation

When discussing the use of adaptation with participants, many participants tended towards discussing adaptive systems similar to *A Place for Everyone*, such as affective adaptation in games and films with notions towards other emotions, like happiness and sadness. Participants showed genuine interest in broadening the current use of adaptation, pushing adaptive systems to better understand a participant and provide potentially more tar-

geted adaptation. This also extended towards educational adaptive systems that can teach users or adapt difficulty levels or tasks and games to the user's needs, as well as the use of adaptation in exposure therapy. When attempting to create an adaptive system that is more tailored to the user, this increases the system's complexity.

With *A Place for Everyone*, as the researcher and developer, I was limited in time and technical capabilities as to how far the adaptive system could alter the audiovisual stimuli. As technology advances, however, solutions such as artificial intelligence (AI) provide the capabilities to produce adaptive content efficiently. AI tools such as Polycam (Polycam, 2025), which generates textures from a text prompt, and Meshy (Meshy, 2025), which generates models from a text prompt, could be utilised to quickly generate adaptive content. If integrated into an adaptive system, tools such as these could potentially produce adaptive content in real-time to produce content aimed at specifically affecting an individual. This process could provide much more detailed adaptive systems; however, this raises important ethical questions around the limitations of adaptation and how far adaptation should go. Without boundaries or limitations, integrating AI into adaptation could cause distress in audiences through phobic or traumatic stimuli. Setting these boundaries, however, is more challenging, as the horror limits between two individuals may not be the same. This opens up the possibility of user-controlled adaptation, where users can define their limitations to adaptation to ensure that content they wish to avoid is not included.

7.3.6 Limitations and Future Directions

Although there was a large data set for this study, the use of 3 conditions spread across 6 scenes created smaller data sets per condition. Variations

were used to provide counter-balancing and an equal variety of conditions in scenes, but with 24 participants, this reduced the participants per condition to 8. More data collection is necessary to provide further insight into the effect of adaptation and the potential collaboration of GSR and fNIRS.

Future directions of this research will look into a closer understanding of the connection between GSR and fNIRS within a similar study to that described in Chapter 4. The aim of this is to firstly see how well GSR and fNIRS can work together outside of an adaptive experience before attempting to integrate them within an adaptive experience.

7.3.7 Conclusion

Having analysed *A Place for Everyone* through a controlled lab study, overall, the experience was a success in the eyes of the audience. Participants enjoyed the experience and found that overall, adaptation was effective in increasing the fear that they experienced. Physiological responses of participants provided some significant results that proved some adaptive scenes were successful in eliciting a fear response greater than some non-adaptive scenes, further bolstering the success of the adaptive experience. While the initial impact of adaptation on immersion, involvement, and fear is positive, more data is required to better understand the impacts of adaptation.

Chapter 8

Discussion

This thesis set out to understand how physiological data could be utilised to understand fear processing, measure it, and apply the data to an adaptive experience that modulates the fear intensity for the audience. To do this, four research questions were raised to best evaluate how this could be done, and what the implications of it mean. The questions are as follows:

- RQ 1: How can we understand fear from fNIRS data and turn this into usable data that could adapt an experience in real-time?
- RQ 2: How can we create an adaptive fear-based narrative within VR that modulates fearful experiences for each user?
- RQ 3: How could media professionals utilise a toolkit for creating adaptive experiences and engage audiences with that content?
- RQ 4: What are the broader generalisations that can be made about emotionally adaptive experiences?

Each question is addressed through a series of discussion points, which are the recognition of fear, the application of fear, the implications and future

of adaptation, and the ethical implications. Throughout this discussion, AI is raised in relation to several themes, including scalability, creative applications, and ethical governance. This is intentional, as AI is not a discrete add-on but a technology that intersects many aspects of adaptive systems. Rather than isolating AI in its own section, I discuss it alongside other key points to highlight both its potential use within each context.

8.1 Recognition of Fear

Fear comes in many forms, from evolutionary fear of pain to social phobias (Meulders, 2020). The ability to recognise fear in others is a fundamental component of social cognition, with significant implications for survival, interpersonal communication, and mental health. Fear, as a basic emotion (Ekman, 1992), serves an adaptive function by alerting individuals to potential threats and enabling them to respond appropriately. However, accurately recognising fear, whether through facial expressions, body language, or physiological signals, is not a straightforward process. It involves a complex interplay of perceptual, cognitive, cultural, and neurobiological factors.

This thesis demonstrates the success of detecting fear processing in real time using fNIRS in VR. Results of the studies shown in Chapter 7 explore this success, through thematic analysis and biodata analysis. Results indicated that, for certain scenes, fNIRS could successfully identify fear processing, and the application of adaptation into the experience overall increased the fear experienced by participants. This section will cover the complexities of attempting to recognise fear, including existing neurophysiological and machine learning models used to classify fear-related brain

activity from fNIRS signals and their scalability in adaptive, immersive systems such as VR. This section and subsequent subsections relate to RQ 1, understanding how fNIRS can be used within an adaptive context.

8.1.1 Complexities of Physiological Fear Recognition

The detection of emotions solely through physiological measures presents significant challenges due to the inherent complexity of emotional states, which involve ambiguity, inter-individual variability, contextual influences, and technical limitations (Luong and Holz, 2022). For instance, heart rate is commonly used as an indicator of arousal; an increase in heart rate is often interpreted as a sign of heightened arousal, which may be associated with emotions such as fear. However, arousal is a non-specific physiological response that can correspond to various emotional states, including excitement, anger, or surprise (Russell, 1980).

Without additional contextual or subjective data, it is not possible to definitively attribute increased arousal to a specific emotion such as fear. Furthermore, individual differences in physiological reactivity complicate interpretation. For example, the sight of a spider may elicit a strong autonomic response in one individual, but only a mild response in another. This variability is further influenced by contextual factors; for example, an elevated heart rate may reflect nervous anticipation rather than a direct response to an external stimulus (Knopf and Pössel, 2009). Technical limitations, including external noise and environmental artefacts, also reduce the reliability and validity of physiological data, thereby constraining the inferences that can be drawn. While these limitations do not prevent the possibility of inferring emotional states from physiological signals, they underscore the need for multimodal approaches. Without complementary

data, such as self-reported or behavioural data, physiological signals alone cannot reliably identify discrete emotional states.

These challenges also apply to brain activity measures; however, neurophysiological data offer a richer level of detail compared to physiological measures such as heart rate or galvanic skin response (Hogervorst et al., 2014). Brain activity not only identifies arousal but also captures cognitive processing and affective evaluation by measuring how different brain regions respond to stimuli. For example, emotional responses to fear-inducing stimuli can be more precisely mapped to brain structures using EEG or fNIRS, which measure changes in electrical activity and haemodynamic responses, respectively (Glotzbach et al., 2011; Rosenbaum et al., 2020). This level of resolution enables a more nuanced understanding of emotional processing, although it too is subject to individual and contextual variability, as well as technical limitations. A multimodal approach is increasingly employed in emotion research to enhance data quality and provide a comprehensive understanding of an individual's physiological and neural responses. By integrating brain activity measures with peripheral physiological signals, such as heart rate or galvanic skin response, researchers can gain deeper insight into the complex interplay between cognitive, affective, and bodily underlying emotional states (Rosenbaum et al., 2020; Bălan et al., 2020; Balconi et al., 2015).

Within this thesis, an initial approach employed fNIRS for detecting inferences of fear when comparing fear and calm videos within VR. This successfully found increased brain activation in the left DLPFC for the fear conditions. These results are backed by existing research that found similar results (Landowska et al., 2018). A multimodal approach was not used here, as that approach to an adaptive system would provide increased complexity beyond the scope of this thesis. Instead, simply understand-

ing the induction of fear in fNIRS was a valuable first step to creating the adaptive system in *A Place for Everyone*. When using the adaptive system, GSR was added as an additional measure to understand whether it would provide complementary data to fNIRS for use within adaptive systems.

The results of this indicated some response to fear stimuli, but also conflicting results for one scene. These results found GSR to provide a higher SCR count for the low fear condition when compared to the high fear condition, while fNIRS found HbO to increase for the high fear condition compared to the low fear condition. This conflict could be caused by a potential low participant data count (n = 8 per condition), but also the different processing strategies in participants. Participants in the high fear condition may have engaged in more sustained cognitive or emotional regulation, while those in the low fear condition remained more reactive to moment-to-moment scene elements. This suggests more data and more research into the combined use of fNIRS and GSR before being used as a multimodal approach to an adaptive system.

Developing within VR provides another level of complexity beyond physiological measurements within other media such as 2D film and desktop/console games. VR typically introduces more movement, whether it be simply head movement from a sit-down experience, body rotation, or room-scale movement where a user physically walks around their surroundings. As physiological measures are susceptible to noise, introducing movement beyond slight adjustments when looking at a screen reduces data validity. Because of this, when designing *A Place for Everyone*, I had to take into account the ability to accurately measure fear processing while ensuring some freedom of movement. A sit-down, filmic experience alongside fNIRS was chosen to mitigate noise, as fNIRS has shown less susceptibility to noise than other physiological measures such as GSR, HR, and EEG.

8.1.2 Computational Models and Thesis Approach

Various computational models exist for the exploration of emotion recognition, including machine learning models, rule-based models, and multimodal fusion models. Each model offers its distinct advantages and limitations regarding accuracy, scalability, and feasibility for real-time implementation. Machine learning models have shown promise in classifying emotional states. The exploration of real-time applications provides positive results, such as a combined approach of EEG with facial recognition where a convolutional neural network and long short-term memory classifiers both achieved over 87% accuracy for emotion detection (Hassouneh et al., 2020). Models such as support vector machines have been used to correctly classify emotional states such as amusement, sadness, and neutral through offline analysis (Domínguez-Jiménez et al., 2020). When attempting to classify fear, however, models tend to be less accurate than for other emotions (Barman and Dutta, 2019; Ortmann et al., 2024).

By contrast, a rule-based or threshold-based model offers more transparency and less complexity at the cost of accuracy and nuance. This approach uses a predefined set of rules or thresholds to determine emotional states (Gera et al., 2024; Khanna and M., 2013). While their accuracy and detection of emotional states are limited, their simplicity enables faster response times and more predictable behaviour, providing suitability for adaptation where rapid feedback is essential. Within this thesis, a threshold-based approach was adopted for the real-time adaptive system to prioritise responsiveness and reduce the complexity of the system. A method for identifying inferences of fear from fNIRS had been established earlier in the thesis in Chapter 4, making a threshold-based approach more fitting. The calibration process was used to establish an individual's threshold before being

used to determine a change in response to fear stimuli, and have the experience respond accordingly.

For data collection and analysis, a multimodal approach was employed to gain a deeper understanding of emotional states within an offline context. This included the integration of fNIRS to measure cortical activity, GSR to measure electrodermal activity, and self-reported data to gather fear ratings. Including multiple data streams allows for more refined analysis, which was later used to validate the real-time application of fNIRS. When analysing the results, calibration showed some significant results for GSR but lacked any meaningful results for fNIRS. Within *A Place for Everyone*, both GSR and fNIRS yielded significant results, indicating that certain scenes were effective in producing inferences of fear or positively impacting visual immersion and involvement.

Although there were limited results, there is evidence to show that the threshold-based approach was effective, most notably from individual feedback where 54% of participants said that they felt adaptation reflected their fear level. Additionally, 48% of participants said that the calibration video they chose for their threshold also best reflected the fear they experienced in *A Place for Everyone*. Therefore, for around half of the participants, the threshold-based approach was effective. For the other half, the subjectivity of fear and limitations of adaptation play a key role. Some participants found the adaptation or the experience as a whole to be lacking in fear. When implementing the adaptation, 3 stages of adaptation were chosen to ensure a degree of increase in fear as participants were subjected to more fear-based audiovisual stimuli. Implementing more stages of fear or more variations of audiovisual stimuli could target a wider range of audiences, but opens discussion to the ethics of adaptation and the feasibility of implementing more adaptations. This will be discussed further in the sections

8.2 and 8.4 below.

8.1.3 fNIRS Capabilities and Broader Implications for Emotion Recognition

fNIRS was determined to be the most effective physiological measure for use within a fear-based adaptive system due to its higher spatial resolution compared to EEG, reduced susceptibility to noise compared to HR, GSR, and EEG, and its ability to localise cortical brain activity. Moreover, fNIRS is non-invasive, portable, and well-suited for use in VR contexts where participant comfort and freedom of movement are controllable. Previous studies have demonstrated its effectiveness in inferring emotional states, including fear, through cortical activation patterns (Landowska et al., 2018). When working with VR, the practicality of emotion recognition techniques is a priority, as the use of expression recognition, for example, is caveated by obscured facial features. Technological advancements are beginning to overcome this, however, with some VR headsets containing eye tracking or mouth tracking, such as the Meta Quest Pro (Meta, 2022) and Vive XR Elite (VIVE, 2023). These advancements could provide the possibility to combine expression recognition with other physiological measures for a further refined emotion recognition approach.

When measuring through fNIRS, fear itself is not measured, but instead the processing involved in response to a fearful stimulus. In particular, this research focused on the left DLPFC, a region of the brain associated with emotional regulation, cognitive control, and the top-down processing of affective responses (Goldin et al., 2008; Etkin et al., 2015). The first study in this thesis (see Chapter 4) confirmed the responsiveness of this region to fear-inducing stimuli, showing significantly increased activity under fear

conditions compared to calm conditions. This localisation of activity enabled fNIRS to provide more specific inference of fear-related cognitive and emotional responses than other physiological measures, such as HR and GSR, which work on measuring arousal.

The application of fNIRS allowed for the localised mapping of a participant's inferred fear state, offering insights into how fear was processed and modulated in real-time. However, fNIRS is not without limitations as it is sensitive to motion artefacts, requires careful placement and lacks depth sensitivity deeper than approximately 1.5cm below the scalp. These limitations were accommodated where possible, ensuring that the experience involved minimal movement through a sit-down experience and standardisation of optode placement across participants. Nevertheless, its non-invasiveness and portability made it a suitable tool for the adaptive VR experience.

When analysing the results of the fNIRS data during *A Place for Everyone*, results were mixed. One significant finding emerged during the Refugee scene, where the high fear condition showed a statistically significant difference in AUC for HbO compared to the low fear condition within the left DLPFC. This is a positive result, supporting the effectiveness of the adaptive stimuli in modulating emotional intensity and indicating that the system successfully induced greater activation when within a higher fear condition.

However, other scenes and conditions did not yield significant differences. This variability may be attributed to differences in the audiovisual design, scene content, or the overall subjective nature of horror. Additionally, the subtlety of fear-based transitions and participant variability may have contributed to inconsistent patterns in the fNIRS data. Importantly, all

participants experienced real-time adaptation based on the fNIRS readings, with the system responding to changes in the left DLPFC (specifically channel D2-S8), demonstrating the feasibility of using fNIRS as a live input source in affective VR systems.

While fNIRS has limitations in signal consistency across all scenes, its ability to detect meaningful activation in fear-relevant brain regions during peak moments highlights its potential for future adaptive experiences. These findings suggest that with refined calibration, scene-specific optimisation, and possible integration with other complementary physiological measures (e.g. GSR), fNIRS could serve as a useful technology in adaptive systems.

This thesis covered the concept of using GSR alongside fNIRS for a multimodal approach to adaptation. Although GSR was not used directly within the adaptive system, it was measured alongside fNIRS to test for compatibility. The results indicated that GSR did identify some significant differences, indicating fear processing in calibration and *A Place for Everyone*. One key insight, however, was a contrasting difference in GSR and fNIRS data for the first scene *Refugee*. The difference showed that although fNIRS may detect longer-term impacts of cortical activation, GSR may respond to more moment-to-moment activations. Therefore, the use of a multimodal approach may not be as simple as using fNIRS for cortical activation and GSR for general arousal, but instead a more complex model that detects more immediate effects of fear alongside a general controlled measure of fear processing. This approach could also work well with the integration of more immediate fearful elements, such as jump scares, to analyse their immediate and longer-term effect on a participant.

The approach of this thesis did not follow the traditional methods for de-

tecting fear or other emotions. Traditional methods include the use of approaches such as valence and arousal as defined by Russel's circumplex model of affect (Russell, 1980). This typically uses a physiological measure, such as HR or GSR, to detect general arousal alongside the context or subjective feedback to determine the potential emotion being detected (Zhu et al., 2019; Wu et al., 2019). When using these physiological measures alone, arousal only indicates a set of emotions; for example, high arousal could refer to fear, surprise, or happiness. The use of fNIRS for emotion detection uses cortical activation to determine which brain regions respond to emotion-evoking stimuli, and then localising the activity to provide methods for measuring emotive responses. This provides, as demonstrated in this thesis, a method of detecting an emotional response without the need for subjective feedback.

Recognition of fear processing through fNIRS is possible following this approach. The adaptive system responded differently to individuals, with evidence that the system reflected the fear levels of some participants. With the capability of understanding fear processing, this opens up the use of fNIRS for other basic emotions such as surprise, anger, disgust, sadness and joy (Ekman, 1999). Using fNIRS for emotion detection beyond fear is already an area of research (Hu et al., 2019; Wang et al., 2018; Tang et al., 2021). However, using these emotions for adaptation is a gap in research that this thesis contributes towards by demonstrating that fear can successfully be applied within an adaptive system to modulate the fear experienced by participants in real-time.

With this, adaptive experiences could be made in other genres, such as comedy and drama. The approach of detecting these other basic emotions would require a different set of stimuli, protocols and threshold classification. Taking joy as an example, stimuli would need to be designed to

explicitly induce joy in an individual. This would entail finding generalised joy-based stimuli, developing an experience that could involve the stimuli within a complementary setting, and defining a calibration process capable of defining a joy threshold. This follows a similar process, and in practice, can use the same adaptive toolkit, with adjustments in place for the specific elements that involve fear. For example, "Adaptive systems must retain narrative coherence even when modifying or omitting genre expectations" can remain, as this is a core function of the adaptive system as a whole, while "adaptive horror should prioritise stimuli that evoke tension while allowing flexibility in themes" would need to change to reflect joy-based stimuli rather than fear-based stimuli. For other emotions, a similar approach would be needed to ensure the targeted emotion is being engaged by the correct stimuli.

The recognition of fear processing is a valuable asset to entertainment; it has demonstrated validity in the case of *A Place for Everyone*, and has potential to be applied in other scenarios, including video games and film. This comes at the cost of risks through emotion recognition. When discussing the broader uses of an adaptive system with participants, for negative applications, they tended to focus on controlling or manipulating someone's emotions. Through having access to someone's emotional state, those with ill intent could maliciously use this information to take advantage of a person. Other issues raised were the misuse of personal data, individuals being unaware of their data being collected, and the use of data for personal advertising. Some of these scenarios are evident in existing personal data, where data is passed to third parties for advertising purposes (Estrada-Jiménez et al., 2019; Cabañas et al., 2018).

With the introduction of more personal data, such as brain activity, it is even more important that this type of data is only stored if necessary

and kept secure if collected. Within the case of the controlled lab study (detailed in Section 7.3), although participants weren't aware of the use of their brain activity, participants were told their brain activity was collected and updated in the post-experience interview as to what their brain activity was used for. They were also allowed to remove their data at any point up until a specified date, at which time their data was officially anonymised. This transparency is important for participants to maintain trust. This is not to say that the recognition of fear processing from brain activity should not be done, as the detection and application laid out in this thesis provides valuable results. Instead, the processes should be done with caution for data protection and to further research for positive applications.

8.1.4 Scalability and Complementary Measures

Working with technologies like fNIRS, while effective for adaptation, limits the scalability and deployability of *A Place for Everyone*. Not only does this experience require the availability of a fNIRS headset, but also a technician who can perform the setup to run the experience. As technologies improve and develop, the integration of fNIRS and VR would provide an effective solution to this problem. Such headsets are not yet available, but various fNIRS-related companies discuss the combination of fNIRS and VR, pushing the way for a combined solution (Artinis Medical Systems, 2016; Cortivision, 2025; BIOPAC, 2025).

Another route could involve using a different, more accessible physiological measure for adaptation, albeit a simpler and potentially less effective approach. Other measures shown to be effective at inferring fear responses are HR and GSR (Rathod et al., 2016; Fernández-Aguilar et al., 2019). This would, however, alter the current implementation of the adaptive system.

As these peripheral measures focus generally on arousal, there is potential for a threshold-based approach to adaptation. Further research would be required to understand their application and the extent to which they can reflect an individual's fear level.

The experience, in its current state, is deployable in controlled environments, but is not currently feasible for at-home or commercial use without significant simplification to the adaptive system, including the sensor technology and data interpretation pipeline. Nonetheless, the foundation laid by this research offers pathways toward future lightweight adaptive systems with consumer-grade biosensors integrated into VR headsets.

In addition to HR and GSR, other measures could assist in estimating fear intensity. heart rate variability (HRV) may provide a finer-grained indicator of sustained stress or fear states. Similarly, facial expression recognition could supplement physiological measures, particularly in non-VR contexts. Eye-tracking, pupil dilation, and posture changes may also serve as indicators of emotional intensity. A multimodal approach incorporating such measures could help address the current limitation that the system detects the presence of fear but not its magnitude.

8.2 Application of Fear in Adaptive Storytelling

Establishing a method for recognising fear was the first pivotal step in this thesis. The left DLPFC was shown to respond to fear stimuli within a VE, providing the key to developing the adaptive system and providing an application of the measured fear processing. This section will cover the

applications of fear, looking at it through a creative lens to understand the innovative aspects of applying fear within an adaptive context, including how it has been done in this thesis for *A Place for Everyone*. This section and subsequent subsections address RQ 2 and part of RQ 3, detailing how this thesis created an adaptive experience and how audiences engaged with the content.

8.2.1 Subjectivity and Media Contexts of Fear

Fear is a deeply subjective experience, shaped by individual experiences, cultural background, and personal sensitivities (Rachman, 1978; Bolles and Fanselow, 1980; Reiss, 1991). What terrifies one viewer may leave another unaffected, meaning that a "one size fits all" horror design inevitably leaves parts of the audience under-stimulated or disengaged. This variability strengthens the case for adaptive systems that respond dynamically to individual responses, as demonstrated with *A Place for Everyone*, where participants noted increased fear, immersion, and involvement. Looking towards the commercial impacts, horror remains a significant segment of the games market, with sustained popularity in VR titles and expected growth from now until at least 2030 (Foresights, 2025).

Steam, the digital game distribution platform by Valve (Valve, 2025), provides data on their top played VR games. Currently, as of writing, 4 of the top 10 games for VR are of the horror genre, with the titles: Subnautica, Phasmophobia, Resident Evil 4, and Sons Of The Forest. Recent developments, such as Apple's Vision Pro (Apple, 2024), suggest VR is increasingly positioned for mainstream media consumption beyond gaming. Using the integrated augmented reality (AR) features, experiences such as Hauntify Mixed Reality (Virtual Go LLC, 2022) allow for the integration

of horror within your surrounding physical environment, where you must fend off evil spirits. Apple Vision Pro also contains a cinema mode, which aims to immerse the user in a customisable environment whilst viewing films. This could provide capabilities with horror, where users can set fearful environments to feel further immersed in horror media. Going further, these environments could be combined with adaptation to alter the environment in response to the user. This could be done in a series of ways, either to reflect the participant in their current state of fear, such as an environment that directly reflects moment-to-moment fear levels, or through changes caused by extended exposure to fear, subtly changing the environment around the user as their fear levels change.

Immersive horror experiences like Alien Earth (Networks, 2025) demonstrate an interest in fear-driven content in VR and are one example of the use of Apple Vision Pro's immersive environments. The experience provides panoramic images of the environment within the Alien: Earth series (*Alien: Earth*, 2025) designed to immerse viewers in the show's universe. Adaptation could amplify this by tailoring intensity to each user. In this way, adaptive systems align both with the subjective nature of fear and the evolving market for immersive media. Other VR headsets are also starting to introduce new features, such as the Vive XR Elite (VIVE, 2023) and Meta Quest 3 (Meta, 2023), which contain both AR and VR. The Vive XR Elite also includes eye tracking and mouth tracking for expression recognition capabilities. This opens up possibilities to adapt AR elements or use user expression within adaptation.

8.2.2 Creative Applications in VR and Film

Fear has long been a central narrative and aesthetic tool in storytelling, but the limitations of control can depend on the medium used to present fear. Horror films have created unique applications of visuals and audio, such as manipulation of tempo, intensity, loudness, and pitch for audio (Brown, 1982; McAlpine et al., 1999; Beato, 2022; Juslin, 2019; Trevor et al., 2023), and low lighting, shadows, silhouettes, and eerie locations for visuals (Sipos, 2010). These have become known as horror tropes. Horror games use these tropes while also blending fear into spatial orientation, storytelling, tension, and agency (Krzywinska, 2002). Horror in VR then also employs place illusion and plausibility illusion (Slater, 2009) and further controls agency (Madsen, 2016). This is not to say that VR is the best medium for providing horror content, but it does offer higher flexibility of control over fear compared to desktop/console games and 2D films. The application of adaptation aims to alter this, providing more control over fear in all media.

Discussing the design and development of horror films with horror filmmakers (see Chapter 5) provided valuable insight into how to apply fear within an adaptive context and develop a toolkit for an adaptive horror system. As a researcher, I explored what was needed for using adaptation within horror media, which returned a list of what could be used within adaptation to further induce horror while retaining the foundations that horror is built on. The list produced is not exhaustive, as other possibilities could provide value, but it aims to provide a foundation for other filmmakers to build upon. The toolkit can be seen in Table 5.4.

These insights contributed to a dynamic, responsive framework that adjusts to the viewer's real-time inferred fear state, creating a novel type of affective agency, not through conscious choice, but through biometric feed-

back, that changes the intensity and atmosphere of the experience. This form of agency does not allow the viewer to alter the narrative structure or outcome of the experience, but instead, it enables them to influence the emotional intensity of the experience in real-time. Taking the adaptive system from *A Place for Everyone* as an example of this toolkit, the adaptation responses showed heightened fear intensity, visual immersion, and involvement. The project explores fear not as a static emotion to be triggered but as a spectrum that the adaptive system actively modulates, depending on the desired fear of the viewer.

Existing research on adaptive fear included adapting lighting effects (Zaib and Yamamura, 2022), auditory hallucinations (Demarque and Lima, 2013), and fearful elements (de Lima et al., 2022). Each of these studies found that the application of fear within an adaptive system increased the fear experienced by participants. Results of my adaptive system in *A Place for Everyone* provided similar results, with a majority of participants (88%) finding adaptation to increase the fear that they experienced. Participants also highlighted the effectiveness of the visuals, immersion, and sound cues. This extends previous findings in three key ways: first, by demonstrating adaptation in a full narrative VR experience rather than in isolated or scripted stimuli; second, by grounding the design of adaptive mechanisms in a practitioner-informed toolkit developed with horror filmmakers; and third, by integrating multimodal physiological measures into real-time adaptation. Together, these contributions show that adaptive fear can be embedded into coherent, story-driven VR experiences.

Overall, the application of fear in an adaptive system documented in this thesis advances understanding of how adaptive technologies can reshape emotional impact in horror, offering new creative possibilities through the adaptive toolkit and deeper audience engagement in comparison to tradi-

tional linear approaches to horror media.

8.2.3 Case Study: A Place for Everyone

The interdisciplinary collaboration between AlbinoMosquito and me as a researcher followed a hybrid methodological approach, utilising methodologies such as RtD and practice-based research. While the methodology shares similarities with RtD (Gaver, 2012), it goes further in integrating creative practice with empirical HCI research. My role combined that of creative technologist, embedded collaborator, and empirical researcher, creating a hybrid approach. This enabled a fluid design and development process that balanced artistic vision with technical innovation. Transitioning from 2D to VR introduced challenges around 360-degree environments, user interaction, and embodiment, which we addressed by restricting user movement and filming all scenes from a first-person perspective. Volumetric video capture played a central role in immersing actors within an adaptive system, though technical limitations, particularly computational demands, prevented a standalone version. By streamlining the filming workflow and reducing equipment complexity, we created a visually rich experience while keeping production costs manageable. This project highlights the value of co-creation in navigating the complexities of immersive media, particularly when aligning creative goals with technological constraints.

Although the implementation of fear-based adaptation has been done before (Zaib and Yamamura, 2022; de Lima et al., 2020, 2022; Houzangbe et al., 2018), there is neither a system which explicitly recognises fear (other systems use some form of arousal, contextualised as fear), nor a formal approach to how to 'do' adaptation in fear contexts. I started from a position of being able to reliably detect the presence of fear, then I followed a pro-

cess of establishing common methods of inducing fear in horror films and combined this with the trajectories framework (Benford et al., 2009). I outlined a trajectory of fear for each scene, stating which key moments would have adaptation, before developing adaptations for those key moments that draw from the horror literature. I argue that this approach is beneficial for creating flexible fearful experiences, but also dependent on the expertise and experience of the creator to correctly specify the canonical fear trajectory.

The collaboration with AlbinoMosquito established these fear trajectories, enabling the project to include adaptation whilst maintaining narrative structure. By mapping scenes to a canonical fear trajectory, I established a structured yet flexible framework for adaptation. Participant trajectories captured within data collection from *A Place for Everyone* in the controlled lab study (see Section 7.3) followed a similar shape to the predefined fear trajectories per scene outlined by me and AlbinoMosquito. This is a key insight into the successful delivery of the narrative and adaptation. Fear ratings for participant trajectories were lower than the planned fear trajectories, suggesting that the overall horror of the experience was not as effective as intended.

When asked about the experience and its categorisation as horror, for the controlled lab study, I received mixed feedback. 54% of participants said the experience was a horror experience, yet 67% of participants said that the horror in the experience was effective. Comparing this to the results of the fully adaptive experience in the in-situ study (see Section 7.2), 71% of participants said that the experience was a horror experience, and 76% of participants said it was effective as a horror. It is evident that those who saw the experience as fully adaptive felt it better matched a horror experience and was effective as a horror, suggesting that adaptation has an

impact on the genre definition of the experience as well as the effectiveness of the horror. Other feedback from both studies showed increased immersion, involvement, and engagement with the content, expressing an interest in adaptation and its unique approach in experiences.

Adaptation was well received by participants, finding the adaptive system to increase the fear that they experience. 82% of the in-situ participants and 88% of the controlled lab participants found adaptation to increase the fear that they experienced. The adaptive approach taken was drawn from existing literature and corroborated by the horror filmmaker interviews. This proved an effective method at defining the adaptive elements and supports the use of the adaptive toolkit developed in Chapter 5. Those who provided negative feedback on the adaptive system expressed a low impact from the fear in the adaptive content. Some had hoped for the experience to provide more gore, jump scares, or other, arguably more intense, tropes. Although these tropes were not intentionally excluded, the adaptive system in this thesis aimed to complement the narrative. If a trope did not fit the existing atmosphere of the scene, it was not included. Additionally, tropes such as jump scares could distract participants from the overarching narrative. Additionally, time and technical limitations restricted the variation in adaptive elements. This, however, opens the discussion to potential opportunities in which AI could be used within this context (to be discussed later in the Section 8.5).

A Place for Everyone serves as a proof of concept for the artistic and technical vision of adaptive fear. It successfully integrated fNIRS and a threshold-based approach into a cohesive narrative experience, demonstrating both feasibility and impact. The adaptive system, developed through a toolkit based on structured interviews with horror filmmakers, provided participants with adaptations that overall increased the fear they experi-

enced, partially reflecting their current level of fear. Participant feedback showed increased immersion and emotional engagement, while technical analysis confirmed meaningful adaptation through the adaptive system.

8.3 Implications for Creative Practitioners

The adaptive system developed in this research presents a novel opportunity for filmmakers, in particular those working in VR, immersive media, and interactive cinema, to rethink how storytelling can be structured and experienced. By integrating real-time biofeedback into the narrative structure, filmmakers gain the ability to modulate the intensity and pacing of fear in response to each viewer's physiological state. This not only extends the creative control into new domains but also alters the cinematic experience in ways traditional linear formats cannot.

The adaptive toolkit applied in *A Place for Everyone* demonstrated how physiological data, specifically brain activity, can shape narrative delivery by subtly adjusting audiovisual elements. Although the induced fear response was not as strong as initially intended, the overall modulation of participants' emotional trajectories confirmed the viability of this method. Rather than undermining the toolkit's potential, this outcome highlights the complexity of emotional engineering in immersive media and underscores the need for finely tuned calibration between content, pacing, and physiological interpretation. Importantly, the toolkit offers a flexible framework rather than a rigid structure. It provides filmmakers with parameters for where, when, and how adaptation can be introduced, such as scene configuration, sound design, and lighting, without compromising their vision. This balance is crucial, especially in horror, where subtle shifts in tone can

significantly affect audience immersion.

Integrating adaptive systems into storytelling introduces new challenges, particularly around authorship, narrative ownership, and viewer affective agency. A concern raised in the filmmaker interviews (see Chapter 5) was the potential loss of authorial control. If the experience changes based on each viewer's physiological state, to what extent does the filmmaker retain ownership of the final narrative? One approach for adaptation that is potentially more commonly used is adaptive narrative, like *Bandersnatch* (2018), *The Disadvantages of Time Travel* (2015), *The Moment* (2018), and *Before We Disappear* (2023). This form of adaptation directly alters the narrative and storyline based on user input, where viewership becomes more of an active participation. The adaptive approach taken in this thesis, however, transforms passive viewership into a form of co-authorship, where the viewer's physiology shapes the horror of the experience in real-time. The toolkit responds to this concern by ensuring adaptation operates primarily on the fear intensity, adjusting the tone of fear rather than the core structure or direction of the narrative.

This research builds upon the existing discussions by Benford et al, such as their Uncomfortable Interactions paper (Benford et al., 2012) and trajectories framework (Benford et al., 2009) previously mentioned in Chapter 2. These works discuss techniques for designing experiences that cause discomfort by laying out an experience using trajectories. The research discussed in this thesis modifies Benford's trajectories framework, applying fear as the managed trajectory and utilising discomfort to maintain a customised level of fear. Through this, creative autonomy is preserved as the adaptation aims to maintain a participant's level of fear in line with a predefined fear trajectory for an experience. Taking *A Place for Everyone* as an example, participant trajectories were shaped similarly to the prede-

fined trajectories outlined by AlbinoMosquito and me. Although the height of the participant trajectories was lower, the similarity in shape shows how adaptation was able to maintain the intended path for participants. Further improvements on adaptation would aim to better fit the scale of the trajectory.

Looking forward, this form of adaptive storytelling invites new industry models where content can be designed as modular, responsive, and emotionally intelligent. For horror filmmakers in particular, it enables the crafting of dynamic, layered fear experiences that adapt with the viewer. As technologies like VR and neuroimaging become more accessible, adaptive storytelling may become a standard tool for filmmakers aiming to create emotionally resonant and adaptive experiences.

8.4 Ethical and Governance Considerations

Using and manipulating the emotional state of a person raises ethical considerations to ensure that there is no harm or trauma inflicted. There is potential for misuse of affective systems, especially within the commercial industry (entertainment, advertising), where boundaries are not maintained and manipulation is involved. To ensure safety within these systems, an ethical framework is necessary to maintain the safety, transparency, and control of users' emotional states.

Within this research, the design of the adaptive system ensured that psychological risk was minimised, viewer autonomy was maintained, and participants provided informed consent. While the system used in this research was carefully designed and tested to ensure control, there are concerns raised in the creative application of fear. What are the boundaries of con-

sent when a system knows you're afraid and is capable of escalating the experience? Could an adaptive system such as this cause psychological harm by misjudging a user's emotional threshold? What are the issues of deploying an adaptive system without a manual override?

Future applications of an adaptive fear-based system may not be as constrained or controlled as the system developed within this thesis. Robust ethical standards, including user safeguarding, override capabilities, and transparency of how data informs the adaptive system, are required to govern the use of affective adaptation. When looking into the use of AI, there should be considerations on the authorship of adaptation, as well as the originality of the content being created. In addition, AI would need a form of understanding of how to modulate the audiovisual stimuli and how far is too far for a participant. Pushing participants too far with fear may cause harm.

8.4.1 Artificial Intelligence Act

The Artificial Intelligence Act (AI Act) is a regulation concerning the rules and legal frameworks for AI within the European Union (European Parliament, 2024). The act classifies AI systems according to their risk (unacceptable, high, limited, minimal), banning certain AI applications, imposing requirements for high-risk AI, and overall ensuring transparency and accountability. Risks are assessed on their threat to safety, livelihoods, and fundamental rights. These can include such things as manipulative AI to cause harm, emotion recognition in workplaces and educational settings, or individual social scoring by governments. Applying this regulatory framework to this thesis, emotion recognition is specifically mentioned as a risk, depending on its use and context.

As previously mentioned, the use of emotion recognition through AI in the workplace and in educational settings is strictly banned as it is seen as an unacceptable risk. However, in other contexts, such as entertainment or commercial uses, it is not banned, but it is noted as being a high-risk application if biometric data is processed. The focus of these risks is to prevent the following: emotional manipulation without informed consent, invasion of privacy, and potential for discrimination or exploitation. Emotional data often is not covered under the General Data Protection Regulation (GDPR) (European Parliament, 2016) unless the data is biometric and able to uniquely identify an individual. This leaves potential grey areas where emotion inference can be carried out without clear legal safeguards. Looking to the research carried out within this thesis, the adaptive VR system for horror is an emotional recognition system, as it uses fNIRS to detect when a viewer is experiencing fear processing. However, it operates locally within a controlled environment, no data is stored as part of the adaptive system, and it is explicitly a consensual and non-commercial application. This ensures that there are minimal privacy and security risks involved with this research. If this work were to be commercialised, then it has potential to fall into the high-risk category under the AI act unless deployed with safeguards in place.

The technological approach to emotion recognition is far broader than through fNIRS, as it is possible to detect the presence of emotions through facial recognition, such as webcams, and other wearables, such as HR and GSR, which are more commonly available. This leads to a greater risk of manipulation, coercion, and targeted advertising when emotion data is involved. Suppose the recognition of emotions were to be extended to other basic emotions, such as joy, sadness, anger, etc. In that case, the risks increase drastically, as this allows for a broader emotional profiling of an

individual. More safeguards and data security measures would be required to ensure that the data is not misused or handled incorrectly. As the use of AI becomes more prevalent within the creative industry, there is a need for more creative industry standards for ethical emotional adaptation, beyond legal compliance.

8.5 Future Directions for Fear and Adaptation

The development and deployment of the adaptive system within *A Place for Everyone* has generated several key insights contributing to research in immersive and adaptive media. This section considers the future potential for adaptation technologies across both entertainment and applied contexts. This section and subsequent subsections address RQ 4, discussing the implications of this work and looking into the future of adaptive systems.

The use of audiovisual stimuli, as determined from discussion with the horror filmmakers, was partly chosen as it is reproducible, reducing the need for budget. The same or similar stimuli could be placed in various locations within and across scenes without the need to be remade each time. Additionally, applying audiovisual stimuli on top of the existing experience didn't require the need to reshoot any scenes; all effects could be done post-filming. This provides scalability and an interchangeable design, where stimuli could easily be replaced, applied, removed, etc. One drawback of this approach is providing enough variability in the audiovisual stimuli to provide a sufficient level of fear for all participants. The approach taken in this thesis drew from existing horror literature, but some participants

found the stimuli to be not scary. This opens the opportunity to use AI as a tool for developing adaptive elements. If AI was employed, more varied adaptations could be included to suit a wider range of audiences. Additionally, content could be customised more towards an individual.

One study uses gameplay data to identify an individual player's fears and modulate the horror elements feared by the player (de Lima et al., 2020, 2022). Employing a similar approach within *A Place for Everyone* could lead to customised adaptive experiences that not only understand the fears of the audience but modulate these fears. For my work, however, the only usable data within the experience itself is head-orientation, which could potentially draw information on how long a viewer looks at certain objects, or if there are rapid head movements.

The largest drawback, for deployability, is the cost of the fNIRS device. While the Octamon headset was invaluable to the detection of fear processing and the evaluation of the adaptive system, it is not a consumer-grade headset, making it a limitation for the deployment of *A Place for Everyone* outside of its current state as a proof-of-concept. As of writing, other fNIRS headsets are becoming more available to the public, with examples like the Muse S Athena (Muse, 2025) and Mendi (Mendi, 2025). With headsets such as these, it is much more possible to deploy *A Place for Everyone*, ensuring that the headset used is capable of detecting activation within the left DLPFC.

As a result of this thesis, we can recognise fear processing in real-time within an adaptive experience and alter the audiovisual stimuli to modulate the fear experienced. Although fear intensity cannot be identified, there are routes in which this could potentially be established, such as multimodal applications or durational processing of existing fNIRS data. The next

section will cover the technical and methodological improvements to be made to the research established within this thesis. Additionally, I look at potential applications of adaptive systems beyond entertainment and further discuss the use of AI within adaptation and its potential to create adaptive content.

8.5.1 Technical and Methodological Improvements

As demonstrated by the results of *A Place for Everyone*, it is clear that we can detect the presence of fear within participants, but it is not possible to quantify the intensity in real-time. The system, as implemented, identifies discrete moments in which the neural activity associated with fear processing, in particular the left DLPFC, exceeds a predefined threshold. However, the current method does not quantify how much fear the participant is experiencing in that moment. One potential route for development is to incorporate measures that can capture the duration of these fear moments, as sustained activation may act as a substitute for fear intensity. Another possibility is to introduce a scaled measure based on classification. These refinements would enable more nuanced adaptive responses, such as modulating stimuli more proportionally to the inferred level of fear rather than simply toggling between predefined low and high intensity levels.

8.5.2 Applications Beyond Entertainment

Beyond the creative media approach targeted by this thesis, the adaptive emotion recognition approach has potential applications in training and therapeutic contexts. When discussing with participants how they could see the use of adaptive systems beyond the scope of their experiences, these

contexts were mentioned. In exposure therapy for phobias or anxiety disorders, for example, adaptive VR could dynamically adjust the intensity of stimuli, such as the proximity of a feared object or the severity of a simulated scenario, based on the patient's real-time physiological state. This would help maintain engagement while avoiding overwhelming the participant. Similarly, in training environments, such as firefighting, search-and-rescue, or military engagement, adaptive fear modulation would be used to keep trainees in an optimal emotional state, ensuring decision-making is kept optimal while under stress. Importantly, such applications should also assess whether adaptive systems enhance emotional presence, the extent to which the user feels emotionally immersed in the scenario, since this could be a key factor in both learning outcomes and therapeutic efficacy.

augmented reality exposure therapy (ARET) extends digital content into real-world contexts by introducing phobic stimuli into the user's environment. Some studies reported that ARET can be as effective as traditional methods of exposure for small animal phobias, while often being perceived as less avoidant by patients (Botella et al., 2010). This means that patients tend to provide a better exposure response to small animal phobias than other phobias. More recent ARET systems show promising feasibility and effectiveness compared to traditional methods (Zimmer et al., 2021; Jurcik et al., 2024). Adaptation enables contextual and physiological adaptation, which could be useful for the context of ARET.

The use of biofeedback and its impact on participant experiences and outcomes in VR is a growing area of research. Studies report improved stress indicators and anxiety reductions when HRV-based biofeedback is integrated into VR, and HCI research has begun to demonstrate real-time adaptation that modulates scene complexity based on electrodermal activity (EDA)(Kerr et al., 2023; Daniel-Watanabe et al., 2025; Chiossi

et al., 2023). This aligns directly with the approach taken in this thesis, which uses physiological signals to adjust audiovisual intensity to keep users within a threshold-based fear state.

8.5.3 AI-driven Adaptation

The adaptive framework in this thesis was implemented using prebuilt content, with the adaptation working by selecting and modulating the existing audiovisual assets. An alternative future pathway is to integrate real-time generative AI, allowing the system to create or modify scenes dynamically in response to the viewer's state. This could enable far greater granularity and variation in adaptive responses, as environments, characters, and audio could be tailored on the fly to match the desired emotional profile. Google's Gemini 3 AI (Google, 2025) demonstrates one example of what generative AI can do already. The AI works by taking a text prompt and generating a navigatable dynamic world in real-time. This is limited, however, by 24 frames per second and a resolution of 720p, both limitations making it infeasible for use within VR in real-time. However, AI is not strictly limited to real-time use and could be used to prepare content. A practical design rule may therefore be to pre-generate adaptive assets, such as fearful objects, and use AI for fine-grained adjustments, such as lighting and soundscapes, reserving real-time generation for small-scale tasks. Regardless of its use and current limitations, examples such as Gemini 3 provide a step towards what AI could do within the creative industry.

The introduction of creative or generative AI raises significant ethical considerations, including risks of generating inappropriate or psychologically harmful content, loss of authorship for creators, and challenges in maintaining narrative coherence. Drawing on related research, work on adaptive

storytelling and HCI (Martindale et al., 2025) underscores the need for human supervision and creative constraints when deploying generative AI in emotionally adaptive systems. Future research could explore hybrid workflows, combining the reliability of prebuilt assets with the flexibility and responsiveness of AI generated content.

8.6 Bringing the Discussion Together

This discussion has explored the complexities of recognising fear, the practical and creative implications of applying adaptation, and the broader technical, ethical, and social issues that arise from emotion-driven systems. Taken together, these themes feed directly into the core contributions of the thesis. First, the analysis of physiological measures demonstrates that the presence fear can be reliably recognised in controlled VR contexts, providing the foundation for adaptive horror systems. Second, the collaborative development of an adaptive toolkit with filmmakers illustrates how adaptation can be integrated into creative practice while retaining narrative coherence. Third, the design and evaluation of *A Place for Everyone* shows how these principles can be realised in practice, creating an adaptive VR horror experience that participants found immersive, engaging, and fear-inducing. Finally, the examination of scalability, governance, and ethical considerations situates this work within broader debates about the future of affective technologies, highlighting both the opportunities for impact and the risks that require mitigation.

Chapter 9

Conclusion

In this conclusion, I contextualise and discuss my findings by returning to the research questions in an attempt to answer them. By returning to the research questions, I aim to show how the research carried out in this thesis provides a solution to each question and discuss the contributions made in doing so. I also discuss the limitations and future directions of this research and how the contributions interact and benefit multiple disciplines.

9.1 Research Question 1

RQ 1: How can we understand fear from fNIRS data and turn this into usable data that could adapt an experience in real-time?

This thesis has demonstrated, for the first time, that fear processing can be detected from fNIRS in real time and used to drive adaptive changes in a VR experience. Many forms of physiological measures have been used within research to establish inferences of emotions, from peripheral measures like HR and GSR, to behavioural measures like facial recognition, to

cognitive measures like EEG and fNIRS. This thesis aimed to utilise fNIRS as a measure to determine fear processing, thereby providing a valuable contribution to understanding the presence of fear in brain activity and its application within adaptive experiences. Before being able to use fNIRS reliably, it first had to be tested for its efficacy on emotion detection with fear in VR.

Previous studies have shown that the left DLPFC responded to brain activity (Landowska et al., 2018) in a VE when exposing individuals to fearful heights. The proposition in this thesis, however, aims for a more generalised approach and, therefore, requires examination of fear in this context. Looking back at RQ one, this is discussed in Chapter 4, where I examine a study that found significant activation within the left DLPFC when fear is present in a virtual environment compared to a calm virtual environment. From the results of this, I can reliably say that it is possible to detect the presence of fear from fNIRS and, through using the aforementioned brain region, apply changes in this region as a form of change in the presence of fear.

9.2 Research Question 2

RQ 2: How can we create an adaptive fear-based narrative within VR that modulates fearful experiences for each user?

When looking towards RQ 2, an adaptive toolkit was established from discourse with horror filmmakers as discussed in Chapter 5. Analysis of structured interviews detailed a series of tools to be used that would establish when adaptation should be applied, the most effective and efficient way to apply adaptation, and the type of fear-based stimuli to be used (Au-

diovisual). When discussing horror, it was expressed as a flexible genre, taking inspiration from other genres and applying them in creative ways to scare the audience. Adaptation should also provide the same flexibility and, in doing so, maintain the original narrative to ensure that adaptation was applied as an additive effect to fear, rather than as a narrative control. Sound, lighting, and atmosphere were used as categories for the audiovisual stimuli. Some filmmakers expressed a desire for fear-based control through these categories, rather than the more common approach of adaptive narratives. The key aim of adaptation was to modulate the fear experienced by viewers. As such, a fear modifier was incorporated into the adaptive system to control the level of fear present in each scene and provide the ability to alter the intensity at moments where adaptation was active. The adaptive toolkit provides the opportunity for creative professionals to apply adaptation within their own experiences, with *A Place for Everyone* providing a successful use case of the toolkit.

9.3 Research Question 3

RQ 3: How could media professionals utilise a toolkit for creating adaptive experiences and engage audiences with that content?

The findings of *A Place for Everyone* show the promising ability of applying adaptation within an experience for the modulation of fear. The aim of this was to understand the answer to RQ 3.

Chapters 6 and 7 detail the contributions of applying hybrid methodologies, through a combined approach of creative technologist, embedded collaborator, and empirical researcher, following the tools outlined in the adaptive toolkit. Through this process, we successfully created and deployed

an adaptive experience that utilised audiovisual stimuli to modulate fear intensity during key moments, resulting in an additive effect. Audience responses to this experience were highly positive, with participants noting the adaptation to increase the fear that they experienced, as well as finding the adaptation to be an immersive and unique approach to experience design. While the physiological data did not consistently yield statistically significant results across all conditions, there were clear trends indicating increased immersion, involvement, and fear responses with adaptation. With more data collection, more significant results could be found, further indicating the efficacy of the adaptive system.

9.4 Research Question 4

RQ 4: What are the broader generalisations that can be made about emotionally adaptive experiences?

Analysing an adaptive experience and discussion with participants opened up a series of discussions to be had about how adaptive experiences alter the way audiences consume content. This relates directly to RQ 4. Adaptive content within the domain of horror is a useful tool to tailor horror content to a wider range of audiences. Horror is highly subjective: what terrifies one viewer may leave another viewer unaffected. Adaptive systems can help bridge this gap by modulating intensity to suit individual responses, ensuring both accessibility for those more sensitive to fear and heightened engagement for those seeking stronger thrills.

For creative media professionals, the adaptive toolkit offers a structured yet flexible foundation to design such systems. As shown in *A Place for Everyone*, filmmakers can use adaptive sound, lighting, and atmosphere

as additive tools to enhance fear while maintaining narrative coherence. This approach provides an alternative to traditional adaptive narratives, emphasising emotional modulation rather than altering storylines. The use of fear as an adaptive emotion also opens up the opportunity to use other basic emotions for adaptation, such as joy, sadness, and anger (Ekman, 1992). Adapting to these emotions would require an understanding of their own physiological measures. Still, it could draw on the adaptive toolkit as a basis for applying the emotion within an adaptive context.

The implications extend beyond entertainment. Adaptive emotion recognition could support education and training, where controlling stress and emotional states is critical. For example, adaptive VR simulations for firefighting or search-and-rescue could keep trainees in an optimal emotional state. Similarly, in clinical contexts, adaptive VR exposure therapy could dynamically control phobic stimuli, improving safety and efficacy. By demonstrating that fear can be recognised and modulated in real-time, this thesis lays the groundwork for adaptive systems that span creative, educational, and therapeutic domains.

9.5 The future of Adaptation

Looking forward, emerging technologies such as AI present both significant possibilities and challenges for adaptive content. The system implemented in this thesis was built on predesigned audiovisual assets, but generative AI could allow content to be created dynamically in response to the viewer's state. This could increase the granularity and responsiveness of adaptive systems, enabling experiences that are not just modulated but also co-created with the user. However, this also raises ethical questions: who

controls authorship when content is AI generated? How do we safeguard against harmful or manipulative experiences?

Scalability is another key challenge. Currently, adaptive VR using fNIRS is limited to controlled environments with specialist equipment and trained technicians. Technical progress of consumer-grade biosensors could see integration with VR headsets. Current industry trends point in this direction, with devices such as Apple's Vision Pro promoting VR as a mainstream media platform (Apple, 2024), and VR horror games projected for further growth over the next 5 years (Foresights, 2025).

Governance will also shape this future. The EU AI Act has already prohibited certain uses of emotion recognition, particularly in sensitive domains like education and employment. While this thesis demonstrates a safe, enclosed system where no data was stored beyond use within the adaptive system, widespread deployment of adaptive emotion recognition raises ethical and regulatory challenges. Ensuring user consent, privacy, and safety will be crucial.

To further understand the efficacy and broader applicability of the toolkit shown in Table 5.4, future work should involve studying practitioners as they apply the toolkit in their own adaptive experiences. Such studies would provide empirical insight into the toolkit's strengths, limitations, and usability in diverse creative and technical contexts. This would help validate the toolkit as a transferable methodological contribution and situate it within the wider community of adaptive and immersive media practitioners.

The work presented here opens opportunities for interaction across fields beyond horror cinema and immersive media. Adaptive emotion recognition could inform therapeutic interventions in mental health, contribute

to affective computing research, enhance interactive storytelling, and offer new evaluation tools for creative industries. By situating adaptation at the intersection of neuroscience, HCI, creative practice, and ethics, this thesis lays the foundation for multidisciplinary collaboration.

9.6 Core Contributions

Overall, this thesis makes three interlinked contributions. First, I provide empirical evidence that fear can be reliably detected through fNIRS data, demonstrating not only that this is possible but that it can be meaningfully applied in real-world contexts. Second, I translate this knowledge into a practical adaptive toolkit, co-developed through qualitative discussions with industry experts, particularly horror filmmakers. This toolkit was informed by their needs and creative approach, ensuring that it is grounded in both creative and technical practices. Third, I apply the toolkit to the adaptive experience *A Place for Everyone*, where results show that participants found adaptation increased fear intensity, immersion, and involvement.

Beyond these findings, through the thesis, I highlight why such work is relevant to and valuable for the community. I demonstrate that emotion-driven adaptation is both technically possible and creatively valuable, offering researchers, creators, and industry stakeholders a new method for validating existing horror experiences and designing future immersive media. Importantly, the contributions extend across disciplines by benefiting media researchers, horror practitioners, affective computing specialists, and regulators concerned with the ethical implications of emotionally adaptive systems. By advancing the understanding of how fear can be detected, in-

terpreted, and applied within creative practice, I generate new knowledge, strengthen connections between academic and industry communities, and open future pathways for innovation in horror cinema.

Bibliography

Adolphs, R. (2013), 'The biology of fear', *Current Biology* **23**(2), R79–R93.
URL: *https://www.sciencedirect.com/science/article/pii/S0960982212014352*

Alarcao, S. M. and Fonseca, M. J. (2019), 'Emotions Recognition Using EEG Signals: A Survey', *IEEE Transactions on Affective Computing* **10**(3), 374–393.
URL: *https://ieeexplore.ieee.org/document/7946165/*

Alchalcabi, A. E., Eddin, A. N. and Shirmohammadi, S. (2017), More attention, less deficit: Wearable EEG-based serious game for focus improvement, *in* '2017 IEEE 5th International Conference on Serious Games and Applications for Health (SeGAH)', IEEE, pp. 1–8.
URL: *http://ieeexplore.ieee.org/document/7939288/*

Alien: Earth (2025). IMDb ID: tt13623632 event-place: United Kingdom, United States, Thailand.

American Psychiatric Association and American Psychiatric Association, eds (2013), *Diagnostic and statistical manual of mental disorders: DSM-5*, 5th ed edn, American Psychiatric Association, Washington, D.C.

Ammer, S. M. E. I. (2020), 'Content Analysis of Lighting and Color in the Embodiment of Fear Concept in Horror Movies: A Semiotic Approach', *Information Sciences Letters* **9**(2), 135–142.
URL: *http://www.naturalspublishing.com/Article.asp?ArtcID=21469*

Ando, S., Yamada, Y. and Kokubu, M. (2010), 'Reaction time to peripheral visual stimuli during exercise under hypoxia', *Journal of Applied Physiology* **108**(5), 1210–1216. Publisher: American Physiological Society.

URL: *https://journals.physiology.org/doi/full/10.1152/japplphysiol.01115.2009*

Angelini, L., Mecella, M., Liang, H.-N., Caon, M., Mugellini, E., Abou Khaled, O. and Bernardini, D. (2022), Towards an Emotionally Augmented Metaverse: a Framework for Recording and Analysing Physiological Data and User Behaviour, *in* '13th Augmented Human International Conference', ACM, New York, NY, USA, pp. 1–5.

Apple (2024), 'Apple Vision Pro'.

URL: *https://www.apple.com/uk/apple-vision-pro/*

Aros, M., Tyger, C. L. and Chaparro, B. S. (2024), Unraveling the Meta Quest 3: An Out-of-Box Experience of the Future of Mixed Reality Headsets, *in* C. Stephanidis, M. Antona, S. Ntoa and G. Salvendy, eds, 'HCI International 2024 Posters', Springer Nature Switzerland, Cham, pp. 3–8.

Artinis Medical Systems (2016), 'Combining Virtual Reality and wearable fNIRS'.

URL: *https://www.artinis.com/blogpost-all/2022/combining-virtual-reality-and-portable-fnirs*

Artinis Medical Systems (2018*a*), 'Brite - Wearable & flexible multichannel fNIRS device'.

URL: *https://www.artinis.com/brite*

Artinis Medical Systems (2018*b*), 'Octamon'.

URL: *https://www.artinis.com/octamon*

Artinis Medical Systems (2019), 'Oxysoft'.
URL: *https://www.artinis.com/oxysoft*

Aue, T., Hoeppli, M.-E. and Piguet, C. (2012), 'The Sensitivity of Physiological Measures to Phobic and Nonphobic Fear Intensity', *Journal of Psychophysiology* **26**(4), 154–167. Publisher: Hogrefe Publishing.
URL: *https://econtent.hogrefe.com/doi/10.1027/0269-8803/a000078*

Balconi, M., Grippa, E. and Vanutelli, M. E. (2015), 'What hemodynamic (fNIRS), electrophysiological (EEG) and autonomic integrated measures can tell us about emotional processing', *Brain and Cognition* **95**, 67–76.
URL: *https://www.sciencedirect.com/science/article/pii/S0278262615000159*

Baldini, A., Frumento, S., Menicucci, D., Gemignani, A., Scilingo, E. P. and Greco, A. (2022), 'Subjective Fear in Virtual Reality: A Linear Mixed-Effects Analysis of Skin Conductance', *IEEE Transactions on Affective Computing* **13**(4), 2047–2057.
URL: *https://ieeexplore.ieee.org/document/9854181/*

Barman, A. and Dutta, P. (2019), 'Facial expression recognition using distance and texture signature relevant features', *Applied Soft Computing* **77**, 88–105.
URL: *https://linkinghub.elsevier.com/retrieve/pii/S1568494619300158*

Barrett, L. F. (2004), 'Feelings or Words? Understanding the Content in Self-Report Ratings of Experienced Emotion', *Journal of Personality and Social Psychology* **87**(2), 266–281. Place: US Publisher: American Psychological Association.

Beato, R. (2022), 'What Makes Music Creepy? | Inside the Science of Horror Music'.
URL: *https://www.youtube.com/watch?v=y-dMimIr1pY&ab_channel=RickBeato*

Benerradi, J. (2023), 'Workload bci: live_processing.py'.

URL: *https://gitlab.com/HanBnrd/workload-bci/-/blob/master/src/scripts_lsl/live_processing.py?ref_type=heads*

Benford, S. and Giannachi, G. (2011), *Performing Mixed Reality*, MIT Press.

URL: *https://books.google.co.uk/books?id=AvsMEAAAQBAJ*

Benford, S., Giannachi, G., Koleva, B. and Rodden, T. (2009), From interaction to trajectories, *in* 'Proceedings of the SIGCHI Conference on Human Factors in Computing Systems', ACM, New York, NY, USA, pp. 709–718. Series Title: CHI '09.

URL: *https://dl.acm.org/doi/10.1145/1518701.1518812*

Benford, S., Greenhalgh, C., Crabtree, A., Flintham, M., Walker, B., Marshall, J., Koleva, B., Rennick Egglestone, S., Giannachi, G., Adams, M., Tandavanitj, N. and Row Farr, J. (2013), 'Performance-Led Research in the Wild', *ACM Transactions on Computer-Human Interaction* **20**(3), 1–22.

URL: *https://dl.acm.org/doi/10.1145/2491500.2491502*

Benford, S., Greenhalgh, C., Giannachi, G., Walker, B., Marshall, J. and Rodden, T. (2012), Uncomfortable interactions, *in* 'Proceedings of the SIGCHI Conference on Human Factors in Computing Systems', ACM, New York, NY, USA, pp. 2005–2014.

URL: *https://dl.acm.org/doi/10.1145/2207676.2208347*

Benford, S., Sundnes Løvlie, A., Ryding, K., Rajkowska, P., Bodiaj, E., Paris Darzentas, D., Cameron, H., Spence, J., Egede, J. and Spanjevic, B. (2022), Sensitive Pictures, *in* 'CHI Conference on Human Factors in Computing Systems', ACM, New York, NY, USA, pp. 1–16.

Berger, C. (2025), 'CBerger1997/A-Place-For-Everyone-LSL-Scripts'. original-date: 2026-01-14T10:32:37Z.
URL: *https://github.com/CBerger1997/A-Place-For-Everyone-LSL-Scripts*

BIOPAC (2025), 'MedelOpt fNIRS Systems for VR | BIOPAC'.
URL: *https://www.biopac.com/product/medelopt-vr/*

Birch, I., Birch, T. and Bray, D. (2016), 'The identification of emotions from gait', *Science & Justice* **56**(5), 351–356.
URL: *https://linkinghub.elsevier.com/retrieve/pii/S1355030616300302*

Blake, M. (2013), *Writing the Horror Movie*, Bloomsbury Academic & Professional, New York.

Bloom, C. (2017), *Gothic Horror: A Guide for Students and Readers*, Bloomsbury Publishing. Google-Books-ID: UyNIEAAAQBAJ.

Blythe, M., Hassenzahl, M. and Law, E. (2009), 'Now with Added Experience?', *New Review of Hypermedia and Multimedia* **15**(2), 119–128. Publisher: Taylor & Francis, Inc. Place: USA.
URL: *https://www.tandfonline.com/doi/full/10.1080/13614560903251100*

Bolles, R. C. and Fanselow, M. S. (1980), 'A perceptual-defensive-recuperative model of fear and pain', *Behavioral and Brain Sciences* **3**(2), 291–301. Publisher: Cambridge University Press.
URL: *https://www.cambridge.org/core/product/identifier/S0140525X0000491X/type/journal_article*

Bonilauri, A., Sangiuliano Intra, F., Baselli, G. and Baglio, F. (2021), 'Assessment of fNIRS Signal Processing Pipelines: Towards Clinical Applications', *Applied Sciences* **12**(1), 316.
URL: *https://www.mdpi.com/2076-3417/12/1/316*

Bontchev, B. (2016), 'Adaptation in Affective Video Games: A Literature Review', *Cybernetics and Information Technologies* **16**(3), 3–34.
URL: *https://www.sciendo.com/article/10.1515/cait-2016-0032*

Bontchev, B. and Vassileva, D. (2017), 'Affect-based adaptation of an applied video game for educational purposes', *Interactive Technology and Smart Education* **14**(1), 31–49.
URL: *https://www.emerald.com/insight/content/doi/10.1108/ITSE-07-2016-0023/full/html*

Botella, C., Bretón-López, J., Quero, S., Baños, R. and García-Palacios, A. (2010), 'Treating cockroach phobia with augmented reality', *Behavior Therapy* **41**(3), 401–413.

Botella, C., Fernández-Álvarez, J., Guillén, V., García-Palacios, A. and Baños, R. (2017), 'Recent Progress in Virtual Reality Exposure Therapy for Phobias: A Systematic Review', *Current Psychiatry Reports* **19**(7), 42.

Bound, K. (2016), " TERROR & TENSION ' Psychophysiological Suspense : Defining a framework to measure cinematic suspense in 21 st century horror films', *Phd Thesis* (May), 315.

Bradley, M. M. and Lang, P. J. (1994), 'Measuring emotion: The self-assessment manikin and the semantic differential', *Journal of Behavior Therapy and Experimental Psychiatry* **25**(1), 49–59.
URL: *https://linkinghub.elsevier.com/retrieve/pii/0005791694900639*

Brigadoi, S., Ceccherini, L., Cutini, S., Scarpa, F., Scatturin, P., Selb, J., Gagnon, L., Boas, D. A. and Cooper, R. J. (2014), 'Motion artifacts in functional near-infrared spectroscopy: A comparison of motion correction techniques applied to real cognitive data', *NeuroImage* **85**, 181–191.
URL: *https://linkinghub.elsevier.com/retrieve/pii/S1053811913004291*

Bronkhorst, M., Mukisa, R., Colier, W. N. J. M., Stothers, L. and Macnab, A. J. (2019), Functional near infrared spectroscopy (fNIRS) in pigmented subjects: a maneuver to confirm sufficient transcutaneous photon transmission for measurement of hemodynamic change in the anterior cortex, *in* R. A. Lieberman, F. Baldini and J. Homola, eds, 'Optical Sensors 2019', SPIE, p. 41.

Brown, R. S. (1982), 'Herrmann, Hitchcock, and the Music of the Irrational', *Cinema Journal* **21**(2), 14.
URL: *https://www.jstor.org/stable/1225034?origin=crossref*

Butterworth, S. (1930), 'On the Theory of Filter Amplifiers', *Experimental Wireless & the Wireless Engineer* **7**, 536–541.

Bălan, O., Moise, G., Moldoveanu, A., Leordeanu, M. and Moldoveanu, F. (2020), 'An Investigation of Various Machine and Deep Learning Techniques Applied in Automatic Fear Level Detection and Acrophobia Virtual Therapy', *Sensors* **20**(2), 496.
URL: *https://www.mdpi.com/1424-8220/20/2/496*

Cabañas, J. G., Cuevas, A. and Cuevas, R. (2018), Unveiling and Quantifying Facebook Exploitation of Sensitive Personal Data for Advertising Purposes, pp. 479–495.
URL: *https://www.usenix.org/conference/usenixsecurity18/presentation/cabanas*

Cacioppo, J. T., Tassinary, L. G. and Berntson, G. (2007), *Handbook of psychophysiology*, Cambridge university press.

Candy, L. (2006), 'Practice Based Research: A Guide'.

Cannon, W. B. (1915), *Bodily changes in pain, hunger, fear and rage: An account of recent researches into the function of emotional excitement.*,

D Appleton & Company, New York.

URL: *https://content.apa.org/books/10013-000*

Carroll, N. (1999), 'Horror and Humor', *The Journal of Aesthetics and Art Criticism* **57**(2), 145.

URL: *https://www.jstor.org/stable/432309?origin=crossref*

Carroll, N. (2003), *The Philosophy of Horror*, 0 edn, Routledge.

URL: *https://www.taylorfrancis.com/books/9781135965044*

Carruth, D. W. (2017), Virtual reality for education and workforce training, *in* '2017 15th International Conference on Emerging eLearning Technologies and Applications (ICETA)', IEEE, pp. 1–6.

URL: *http://ieeexplore.ieee.org/document/8102472/*

Causse, M., Chua, Z., Peysakhovich, V., Del Campo, N. and Matton, N. (2017), 'Mental workload and neural efficiency quantified in the prefrontal cortex using fNIRS', *Scientific Reports* **7**(1), 5222.

Chaddad, A., Wu, Y., Kateb, R. and Bouridane, A. (2023), 'Electroencephalography Signal Processing: A Comprehensive Review and Analysis of Methods and Techniques', *Sensors* **23**(14), 6434.

URL: *https://www.mdpi.com/1424-8220/23/14/6434*

Chellakumar, P. J., Brumfield, A., Kunderu, K. and Schopper, A. W. (2005), 'Heart rate variability: comparison among devices with different temporal resolutions', *Physiological Measurement* **26**(6), 979–986. Publisher: {IOP} Publishing.

URL: *https://doi.org/10.1088/0967-3334/26/6/008*

Chen, G. and Wang, W. (2024), 'A Survey on 3D Gaussian Splatting'. Version Number: 4.

URL: *https://arxiv.org/abs/2401.03890*

Chen, J., Yu, K., Wang, F., Zhou, Z., Bi, Y., Zhuang, S. and Zhang, D. (2024), 'Temporal Convolutional Network-Enhanced Real-Time Implicit Emotion Recognition with an Innovative Wearable fNIRS-EEG Dual-Modal System', *Electronics* **13**(7), 1310.
URL: *https://www.mdpi.com/2079-9292/13/7/1310*

Chen, T., Yue, G. H., Tian, Y. and Jiang, C. (2017), 'Baduanjin Mind-Body Intervention Improves the Executive Control Function', *Frontiers in Psychology* **7**. Publisher: Frontiers.
URL: *https://www.frontiersin.org/journals/psychology/articles/10.3389/fpsyg.2016.0201*

Cheng, R., Wu, N., Varvello, M., Chai, E., Chen, S. and Han, B. (2024), A First Look at Immersive Telepresence on Apple Vision Pro, *in* 'Proceedings of the 2024 ACM on Internet Measurement Conference', ACM, Madrid Spain, pp. 555–562.
URL: *https://dl.acm.org/doi/10.1145/3646547.3689006*

Cherry, B. (2009), *Horror*, Routledge, London.

Chesham, R. K., Malouff, J. M. and Schutte, N. S. (2018), 'Meta-Analysis of the Efficacy of Virtual Reality Exposure Therapy for Social Anxiety', *Behaviour Change* **35**(3), 152–166.

Chiarelli, A. M., Maclin, E. L., Fabiani, M. and Gratton, G. (2015), 'A kurtosis-based wavelet algorithm for motion artifact correction of fNIRS data', *NeuroImage* **112**, 128–137.
URL: *https://linkinghub.elsevier.com/retrieve/pii/S1053811915001585*

Chiossi, F., Turgut, Y., Welsch, R. and Mayer, S. (2023), 'Adapting Visual Complexity Based on Electrodermal Activity Improves Working Memory Performance in Virtual Reality', *Proc. ACM Hum.-Comput. Interact.* **7**(MHCI), 196:1–196:26.
URL: *https://doi.org/10.1145/3604243*

Ciuk, D., Troy, A. and Jones, M. (2015), 'Measuring Emotion: Self-Reports vs. Physiological Indicators'.
URL: *https://papers.ssrn.com/abstract=2595359*

Clarke, V. and Braun, V. (2017), 'Thematic analysis', *The Journal of Positive Psychology* **12**(3), 297–298. Publisher: Routledge _eprint: https://doi.org/10.1080/17439760.2016.1262613.
URL: *https://doi.org/10.1080/17439760.2016.1262613*

Cohen, M. X. (2014), *Analyzing Neural Time Series Data: Theory and Practice*, The MIT Press.
URL: *https://direct.mit.edu/books/book/4013/Analyzing-Neural-Time-Series-DataTheory-and*

Colombetti, G. (2014), *The feeling body: affective science meets the enactive mind*, The MIT Press, Cambridge (Mass.).

Concannon, S., Rajan, N., Shah, P., Smith, D., Ursu, M. and Hook, J. (2020), Brooke Leave Home: Designing a Personalized Film to Support Public Engagement with Open Data, *in* 'Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems', CHI '20, Association for Computing Machinery, New York, NY, USA, pp. 1–14.
URL: *https://dl.acm.org/doi/10.1145/3313831.3376462*

Corstorphine, K. (2023), 'Horror Theory Now', *The Evolution of Horror in the Twenty-First Century* p. 13. Publisher: Rowman & Littlefield ISBN: 9781793643414.

Cortivision (2025), 'fNIRS+VR | Silicolabs'.
URL: *https://www.cortivision.com/fnirsvr-silicolabs/*

Costadopoulos, N., Islam, M. Z. and Tien, D. (2019), Using Z-score to Extract Human Readable Logic Rules from Physiological Data, *in* '2019

11th International Conference on Knowledge and Systems Engineering (KSE)', pp. 1–6. ISSN: 2164-2508.
URL: *https://ieeexplore.ieee.org/abstract/document/8919473*

Cui, X., Bray, S. and Reiss, A. L. (2010), 'Functional near infrared spectroscopy (NIRS) signal improvement based on negative correlation between oxygenated and deoxygenated hemoglobin dynamics', *NeuroImage* **49**(4), 3039–3046.
URL: *https://linkinghub.elsevier.com/retrieve/pii/S105381190901235X*

Dahdal, S. (2023), 'The Benefits of Involving Undergraduate University Students in Creative Practice-led Research Projects', *International Journal of Educational Reform* **32**(4), 375–395. Publisher: SAGE Publications Inc.
URL: *https://doi.org/10.1177/10567879211064871*

Daniel-Watanabe, L., Cook, B., Leung, G., Krstulović, M., Finnemann, J., Woolley, T., Powell, C. and Fletcher, P. (2025), 'Using a virtual reality game to train biofeedback-based regulation under stress conditions', *Psychophysiology* **62**(1), e14705.

Davis, M. (1992), 'The role of the amygdala in fear and anxiety', *Annual review of neuroscience* **15**(1), 353–375. Publisher: Annual Reviews 4139 El Camino Way, PO Box 10139, Palo Alto, CA 94303-0139, USA.

Dawson, G. (1954), 'A summation technique for the detection of small evoked potentials', *Electroencephalography and Clinical Neurophysiology* **6**, 65–84.
URL: *https://linkinghub.elsevier.com/retrieve/pii/0013469454900073*

De Haan, G. (2015), HCI Design Methods: where next? from user-centred to creative design and beyond, *in* 'Proceedings of the European Confer-

ence on Cognitive Ergonomics 2015', ACM, Warsaw Poland, pp. 1–8.
URL: *https://dl.acm.org/doi/10.1145/2788412.2788418*

de Lima, E. S., Silva, B. M. C. and Galam, G. T. (2020), Towards the Design of Adaptive Virtual Reality Horror Games: A Model of Players' Fears Using Machine Learning and Player Modeling, *in* '2020 19th Brazilian Symposium on Computer Games and Digital Entertainment (SBGames)', IEEE, pp. 171–177.

de Lima, E. S., Silva, B. M. and Galam, G. T. (2022), 'Adaptive virtual reality horror games based on Machine learning and player modeling', *Entertainment Computing* **43**, 100515.
URL: *https://linkinghub.elsevier.com/retrieve/pii/S1875952122000398*

de With, L. A., Thammasan, N. and Poel, M. (2022), 'Detecting Fear of Heights Response to a Virtual Reality Environment Using Functional Near-Infrared Spectroscopy', *Frontiers in Computer Science* **3**.
URL: *https://www.frontiersin.org/articles/10.3389/fcomp.2021.652550/full*

Dechant, M. J., Birk, M. V., Shiban, Y., Schnell, K. and Mandryk, R. L. (2021), How Avatar Customization Affects Fear in a Game-based Digital Exposure Task for Social Anxiety, *in* 'Proceedings of the ACM on Human-Computer Interaction', Vol. 5, Association for Computing Machinery, New York, NY, USA, pp. 1–27. Issue: CHIPLAY ISSN: 25730142.
URL: *https://dl.acm.org/doi/10.1145/3474675*

Dekker, A. and Champion, E. (2007), Please biofeed the zombies: enhancing the gameplay and display of a horror game using biofeedback, *in* 'DiGRA'07-Proceedings of the 2007 DiGRA International Conference: Situated Play', pp. 550–558.

Demarque, T. C. and Lima, E. S. (2013), 'Auditory Hallucination: Audiological Perspective for Horror Games', *SBC–Proceedings of SBGames* **2013**.

Deodatis, G. and Shinozuka, M. (1988), 'Auto-Regressive Model for Nonstationary Stochastic Processes', *Journal of Engineering Mechanics* **114**(11), 1995–2012.

Depthkit (2024), 'Depthkit'.
URL: *https://www.depthkit.tv/*

Desmet, P., Overbeeke, K. and Tax, S. (2001), 'Designing Products with Added Emotional Value: Development and Appllcation of an Approach for Research through Design', *The Design Journal* **4**(1), 32–47. Publisher: Routledge _eprint: https://doi.org/10.2752/146069201789378496.
URL: *https://doi.org/10.2752/146069201789378496*

Ding, N., Zhou, W. and Fung, A. Y. (2018), 'Emotional effect of cinematic VR compared with traditional 2D film', *Telematics and Informatics* **35**(6), 1572–1579.
URL: *https://linkinghub.elsevier.com/retrieve/pii/S0736585317309085*

Dixon, M. L., Thiruchselvam, R., Todd, R. and Christoff, K. (2017), 'Emotion and the prefrontal cortex: An integrative review.', *Psychological Bulletin* **143**(10), 1033–1081.

Domínguez-Jiménez, J. A., Campo-Landines, K. C., Martínez-Santos, J. C., Delahoz, E. J. and Contreras-Ortiz, S. H. (2020), 'A machine learning model for emotion recognition from physiological signals', *Biomedical Signal Processing and Control* **55**, 101646.
URL: *https://www.sciencedirect.com/science/article/pii/S1746809419302277*

Duan, L., Zhao, Z., Lin, Y., Wu, X., Luo, Y. and Xu, P. (2018), 'Wavelet-based method for removing global physiological noise in functional near-infrared spectroscopy', *Biomedical Optics Express* **9**(8), 3805.
URL: *https://opg.optica.org/abstract.cfm?URI=boe-9-8-3805*

Ekman, P. (1992), 'An argument for basic emotions', *Cognition and Emotion* **6**(3-4), 169–200. Publisher: Routledge.
URL: *https://www.tandfonline.com/doi/full/10.1080/02699939208411068*

Ekman, P. (1999), Basic Emotions, *in* 'Handbook of Cognition and Emotion', Wiley, pp. 45–60.
URL: *https://onlinelibrary.wiley.com/doi/10.1002/0470013494.ch3*

Ekman, P. (2009), 'Darwin's contributions to our understanding of emotional expressions', *Philosophical Transactions of the Royal Society B: Biological Sciences* **364**(1535), 3449–3451.
URL: *https://royalsocietypublishing.org/doi/10.1098/rstb.2009.0189*

El Naqa, I. and Murphy, M. J. (2015), What Is Machine Learning?, *in* I. El Naqa, R. Li and M. J. Murphy, eds, 'Machine Learning in Radiation Oncology: Theory and Applications', Springer International Publishing, Cham, pp. 3–11.
URL: *https://doi.org/10.1007/978-3-319-18305-3_1*

Elhai, J. D., Yang, H. and Montag, C. (2021), 'Fear of missing out (Fomo): Overview, theoretical underpinnings, and literature review on relations with severity of negative affectivity and problematic technology use', *Brazilian Journal of Psychiatry* **43**(2), 203–209. Publisher: Associação Brasileira de Psiquiatria.
URL: *http://www.scielo.br/scielo.php?script=sci_arttext&pid=S1516-44462021000200017&tlng=en*

Engelmann, J. B. and Pogosyan, M. (2013), 'Emotion perception across cultures: the role of cognitive mechanisms', *Frontiers in Psychology* **4**.
URL: *http://journal.frontiersin.org/article/10.3389/fpsyg.2013.00118/abstract*

Estrada-Jiménez, J., Parra-Arnau, J., Rodríguez-Hoyos, A. and Forné, J. (2019), 'On the regulation of personal data distribution in online advertising platforms', *Engineering Applications of Artificial Intelligence* **82**, 13–29.
URL: *https://www.sciencedirect.com/science/article/pii/S0952197619300636*

Etkin, A., Büchel, C. and Gross, J. J. (2015), 'The neural bases of emotion regulation', *Nature Reviews Neuroscience* **16**(11), 693–700. Publisher: Nature Publishing Group.
URL: *https://www.nature.com/articles/nrn4044*

European Parliament (2016), 'General Data Protection Regulation (GDPR) – Legal Text'.
URL: *https://gdpr-info.eu/*

European Parliament (2024), 'EU Artificial Intelligence Act | Up-to-date developments and analyses of the EU AI Act'.
URL: *https://artificialintelligenceact.eu/*

Ewan Kirkland (2010), 'Silent Hill: Shattered Memories - ProQuest'.
URL: *https://www.proquest.com/openview/38b5bd8e55002e27f29793b811877828/1?pq-origsite=gscholar&cbl=2035804*

Fernández-Aguilar, L., Martínez-Rodrigo, A., Moncho-Bogani, J., Fernández-Caballero, A. and Latorre, J. M. (2019), Emotion Detection in Aging Adults Through Continuous Monitoring of Electro-Dermal Activity and Heart-Rate Variability, *in* J. M. Ferrández Vicente, J. R. Álvarez

Sánchez, F. de la Paz López, J. Toledo Moreo and H. Adeli, eds, 'Understanding the Brain Function and Emotions', Springer International Publishing, Cham, pp. 252–261.

Field, S. (2005), *Screenplay: the foundations of screenwriting*, rev. ed edn, Delta Trade Paperbacks, New York, N.Y.

Filko, D. and Martinović, P. G. (2013), 'Emotion Recognition System by a Neural Network Based Facial Expression Analysis', *Automatika* **54**(2), 263–272. Publisher: Taylor & Francis.
URL: *https://doi.org/10.7305/automatika.54-2.73*

Fishburn, F. A., Ludlum, R. S., Vaidya, C. J. and Medvedev, A. V. (2019), 'Temporal Derivative Distribution Repair (TDDR): A motion correction method for fNIRS', *NeuroImage* **184**, 171–179.
URL: *https://linkinghub.elsevier.com/retrieve/pii/S1053811918308103*

Fleck, M. (2021), 'LSL4Unity'.
URL: *https://github.com/labstreaminglayer/LSL4Unity*

Foresights, M. (2025), 'UK Virtual Reality (VR) Gaming Market Size and Forecasts 2030'.
URL: *https://mobilityforesights.com/product/uk-virtual-reality-vr-gaming-market*

Frayling, C. (1994), 'Research in Art and Design (Royal College of Art Research Papers, Vol 1, No 1, 1993/4)'. Num Pages: 9 Place: London Publisher: Royal College of Art.
URL: *https://researchonline.rca.ac.uk/384/*

Freytag, G. (1863), *Die Technik des Dramas, Leipzig S*, Hirzel, Leipzig.

Friston, K. J., Holmes, A. P., Worsley, K. J., Poline, J., Frith, C. D. and Frackowiak, R. S. J. (1994), 'Statistical parametric maps in functional

imaging: A general linear approach', *Human Brain Mapping* **2**(4), 189–210.

URL: *https://onlinelibrary.wiley.com/doi/10.1002/hbm.460020402*

Fuentes, C., Herskovic, V., Rodríguez, I., Gerea, C., Marques, M. and Rossel, P. O. (2017), 'A systematic literature review about technologies for self-reporting emotional information', *Journal of Ambient Intelligence and Humanized Computing* **8**(4), 593–606.

URL: *https://doi.org/10.1007/s12652-016-0430-z*

Fullana, M. A., Albajes-Eizagirre, A., Soriano-Mas, C., Vervliet, B., Cardoner, N., Benet, O., Radua, J. and Harrison, B. J. (2018), 'Fear extinction in the human brain: A meta-analysis of fMRI studies in healthy participants', *Neuroscience & Biobehavioral Reviews* **88**, 16–25.

Fumero, A., Marrero, R. J., Olivares, T., Rivero, F., Alvarez-Pérez, Y., Pitti, C. and Peñate, W. (2022), 'Neuronal Activity during Exposure to Specific Phobia through fMRI: Comparing Therapeutic Components of Cognitive Behavioral Therapy', *Life* **12**(8), 1132.

Galea (2024), 'Galea'.

URL: *https://galea.co*

Gaver, W. (2012), What should we expect from research through design?, *in* 'Proceedings of the SIGCHI Conference on Human Factors in Computing Systems', CHI '12, Association for Computing Machinery, New York, NY, USA, pp. 937–946.

URL: *https://doi.org/10.1145/2207676.2208538*

Geer, J. H. (1965), 'The development of a scale to measure fear', *Behaviour Research and Therapy* **3**(1), 45–53.

URL: *https://linkinghub.elsevier.com/retrieve/pii/0005796765900409*

Gera, D., Raj Kumar, B. V., Badveeti, N. S. K. and Balasubramanian, S. (2024), 'Dynamic adaptive threshold based learning for noisy annotations robust facial expression recognition', *Multimedia Tools and Applications* **83**(16), 49537–49566.
URL: *https://doi.org/10.1007/s11042-023-17510-3*

Giang Barrera, K. and Shah, D. (2023), 'Marketing in the Metaverse: Conceptual understanding, framework, and research agenda', *Journal of Business Research* **155**, 113420.
URL: *https://linkinghub.elsevier.com/retrieve/pii/S0148296322008852*

Glotzbach, E., Mühlberger, A., Gschwendtner, K., Fallgatter, A. J., Pauli, P. and Herrmann, M. J. (2011), 'Prefrontal Brain Activation During Emotional Processing: A Functional Near Infrared Spectroscopy Study (fNIRS)', *The Open Neuroimaging Journal* **5**, 33–39.

Goldin, P. R., McRae, K., Ramel, W. and Gross, J. J. (2008), 'The Neural Bases of Emotion Regulation: Reappraisal and Suppression of Negative Emotion', *Biological Psychiatry* **63**(6), 577–586. Publisher: Elsevier.
URL: *https://www.biologicalpsychiatryjournal.com/article/S0006-3223(07)00592-6/fulltext*

Gomaa, Y. S., Awad, M. I., Emara, T., Elbokl, A., Al-Yahya, E. and ElMeligie, M. M. (2024), 'Role of virtual reality in examining the effect of fear of falling (FOF) on postural stability in individuals without and with Parkinson's disease in Egypt: a mixed-methods feasibility study protocol', *BMJ open* **14**(5), e080592.

Google (2025), 'Genie 3: A New Frontier for World Models'.
URL: *https://deepmind.google/discover/blog/genie-3-a-new-frontier-for-world-models/*

Grassini, S. and Laumann, K. (2020), 'Questionnaire Measures and Physiological Correlates of Presence: A Systematic Review', *Frontiers in Psychology* **11**, 349.
URL: *https://www.frontiersin.org/article/10.3389/fpsyg.2020.00349/full*

Griffiths, P. (1998), *What emotions really are: the problem of psychological categories*, Science and its conceptual foundations, paperback ed edn, Univ. of Chicago Press, Chicago, Ill.

Gromer, D., Reinke, M., Christner, I. and Pauli, P. (2019), 'Causal Interactive Links Between Presence and Fear in Virtual Reality Height Exposure', *Frontiers in Psychology* **10**.

Guthrie Yarwood, M. (2022), *Psychology of Human Emotion: An Open Access Textbook*, Pressbooks.
URL: *https://psu.pb.unizin.org/psych425/*

Habel, C., and Kooyman, B. (2014), 'Agency mechanics: gameplay design in survival horror video games', *Digital Creativity* **25**(1), 1–14. Publisher: CAA Website _eprint: https://doi.org/10.1080/14626268.2013.776971.
URL: *https://doi.org/10.1080/14626268.2013.776971*

Halbig, A. and Latoschik, M. E. (2021), 'A Systematic Review of Physiological Measurements, Factors, Methods, and Applications in Virtual Reality', *Frontiers in Virtual Reality* **2**.
URL: *https://www.frontiersin.org/articles/10.3389/frvir.2021.694567/full*

Hamm, A. O., Cuthbert, B. N., Globisch, J. and Vaitl, D. (1997), 'Fear and the startle reflex: Blink modulation and autonomic response patterns in animal and mutilation fearful subjects', *Psychophysiology* **34**(1), 97–107.
URL: *https://onlinelibrary.wiley.com/doi/10.1111/j.1469-8986.1997.tb02420.x*

Hamm, A. O., Vaitl, D. and Lang, P. J. (1989), 'Fear conditioning, meaning, and belongingness: A selective association analysis.', *Journal of Abnormal Psychology* **98**(4), 395–406.
URL: *https://doi.apa.org/doi/10.1037/0021-843X.98.4.395*

Hanich, J. (2011), *Cinematic Emotion in Horror Films and Thrillers*, Routledge.
URL: *https://www.taylorfrancis.com/books/9781136991592*

Harun, A., Razeef, M., Abd Razak, M. R., Nasir, M. N. F., Nasir, M. and Ali, A. (2013), Freytag's Pyramid: An Approach for Analyzing The Dramatic Elements and Narrative Structure in Filem Negara Malaysia's First Animated Cartoon.

Hassouneh, A., Mutawa, A. M. and Murugappan, M. (2020), 'Development of a Real-Time Emotion Recognition System Using Facial Expressions and EEG based on machine learning and deep neural network methods', *Informatics in Medicine Unlocked* **20**, 100372.
URL: *https://www.sciencedirect.com/science/article/pii/S235291482030201X*

Hawkins, B. and Wilson, B. (2017), 'A Fresh Theoretical Perspective on Practice-Led Research', *International Journal of Art & Design Education* **36**(1), 82–91. _eprint: https://onlinelibrary.wiley.com/doi/pdf/10.1111/jade.12074.
URL: *https://onlinelibrary.wiley.com/doi/abs/10.1111/jade.12074*

Haxby, J. V. and Ida Gobbini, M. (2007), 'The perception of emotion and social cues in faces', *Neuropsychologia* **45**(1), 1.

Hjelm, S. I. and Browall, C. (2000), Brainball-using brain activity for cool competition, *in* 'Proceedings of NordiCHI', Vol. 7, p. 19. Issue: 9.

Hogervorst, M. A., Brouwer, A.-M. and van Erp, J. B. F. (2014), 'Combining and comparing EEG, peripheral physiology and eye-related measures for the assessment of mental workload', *Frontiers in Neuroscience* **8**. Publisher: Frontiers.
URL: *https://www.frontiersin.org/journals/neuroscience/articles/10.3389/fnins.2014.00*

Houzangbe, S., Christmann, O., Gorisse, G. and Richir, S. (2018), Fear as a biofeedback game mechanic in virtual reality, *in* 'Proceedings of the 13th International Conference on the Foundations of Digital Games', ACM, New York, NY, USA, pp. 1–6.

Hu, X., Zhuang, C., Wang, F., Liu, Y.-J., Im, C.-H. and Zhang, D. (2019), 'fNIRS Evidence for Recognizably Different Positive Emotions', *Frontiers in Human Neuroscience* **13**. Publisher: Frontiers.
URL: *https://www.frontiersin.org/journals/human-neuroscience/articles/10.3389/fnhum.2019.00120/full*

Hufendiek, R. (2015), *Embodied Emotions*, 0 edn, Routledge.
URL: *https://www.taylorfrancis.com/books/9781317329039*

Huppert, T. J., Diamond, S. G., Franceschini, M. A. and Boas, D. A. (2009), 'HomER: a review of time-series analysis methods for near-infrared spectroscopy of the brain', *Applied Optics* **48**(10), D280.
URL: *https://opg.optica.org/abstract.cfm?URI=ao-48-10-D280*

Hutto, D. D., Robertson, I. and Kirchhoff, M. D. (2018), 'A New, Better BET: Rescuing and Revising Basic Emotion Theory', *Frontiers in Psychology* **9**, 1217.
URL: *https://www.frontiersin.org/article/10.3389/fpsyg.2018.01217/full*

III, R. R. (2009), Match Made in Hell: The Inevitable Success of the Horror Genre in Video Games, *in* B. Perron, ed., 'Horror Video Games: Essays

on the Fusion of Fear and Play', McFarland & Company, Jefferson, NC, pp. 15–25.

Ismail, S., Akram, U. and Siddiqi, I. (2021), 'Heart rate tracking in photoplethysmography signals affected by motion artifacts: a review', *EURASIP Journal on Advances in Signal Processing* **2021**(1), 5.
URL: *https://asp-eurasipjournals.springeropen.com/articles/10.1186/s13634-020-00714-2*

Izard, C. E. (1994), 'Innate and universal facial expressions: Evidence from developmental and cross-cultural research.', *Psychological Bulletin* **115**(2), 288–299.
URL: *http://doi.apa.org/getdoi.cfm?doi=10.1037/0033-2909.115.2.288*

James, W. (1884), 'II.—WHAT IS AN EMOTION ?', *Mind* **os-IX**(34), 188–205.
URL: *https://academic.oup.com/mind/article-lookup/doi/10.1093/mind/os-IX.34.188*

Jerald, J. (2015), *The VR Book*, Association for Computing Machinery.
URL: *http://dl.acm.org/citation.cfm?id=2792790*

Jurcik, T., Zaremba-Pike, S., Kosonogov, V., Mohammed, A.-R., Krasavtseva, Y., Sawada, T., Samarina, I., Buranova, N., Adu, P., Sergeev, N., Skuratov, A., Demchenko, A. and Kochetkov, Y. (2024), 'The efficacy of augmented reality exposure therapy in the treatment of spider phobia—a randomized controlled trial', *Frontiers in Psychology* **15**. Publisher: Frontiers.
URL: *https://www.frontiersin.org/journals/psychology/articles/10.3389/fpsyg.2024.1214*

Juslin, P. N. (2019), *Musical emotions explained: unlocking the secrets of musical affect*, first edition edn, Oxford University Press, Oxford.

Kaay, C. V. and Kaay, K. F.-V. (2016), *Horror Films by Subgenre: A Viewer's Guide*, McFarland. Google-Books-ID: mwKQCwAAQBAJ.

Kaplan-Rakowski, R., Johnson, K. R. and Wojdynski, T. (2021), 'The impact of virtual reality meditation on college students' exam performance', *Smart Learning Environments* **8**(1), 21.

Kato, K., Iwamoto, K., Kawano, N., Noda, Y., Ozaki, N. and Noda, A. (2018), 'Differential effects of physical activity and sleep duration on cognitive function in young adults', *Journal of Sport and Health Science* **7**(2), 227–236.
URL: *https://www.sciencedirect.com/science/article/pii/S2095254617300054*

Kerr, J. I., Weibel, R. P., Naegelin, M., Ferrario, A., Schinazi, V. R., La Marca, R., Hoelscher, C., Nater, U. M. and von Wangenheim, F. (2023), 'The effectiveness and user experience of a biofeedback intervention program for stress management supported by virtual reality and mobile technology: a randomized controlled study', *BMC Digital Health* **1**(1), 42.
URL: *https://doi.org/10.1186/s44247-023-00042-z*

Khanna, P. and M., S. (2013), 'Rule Based System for Recognizing Emotions Using Multimodal Approach', *International Journal of Advanced Computer Science and Applications* **4**(7).
URL: *http://thesai.org/Publications/ViewPaper?Volume=4&Issue=7&Code=IJACSA&SerialNo=5*

Kirschstein, T. and Köhling, R. (2009), 'What is the Source of the EEG?', *Clinical EEG and Neuroscience* **40**(3), 146–149.
URL: *http://journals.sagepub.com/doi/10.1177/155005940904000305*

Klein, F. and Kranczioch, C. (2019), 'Signal Processing in fNIRS: A Case for the Removal of Systemic Activity for Single Trial Data', *Frontiers in*

Human Neuroscience **13**, 331.
URL: *https://www.frontiersin.org/article/10.3389/fnhum.2019.00331/full*

Knopf, K. and Pössel, P. (2009), 'Individual response differences in spider phobia: Comparing phobic and non-phobic women of different reactivity levels', *Anxiety, Stress & Coping* **22**(1), 39–55.
URL: *http://www.tandfonline.com/doi/abs/10.1080/10615800802169358*

Kober, S., Wood, G., Kurzmann, J., Friedrich, E., Stangl, M., Wippel, T., Väljamäe, A. and Neuper, C. (2014), 'Near-infrared spectroscopy based neurofeedback training increases specific motor imagery related cortical activation compared to sham feedback', *Biological Psychology* **95**, 21–30.
URL: *https://linkinghub.elsevier.com/retrieve/pii/S0301051113001233*

Komosar, M., Fiedler, P. and Haueisen, J. (2022), 'Bad channel detection in EEG recordings', *Current Directions in Biomedical Engineering* **8**(2), 257–260.
URL: *https://www.degruyter.com/document/doi/10.1515/cdbme-2022-1066/html*

Kristeva, J. (1982), *Powers of Horror; An Essay on Abjection*, COLUMBIA UNIVERSITY PRESS.

Krzywinska, T. (2002), 'Hands-on horror', *Spectator* **22**(2), 12–23.

Landowska, A., Roberts, D., Eachus, P. and Barrett, A. (2018), 'Within- and Between-Session Prefrontal Cortex Response to Virtual Reality Exposure Therapy for Acrophobia', *Frontiers in Human Neuroscience* **12**.
URL: *https://www.frontiersin.org/article/10.3389/fnhum.2018.00362*

LaViola, J. J., Kruijff, E., McMahan, R. P., Bowman, D. A. and Poupyrev, I. (2017), *3D user interfaces: theory and practice*, Pearson always learning, second edition edn, Addison-Wesley, Boston, Mass. Columbus, Ohio

Indianapolis New York San Francisco Amsterdam Cape Town Dubai London Madrid Milan Munich Paris Montreal Toronto Delhi Mexico City São Paulo Sidney Hong Kong Seoul Singapore Taipei Tokyo.

Law, A. (2020), 'The Trajectory of Fear – or How to Use Horror Tropes Effectively in your Game'.

Lawson, G., Shaw, E., Roper, T., Nilsson, T., Bajorunaite, L. and Batool, A. (2019), 'Immersive virtual worlds: Multi-sensory virtual environments for health and safety training', *arXiv preprint arXiv:1910.04697* . arXiv: 1910.04697.
URL: *http://arxiv.org/abs/1910.04697*

LeDoux, J. E. (1998), *The emotional brain: the mysterious underpinnings of emotional life*, A Touchstone book, 1st. touchstone ed edn, Simon & Schuster, New York, NY.

León-Carrión, J. and León-Domínguez, U. (2012), 'Functional near-infrared spectroscopy (fNIRS): principles and neuroscientific applications', *Neuroimaging methods* pp. 48–74. Publisher: IntechOpen.

Li, R., Yang, D., Fang, F., Hong, K.-S., Reiss, A. L. and Zhang, Y. (2022), 'Concurrent fNIRS and EEG for Brain Function Investigation: A Systematic, Methodology-Focused Review', *Sensors* **22**(15), 5865.
URL: *https://www.mdpi.com/1424-8220/22/15/5865*

Li, X., Zhang, Y., Tiwari, P., Song, D., Hu, B., Yang, M., Zhao, Z., Kumar, N. and Marttinen, P. (2023), 'EEG Based Emotion Recognition: A Tutorial and Review', *ACM Computing Surveys* **55**(4), 1–57.
URL: *https://dl.acm.org/doi/10.1145/3524499*

Liang, X., Landowska, A., Ramchurn, R., Berger, C., Wilson, M. L. and Maior, H. A. (2023), The Power of Fear: Exploring the Neural Responses

to Horror Scenes in Different Audiovisual Modes, *in* 'International Conference on Human–Computer Interaction (RoCHI 2023)', Vol. 20.

Lin, J. H. T. (2017), 'Fear in virtual reality (VR): Fear elements, coping reactions, immediate and next-day fright responses toward a survival horror zombie virtual reality game', *Computers in Human Behavior* **72**, 350–361.
URL: *https://linkinghub.elsevier.com/retrieve/pii/S0747563217301383*

Lin, J. H. T., Wu, D. Y. and Tao, C. C. (2018), 'So scary, yet so fun: The role of self-efficacy in enjoyment of a virtual reality horror game', *New Media and Society* **20**(9), 3223–3242. Publisher: SAGE Publications Sage UK: London, England.
URL: *http://journals.sagepub.com/doi/10.1177/1461444817744850*

Littles, C. (2023), The Evolution of Horror and New Media, *in* 'The Evolution of Horror in the Twenty-First Century', Rowman & Littlefield, pp. 143–153.

Luke, R., Larson, E., Shader, M. J., Innes-Brown, H., Van Yper, L., Lee, A. K. C., Sowman, P. F. and McAlpine, D. (2021), 'Analysis methods for measuring passive auditory fNIRS responses generated by a block-design paradigm', *Neurophotonics* **8**(02).
URL: *https://www.spiedigitallibrary.org/journals/neurophotonics/volume-8/issue-02/025008/Analysis-methods-for-measuring-passive-auditory-fNIRS-responses-generated-by/10.1117/1.NPh.8.2.025008.full*

Luong, T. and Holz, C. (2022), 'Characterizing Physiological Responses to Fear, Frustration, and Insight in Virtual Reality', *IEEE Transactions on Visualization and Computer Graphics* **28**(11), 3917–3927.
URL: *https://ieeexplore.ieee.org/abstract/document/9873958*

Léger, L. and Thivierge, M. (1988), 'Heart Rate Monitors: Validity, Stability, and Functionality', *The Physician and Sportsmedicine* **16**(5), 143–151. Publisher: Taylor & Francis.
URL: *https://doi.org/10.1080/00913847.1988.11709511*

Madsen, K. E. (2016), 'The differential effects of agency on fear induction using a horror-themed video game', *Computers in Human Behavior* **56**, 142–146.
URL: *https://www.sciencedirect.com/science/article/pii/S0747563215302569*

Mandrick, K., Derosiere, G., Dray, G., Coulon, D., Micallef, J.-P. and Perrey, S. (2013), 'Utilizing slope method as an alternative data analysis for functional near-infrared spectroscopy-derived cerebral hemodynamic responses', *International Journal of Industrial Ergonomics* **43**(4), 335–341.
URL: *https://linkinghub.elsevier.com/retrieve/pii/S016981411300070X*

Mandrick, K., Derosière, G., Dray, G., Coulon, D., Micallef, J.-P. and Perrey, S. (2012), 'fNIRS data analysis by Slope: an alternative method to distinguish the level of cortical activation pattern during functional tasks.'. Publisher: [object Object].
URL: *http://rgdoi.net/10.13140/2.1.4087.2961*

Mark, G. K., Alan, D. and Jen, A. (2005), Affective Videogames and Modes of Affective Gaming: Assist Me, Challenge Me, Emote Me, *in* 'DiGRA &#3905 - Proceedings of the 2005 DiGRA International Conference: Changing Views: Worlds in Play'.

Marks, I. M. (1969), *Fears and phobias*, Academic Press, London.

Marshall, J., Tennent, P., Li, C., Pacheco, C. N., Garrett, R., Tsaknaki, V., Höök, K., Caleb-Solly, P. and Benford, S. D. (2023), Collision Design, *in* 'Extended Abstracts of the 2023 CHI Conference on Human Factors in Computing Systems', ACM, New York, NY, USA, pp. 1–9.

Martens, M. A., Antley, A., Freeman, D., Slater, M., Harrison, P. J. and Tunbridge, E. M. (2019), 'It feels real: physiological responses to a stressful virtual reality environment and its impact on working memory', *Journal of Psychopharmacology* **33**(10), 1264–1273.
URL: *http://journals.sagepub.com/doi/10.1177/0269881119860156*

Martin, G. N. (2019), '(Why) Do You Like Scary Movies? A Review of the Empirical Research on Psychological Responses to Horror Films', *Frontiers in Psychology* **10**, 2298.
URL: *https://www.frontiersin.org/article/10.3389/fpsyg.2019.02298/full*

Martindale, S., Hook, J. and Carter, R. (2025), 'A collective interdisciplinary agenda for immersive storytelling: Editorial analysis', *Convergence* **31**(1), 3–17. Publisher: SAGE Publications Ltd.
URL: *https://doi.org/10.1177/13548565251321702*

Martis, J. E. and Balasubramani, R. (2020), 'Reckoning of Emotions Through Recognition of Posture Features', *Journal of Applied Security Research* **15**(2), 230–254.
URL: *https://www.tandfonline.com/doi/full/10.1080/19361610.2019.1645530*

Marín-Morales, J., Higuera-Trujillo, J. L., Guixeres, J., Llinares, C., Alcañiz, M. and Valenza, G. (2021), 'Heart rate variability analysis for the assessment of immersive emotional arousal using virtual reality: Comparing real and virtual scenarios', *PLOS ONE* **16**(7), e0254098.
URL: *https://dx.plos.org/10.1371/journal.pone.0254098*

Masataka, N., Perlovsky, L. and Hiraki, K. (2015), 'Near-infrared spectroscopy (NIRS) in functional research of prefrontal cortex', *Frontiers in Human Neuroscience* **9**.
URL: *http://www.frontiersin.org/Human_Neuroscience/10.3389/fnhum.2015.00274/full*

McAlpine, K., Miranda, E. and Hoggar, S. (1999), 'Making Music with Algorithms: A Case-Study System', *Computer Music Journal* **23**(2), 19–30. Publisher: The MIT Press.
URL: *http://www.jstor.org/stable/3680733*

McNamara, A. (2012), 'Six rules for practice-led research', *TEXT: Journal of Writing and Writing Programs* **2012**(S14), 1–15. Number: S14 Publisher: The Australian Association of Writing Programs.
URL: *http://www.textjournal.com.au/*

Mehrabian, A. (1972), *Silent messages*, nachdr. edn, Wadsworth Publishing Company, Belmont, Calif.: Wadsworth.

Meinel, L. S. and Bullerjahn, C. (2022), 'More horror due to specific music placement? Effects of film music on psychophysiological responses to a horror film', *Psychology of Music* **50**(6), 1837–1852.
URL: *http://journals.sagepub.com/doi/10.1177/03057356211073478*

Mendi (2025), 'The Mendi Headset'.
URL: *https://www.mendi.io/products/mendi*

Meshy (2025), 'Meshy AI - The #1 AI 3D Model Generator for Creators'.
URL: *https://www.meshy.ai/en*

Meta (2022), 'Meta Quest Pro Premium mixed reality headset'.
URL: *https://www.meta.com/gb/quest/quest-pro/*

Meta (2023), 'Meta Quest 3: Next-gen mixed reality headset'.
URL: *https://www.meta.com/nl/en/quest/quest-3/*

Meulders, A. (2020), 'Fear in the context of pain: Lessons learned from 100 years of fear conditioning research', *Behaviour Research and Therapy* **131**, 103635.
URL: *https://www.sciencedirect.com/science/article/pii/S0005796720300863*

Midha, S., Maior, H. A., Wilson, M. L. and Sharples, S. (2021), 'Measuring Mental Workload Variations in Office Work Tasks using fNIRS', *International Journal of Human-Computer Studies* **147**, 102580.
URL: *https://linkinghub.elsevier.com/retrieve/pii/S1071581920301828*

Miloff, A., Lindner, P., Hamilton, W., Reuterskiöld, L., Andersson, G. and Carlbring, P. (2016), 'Single-session gamified virtual reality exposure therapy for spider phobia vs. traditional exposure therapy: study protocol for a randomized controlled non-inferiority trial', *Trials* **17**(1), 60.

Miltner, W. H., Trippe, R. H., Krieschel, S., Gutberlet, I., Hecht, H. and Weiss, T. (2005), 'Event-related brain potentials and affective responses to threat in spider/snake-phobic and non-phobic subjects', *International Journal of Psychophysiology* **57**(1), 43–52.
URL: *https://linkinghub.elsevier.com/retrieve/pii/S0167876005000577*

Morélot, S., Garrigou, A., Dedieu, J. and N'Kaoua, B. (2021), 'Virtual reality for fire safety training: Influence of immersion and sense of presence on conceptual and procedural acquisition', *Computers & Education* **166**, 104145.

Murray, J. H. (1997), *Hamlet on the Holodeck: The Future of Narrative in Cyberspace*, The Free Press, New York.

Muse (2025), 'Muse S Athena | Muse® EEG Mental Fitness & Sleep Headband'.
URL: *https://choosemuse.com/products/muse-s-athena*

Mäkelä, M. and Nimkulrat, N. (2018), 'Documentation as a practice-led research tool for reflection on experiential knowledge', *FormAkademisk* **11**(2). Publisher: Formakademisk.
URL: *https://research.aalto.fi/en/publications/documentation-as-a-practice-led-research-tool-for-reflection-on-e*

Networks, F. (2025), 'Alien: Earth Immersive Content'.
URL: *https://www.fxnetworks.com/shows/alien-earth/immersive-content*

NEUROSPEC (2024), 'Home Page | NEUROSPEC AG Research Neurosciences'.
URL: *https://www.neurospec.com/Products/Details/1077/dsi-vr300*

Nicolas-Alonso, L. F. and Gomez-Gil, J. (2012), 'Brain Computer Interfaces, a Review', *Sensors* **12**(2), 1211–1279.
URL: *http://www.mdpi.com/1424-8220/12/2/1211*

Ninaus, M., Tsarava, K. and Moeller, K. (2019), A Pilot Study on the Feasibility of Dynamic Difficulty Adjustment in Game-Based Learning Using Heart-Rate, pp. 117–128.

Nowell, R. (2014), *Merchants of Menace: The Business of Horror Cinema*, Bloomsbury Publishing USA. Google-Books-ID: yr8BAwAAQBAJ.

Oatley, K. and Johnson-Laird, P. (1996), 'The communicative theory of emotions: Empirical tests, mental models, and implications for social interaction', *Striving and feeling: Interactions among goals, affect, and self-regulation* .

Obrig, H., Hirth, C., Junge-Hülsing, J. G., Döge, C., Wenzel, R., Wolf, T., Dirnagl, U. and Villringer, A. (1997), 'Length of resting period between stimulation cycles modulates hemodynamic response to a motor stimulus', *Advances in Experimental Medicine and Biology* **411**, 471–480.

Ochsner, K. and Gross, J. (2005), 'The cognitive control of emotion', *Trends in Cognitive Sciences* **9**(5), 242–249.
URL: *https://linkinghub.elsevier.com/retrieve/pii/S1364661305000902*

Ortmann, T., Wang, Q. and Putzar, L. (2024), 'EmojiHeroVR: A Study on Facial Expression Recognition under Partial Occlusion from Head-Mounted Displays'. Version Number: 1.
URL: *https://arxiv.org/abs/2410.03331*

PARADISO, S. (2002), 'Affective Neuroscience: The Foundations of Human and Animal Emotions', *American Journal of Psychiatry* **159**(10), 1805–1805. Publisher: Oxford university press.

Patashov, D., Menahem, Y., Gurevitch, G., Kameda, Y., Goldstein, D. and Balberg, M. (2023), 'fNIRS: Non-stationary preprocessing methods', *Biomedical Signal Processing and Control* **79**, 104110.
URL: *https://linkinghub.elsevier.com/retrieve/pii/S1746809422005675*

Perron, B. (2014), *Horror Video Games: Essays on the Fusion of Fear and Play*, McFarland. Google-Books-ID: pNaQLQC9XhEC.

Phosphor Games (2016), 'The Brookhaven Experiment'. Place: Chicago, IL.
URL: *https://www.phosphorgames.com/the-brookhaven-experiment*

Pieter Jan Stappers and Elisa Giaccardi (2014), *Research through Design*.
URL: *https://www.interaction-design.org/literature/book/the-encyclopedia-of-human-computer-interaction-2nd-ed/research-through-design*

Pike, M., Ramchurn, R., Benford, S. and Wilson, M. L. (2016), #Scanners: Exploring the Control of Adaptive Films Using Brain-Computer Interaction, *in* 'Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems', Association for Computing Machinery, New York, NY, USA, pp. 5385–5396. Series Title: CHI '16.
URL: *https://doi.org/10.1145/2858036.2858276*

Pinchbeck, D. (2009), Shock, Horror: First-Person Gaming, Horror, and the Art of Ludic Manipulation, *in* B. Perron, ed., 'Horror Video Games: Essays on the Fusion of Fear and Play', McFarland, Jefferson, NC, pp. 79–94.

Pinti, P., Scholkmann, F., Hamilton, A., Burgess, P. and Tachtsidis, I. (2019), 'Current Status and Issues Regarding Pre-processing of fNIRS Neuroimaging Data: An Investigation of Diverse Signal Filtering Methods Within a General Linear Model Framework', *Frontiers in Human Neuroscience* **12**, 505.
URL: *https://www.frontiersin.org/article/10.3389/fnhum.2018.00505/full*

Polycam (2025), 'AI Texture Generator for Blender, Unreal, Unity | Polycam'.
URL: *https://poly.cam/tools/material-generator*

POSNER, J., RUSSELL, J. A. and PETERSON, B. S. (2005), 'The circumplex model of affect: An integrative approach to affective neuroscience, cognitive development, and psychopathology', *Development and Psychopathology* **17**(03).

Powers, M. B. and Emmelkamp, P. M. (2008), 'Virtual reality exposure therapy for anxiety disorders: A meta-analysis', *Journal of Anxiety Disorders* **22**(3), 561–569.

Puerto, P., Heißelmann, D., Müller, S. and Mendikute, A. (2022), 'Methodology to Evaluate the Performance of Portable Photogrammetry for Large-Volume Metrology', *Metrology* **2**(3), 320–334.
URL: *https://www.mdpi.com/2673-8244/2/3/20*

Puntoni, S. (2024), 'Already here: Metaverse in touch and sound', *Journal of Consumer Psychology* **34**(1), 174–176.
URL: *https://myscp.onlinelibrary.wiley.com/doi/10.1002/jcpy.1358*

Putze, F., Putze, S., Sagehorn, M., Micek, C. and Solovey, E. T. (2022), 'Understanding HCI Practices and Challenges of Experiment Reporting with Brain Signals: Towards Reproducibility and Reuse', *ACM Transactions on Computer-Human Interaction* **29**(4), 1–43.

Pöhlmann, K. M. T., Maior, H. A., Föcker, J., O'Hare, L., Parke, A., Ladowska, A. and Dickinson, P. (2023), I think I don't feel sick: Exploring the Relationship Between Cognitive Demand and Cybersickness in Virtual Reality using fNIRS, *in* 'Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems', ACM, New York, NY, USA, pp. 1–16.
URL: *https://dl.acm.org/doi/10.1145/3544548.3581063*

Quaresima, V. and Ferrari, M. (2019), 'A Mini-Review on Functional Near-Infrared Spectroscopy (fNIRS): Where Do We Stand, and Where Should We Go?', *Photonics* **6**(3), 87.
URL: *https://www.mdpi.com/2304-6732/6/3/87*

Rachman, S. (1978), 'Human Fears: A Three Systems Analysis', *Scandinavian Journal of Behaviour Therapy* **7**(4), 237–245. Publisher: Routledge.
URL: *http://www.tandfonline.com/doi/abs/10.1080/16506077809456104*

Ramchurn, R., Martindale, S., Wilson, M. L. and Benford, S. (2019), From Director's Cut to User's Cut: to Watch a Brain-Controlled Film is to Edit it, *in* 'Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems', ACM, Glasgow Scotland Uk, pp. 1–14.
URL: *https://dl.acm.org/doi/10.1145/3290605.3300378*

Ramchurn, R., Martindale, S., Wilson, M. L., Benford, S. and Chamberlain, A. (2019), Brain-Controlled Cinema, *in* A. Nijholt, ed., 'Brain Art: Brain-Computer Interfaces for Artistic Expression', Springer Inter-

national Publishing, Cham, pp. 377–408.
URL: *https://doi.org/10.1007/978-3-030-14323-7_14*

Rathod, P., George, K. and Shinde, N. (2016), Bio-signal based emotion detection device, *in* '2016 IEEE 13th International Conference on Wearable and Implantable Body Sensor Networks (BSN)', pp. 105–108.

Regenbrecht, H., Park, J.-W. N., Ott, C., Mills, S., Cook, M. and Langlotz, T. (2019), 'Preaching Voxels: An Alternative Approach to Mixed Reality', *Frontiers in ICT* **6**, 7.
URL: *https://www.frontiersin.org/article/10.3389/fict.2019.00007/full*

Reiss, S. (1991), 'Expectancy model of fear, anxiety, and panic', *Clinical Psychology Review* **11**(2), 141–153.
URL: *https://linkinghub.elsevier.com/retrieve/pii/0272735891900929*

Rieder, R., Kristensen, C. H. and Pinho, M. S. (2017), Quality Assessment of Interaction Techniques in Immersive Virtual Environments Using Physiological Measures, *in* '2017 IEEE 41st Annual Computer Software and Applications Conference (COMPSAC)', IEEE, pp. 109–117.

Rieke, J. D., Matarasso, A. K., Yusufali, M. M., Ravindran, A., Alcantara, J., White, K. D. and Daly, J. J. (2020), 'Development of a combined, sequential real-time fMRI and fNIRS neurofeedback system to enhance motor learning after stroke', *Journal of Neuroscience Methods* **341**, 108719.
URL: *https://linkinghub.elsevier.com/retrieve/pii/S0165027020301424*

Rimbert, S., Gayraud, N., Bougrain, L., Clerc, M. and Fleck, S. (2019), 'Can a Subjective Questionnaire Be Used as Brain-Computer Interface Performance Predictor?', *Frontiers in Human Neuroscience* **12**, 529.
URL: *https://www.frontiersin.org/article/10.3389/fnhum.2018.00529/full*

Robin Hunicke (2005), (PDF) The case for dynamic difficulty adjustment

in games, *in* 'ResearchGate'.

URL: https://www.researchgate.net/publication/220982524_The_case_for_dynamic_difficulty_adjustment_in_games

Rosenbaum, D., Leehr, E. J., Kroczek, A., Rubel, J. A., Int-Veen, I., Deutsch, K., Maier, M. J., Hudak, J., Fallgatter, A. J. and Ehlis, A.-C. (2020), 'Neuronal correlates of spider phobia in a combined fNIRS-EEG study', *Scientific Reports* **10**(1), 12597.

URL: *https://doi.org/10.1038/s41598-020-69127-3*

Ross, A. and Willson, V. L. (2017), Paired Samples T-Test, *in* A. Ross and V. L. Willson, eds, 'Basic and Advanced Statistical Tests: Writing Results Sections and Creating Tables and Figures', SensePublishers, Rotterdam, pp. 17–19.

URL: https://doi.org/10.1007/978-94-6351-086-8_4

Roy, M. J., Costanzo, M. E., Jovanovic, T., Leaman, S., Taylor, P., Norrholm, S. D. and Rizzo, A. A. (2013), 'Heart rate response to fear conditioning and virtual reality in subthreshold PTSD', *Studies in Health Technology and Informatics* **191**, 115–119.

Royer, C. and Cooper, B. L. (2013), *The Spectacle of Isolation in Horror Films: Dark Parades*, 0 edn, Routledge.

URL: *https://www.taylorfrancis.com/books/9781136417924*

Ruotsalo, T., Mäkelä, K., Spapé, M. M. and Leiva, L. A. (2023), Affective Relevance: Inferring Emotional Responses via fNIRS Neuroimaging, *in* 'Proceedings of the 46th International ACM SIGIR Conference on Research and Development in Information Retrieval', ACM, New York, NY, USA, pp. 1796–1800.

URL: *https://dl.acm.org/doi/10.1145/3539618.3591946*

Russell, J. A. (1980), 'A circumplex model of affect.', *Journal of Personality and Social Psychology* **39**(6), 1161–1178.
URL: *http://doi.apa.org/getdoi.cfm?doi=10.1037/h0077714*

Russell, J. A. and Mehrabian, A. (1977), 'Evidence for a three-factor theory of emotions', *Journal of Research in Personality* **11**(3), 273–294.

S. Fanselow, M. (1984), 'What is conditioned fear?', *Trends in Neurosciences* **7**(12), 460–462.
URL: *https://linkinghub.elsevier.com/retrieve/pii/S0166223684802532*

Sachar, C. O. (2024), *No More Haunted Dolls: Horror Fiction that Transcends the Tropes*, Vernon Press. Google-Books-ID: xCIGEQAAQBAJ.

Santosa, H., Zhai, X., Fishburn, F. and Huppert, T. (2018), 'The NIRS brain AnalyzIR toolbox', *Algorithms* **11**(5), 73. Publisher: MDPI.

Sarris, A. (1968), *The American cinema : directors and directions, 1929-1968*, New York : Dutton.
URL: *http://archive.org/details/americancinemadi0000sarr*

Schachter, S. and Singer, J. (1962), 'Cognitive, social, and physiological determinants of emotional state.', *Psychological Review* **69**(5), 379–399.
URL: *https://doi.apa.org/doi/10.1037/h0046234*

Schienle, A., Schäfer, A. and Naumann, E. (2008), 'Event-Related Brain Potentials of Spider Phobics to Disorder- Relevant, Generally Disgust- and Fear-Inducing Pictures', *Journal of Psychophysiology* **22**(1), 5–13.
URL: *https://doi.org/10.1027/0269-8803.22.1.5*

Schneider, S. J. (2004), Toward an Aesthetics of Cinematic Horror, *in* 'The Horror Film', Vol. 9780813542, Rutgers University Press New Brunswick, pp. 131–149.

URL: *https://www.degruyter.com/document/doi/10.36019/9780813542577-008/html*

Shao, W., You, Z., Liang, L., Hu, X., Li, C., Wang, W. and Hu, B. (2022), 'A Multi-Modal Gait Analysis-Based Detection System of the Risk of Depression', *IEEE Journal of Biomedical and Health Informatics* **26**(10), 4859–4868.

URL: *https://ieeexplore.ieee.org/document/9585554/*

Shimmer (2025), 'Shimmer3 GSR+ Unit'.

URL: *https://www.shimmersensing.com/product/shimmer3-gsr-unit/*

Shin, D. (2018), 'Empathy and embodied experience in virtual environment: To what extent can virtual reality stimulate empathy and embodied experience?', *Computers in Human Behavior* **78**, 64–73.

URL: *https://linkinghub.elsevier.com/retrieve/pii/S0747563217305381*

Sipos, T. M. (2010), *Horror film aesthetics: creating the visual language of fear*, McFarland & Company, London, England. OCLC: 1045075913.

Skal, D. J. (1993), *The monster show : a cultural history of horror*, New York : Faber and Faber.

URL: *http://archive.org/details/isbn_9780571199969*

Slater, M. (2009), 'Place illusion and plausibility can lead to realistic behaviour in immersive virtual environments', *Philosophical Transactions of the Royal Society B: Biological Sciences* **364**(1535), 3549–3557.

URL: *https://royalsocietypublishing.org/doi/10.1098/rstb.2009.0138*

Slater, M. and 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.

URL: *https://direct.mit.edu/pvar/article/6/6/603-616/18157*

Solomon, R. C. (2004), Real Horror, *in* 'In Defense of Sentimentality', Oxford University PressNew York, pp. 108–130.

URL: *https://academic.oup.com/book/2294/chapter/142422109*

Somech, N., Mizrahi, T., Caspi, Y. and Axelrod, V. (2022), 'Functional near-infrared spectroscopy imaging of the prefrontal cortex during a naturalistic comedy movie', *Frontiers in Neuroscience* **16**, 913540.

URL: *https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9493198/*

Statista (2021), 'Virtual reality (VR) gaming revenue worldwide from 2017 to 2024'.

URL: *https://www.statista.com/statistics/499714/global-virtual-reality-gaming-sales-revenue/*

Statista (2025), 'AR & VR - United Kingdom | Statista Market Forecast'.

URL: *http://frontend.xmo.prod.aws.statista.com/outlook/amo/ar-vr/united-kingdom*

Strangman, G., Franceschini, M. A. and Boas, D. A. (2003), 'Factors affecting the accuracy of near-infrared spectroscopy concentration calculations for focal changes in oxygenation parameters', *NeuroImage* **18**(4), 865–879.

URL: *https://linkinghub.elsevier.com/retrieve/pii/S1053811903000211*

Straßburger, L. (2022), *Humor and Horror: Different Emotions, Similar Linguistic Processing Strategies*, Walter de Gruyter GmbH & Co KG. Google-Books-ID: E_RjEAAAQBAJ.

Sudo, M., Komiyama, T., Aoyagi, R., Nagamatsu, T., Higaki, Y. and Ando, S. (2017), 'Executive function after exhaustive exercise', *European Jour-*

nal of Applied Physiology **117**(10), 2029–2038.
URL: *https://doi.org/10.1007/s00421-017-3692-z*

Summan, R., Pierce, S., Macleod, C., Dobie, G., Gears, T., Lester, W., Pritchett, P. and Smyth, P. (2015), 'Spatial calibration of large volume photogrammetry based metrology systems', *Measurement* **68**, 189–200.
URL: *https://linkinghub.elsevier.com/retrieve/pii/S0263224115001189*

Tak, S. and Ye, J. C. (2014), 'Statistical analysis of fNIRS data: A comprehensive review', *NeuroImage* **85**, 72–91.
URL: *https://linkinghub.elsevier.com/retrieve/pii/S1053811913006538*

Tan, S.-L., Spackman, M. P. and Bezdek, M. A. (2007), 'Viewers' Interpretations of Film Characters' Emotions: Effects of Presenting Film Music Before or After a Character is Shown', *Music Perception* **25**(2), 135–152.
URL: *https://online.ucpress.edu/mp/article/25/2/135/95283/Viewers-Interpretations-of-Film-Characters*

Tang, T. B., Chong, J. S., Kiguchi, M., Funane, T. and Lu, C.-K. (2021), 'Detection of Emotional Sensitivity Using fNIRS Based Dynamic Functional Connectivity', *IEEE Transactions on Neural Systems and Rehabilitation Engineering* **29**, 894–904.
URL: *https://ieeexplore.ieee.org/document/9427242*

Tennent, P., Hook, K. and Benford, S. (2021), Articulating Soma Experiences using Trajectories, *in* 'Conference on Human Factors in Computing Systems - Proceedings', ACM, New York, NY, USA, pp. 1–16. Series Title: CHI '21.
URL: *https://dl.acm.org/doi/10.1145/3411764.3445482*

Thayer, J. F. and Levenson, R. W. (1983), 'Effects of music on psychophysiological responses to a stressful film.', *Psychomusicology: A Journal of*

Research in Music Cognition **3**(1), 44–52.
URL: *https://doi.apa.org/doi/10.1037/h0094256*

Tomkins, S. S. (1962), *Affect Imagery Consciousness: The Positive Affects*, Vol. 1, Springer, New York.

Trevor, C., Arnal, L. H. and Frühholz, S. (2020), 'Terrifying film music mimics alarming acoustic feature of human screams', *The Journal of the Acoustical Society of America* **147**(6), EL540–EL545.
URL: *https://pubs.aip.org/jasa/article/147/6/EL540/965901/Terrifying-film-music-mimics-alarming-acoustic*

Trevor, C., Renner, M. and Frühholz, S. (2023), 'Acoustic and structural differences between musically portrayed subtypes of fear', *The Journal of the Acoustical Society of America* **153**(1), 384–399.
URL: *https://pubs.aip.org/jasa/article/153/1/384/2873585/Acoustic-and-structural-differences-between*

Trigeorgis, G., Ringeval, F., Brückner, R., Marchi, E., Nicolaou, M., Schuller, B. and Zafeiriou, S. (2016), Adieu Features? End-to-End Speech Emotion Recognition using a Deep Convolutional Recurrent Network, *in* 'Proc.\ of ICASSP', IEEE, Shanghai, P.R.\ China, pp. 5200–5204.

Turbo-Satori (n.d.), 'Turbo-Satori: Real-Time Analysis Software | fNIRS Systems | NIRS Devices | NIRx'.
URL: *https://nirx.net/turbosatori*

Unity (2025), 'Unity Real-Time Development Platform | 3D, 2D, VR & AR Engine'.
URL: *https://unity.com*

Upton, G. and Cook, I. (2008), *A Dictionary of Statistics*, 2 edn, Oxford

University Press.
URL: *http://www.oxfordreference.com/view/10.1093/acref/9780199541454.001.0001/ac*
9780199541454

Ursu, M., Smith, D., Hook, J., Concannon, S. and Gray, J. (2020), Authoring Interactive Fictional Stories in Object-Based Media (OBM), *in* 'Proceedings of the 2020 ACM International Conference on Interactive Media Experiences', IMX '20, Association for Computing Machinery, New York, NY, USA, pp. 127–137.
URL: *https://doi.org/10.1145/3391614.3393654*

Vachiratamporn, V., Moriyama, K., Fukui, K.-i. and Numao, M. (2014), An implementation of affective adaptation in survival horror games, *in* '2014 IEEE Conference on Computational Intelligence and Games', IEEE, pp. 1–8.
URL: *http://ieeexplore.ieee.org/document/6932893/*

Valstar, M. and Pantic, M. (2006), Biologically vs. Logic Inspired Encoding of Facial Actions and Emotions in Video, *in* '2006 IEEE International Conference on Multimedia and Expo', IEEE, pp. 325–328.
URL: *http://ieeexplore.ieee.org/document/4036602/*

Valve (2025), 'Steam, The Ultimate Online Game Platform'.
URL: *https://store.steampowered.com/about/*

Venture, G., Kadone, H., Zhang, T., Grèzes, J., Berthoz, A. and Hicheur, H. (2014), 'Recognizing Emotions Conveyed by Human Gait', *International Journal of Social Robotics* **6**(4), 621–632.
URL: *http://link.springer.com/10.1007/s12369-014-0243-1*

Victoria, C. and Braun, V. (2014), Thematic Analysis, *in* T. Teo, ed., 'Encyclopedia of Critical Psychology', Springer New York, New York,

NY, pp. 1947–1952.

URL: https://doi.org/10.1007/978-1-4614-5583-7_311

Virtual Go LLC (2022), 'Hauntify Mixed Reality on Meta Quest'.

URL: *https://www.meta.com/en-gb/experiences/hauntify-mixed-reality/4130979187008353/*

VIVE (2023), 'VIVE Full Face Tracker - Eye and Face Tracking on VIVE XR Elite'.

URL: *https://www.vive.com/uk/accessory/vive-full-face-tracker/*

Voigt-Antons, J. N., Spang, R., Kojic, T., Meier, L., Vergari, M. and Muller, S. (2021), Don't worry be happy - Using virtual environments to induce emotional states measured by subjective scales and heart rate parameters, *in* 'Proceedings - 2021 IEEE Conference on Virtual Reality and 3D User Interfaces, VR 2021', IEEE, pp. 679–686.

URL: *https://ieeexplore.ieee.org/document/9417782/*

von Lühmann, A., Ortega-Martinez, A., Boas, D. A. and Yücel, M. A. (2020), 'Using the General Linear Model to Improve Performance in fNIRS Single Trial Analysis and Classification: A Perspective', *Frontiers in Human Neuroscience* **14**.

URL: *https://www.frontiersin.org/article/10.3389/fnhum.2020.00030/full*

Wang, F., Mao, M., Duan, L., Huang, Y., Li, Z. and Zhu, C. (2018), 'Inter-session Instability in fNIRS-Based Emotion Recognition', *IEEE Transactions on Neural Systems and Rehabilitation Engineering* **26**(7), 1324–1333.

URL: *https://ieeexplore.ieee.org/abstract/document/8370130*

Weinel, J. and Cunningham, S. (2021), Practice-led and Interdisciplinary Research: Investigating Affective Sound Design, *in* 'Doing Research in Sound Design', Focal Press. Num Pages: 18.

Weixuan Chen, Jaques, N., Taylor, S., Sano, A., Fedor, S. and Picard, R. W. (2015), Wavelet-based motion artifact removal for electrodermal activity, *in* '2015 37th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC)', IEEE, Milan, pp. 6223–6226.
URL: *http://ieeexplore.ieee.org/document/7319814/*

Wilcoxon, F. (1945), 'Individual Comparisons by Ranking Methods', *Biometrics Bulletin* **1**(6), 80–83. Publisher: [International Biometric Society, Wiley].
URL: *https://www.jstor.org/stable/3001968*

Wisker, G. (2006), Behind Locked Doors: Angela Carter, Horror and the Influence of Edgar Allan Poe, *in* R. Munford, ed., 'Re-visiting Angela Carter: Texts, Contexts, Intertexts', Palgrave Macmillan UK, London, pp. 178–198.
URL: https://doi.org/10.1057/9780230595873_9

Witmer, B. G. and Singer, M. J. (1998), 'Measuring Presence in Virtual Environments: A Presence Questionnaire', *Presence: Teleoperators and Virtual Environments* **7**(3), 225–240.
URL: *https://direct.mit.edu/pvar/article/7/3/225-240/92643*

Worland, R. (2024), *The Horror Film: An Introduction*, John Wiley & Sons. Google-Books-ID: _O4YEQAAQBAJ.

Wright, P., Blythe, M. and McCarthy, J. (2006), User Experience and the Idea of Design in HCI, *in* D. Hutchison, T. Kanade, J. Kittler, J. M. Kleinberg, F. Mattern, J. C. Mitchell, M. Naor, O. Nierstrasz, C. Pandu Rangan, B. Steffen, M. Sudan, D. Terzopoulos, D. Tygar, M. Y. Vardi, G. Weikum, S. W. Gilroy and M. D. Harrison, eds, 'Interactive Systems. Design, Specification, and Verification', Vol. 3941,

Springer Berlin Heidelberg, Berlin, Heidelberg, pp. 1–14. Series Title: Lecture Notes in Computer Science.

URL: *http://link.springer.com/10.1007/11752707_1*

Wu, T., Yuan, Y.-J., Zhang, L.-X., Yang, J., Cao, Y.-P., Yan, L.-Q. and Gao, L. (2024), 'Recent advances in 3D Gaussian splatting', *Computational Visual Media* **10**(4), 613–642.

URL: *https://doi.org/10.1007/s41095-024-0436-y*

Wu, Y., Gu, R., Yang, Q. and Luo, Y.-j. (2019), 'How Do Amusement, Anger and Fear Influence Heart Rate and Heart Rate Variability?', *Frontiers in Neuroscience* **13**, 1131.

URL: *https://www.frontiersin.org/article/10.3389/fnins.2019.01131/full*

Zaib, S. E. and Yamamura, M. (2022), Using Heart Rate and Machine Learning for VR Horror Game Personalization, *in* 'IEEE Conference on Computatonal Intelligence and Games, CIG', Vol. 2022-Augus, IEEE, pp. 213–220. ISSN: 23254289.

URL: *https://ieeexplore.ieee.org/document/9893723/*

Zhang, H., Li, X., Qiu, C. and Fu, X. (2023), Decoding Fear: Exploring User Experiences in Virtual Reality Horror Games, *in* 'Proceedings of the Eleventh International Symposium of Chinese CHI', ACM, Denpasar, Bali Indonesia, pp. 411–419.

URL: *https://dl.acm.org/doi/10.1145/3629606.3629646*

Zhong, R., Li, M., Chen, Q., Li, J., Li, G. and Lin, W. (2019), 'The P300 Event-Related Potential Component and Cognitive Impairment in Epilepsy: A Systematic Review and Meta-analysis', *Frontiers in Neurology* **10**, 943.

URL: *https://www.frontiersin.org/article/10.3389/fneur.2019.00943/full*

Zhu, J., Ji, L. and Liu, C. (2019), 'Heart rate variability monitoring for emotion and disorders of emotion', *Physiological Measurement* **40**(6), 064004.

Zimmer, A., Wang, N., Ibach, M. K., Fehlmann, B., Schicktanz, N. S., Bentz, D., Michael, T., Papassotiropoulos, A. and de Quervain, D. J. F. (2021), 'Effectiveness of a smartphone-based, augmented reality exposure app to reduce fear of spiders in real-life: A randomized controlled trial', *Journal of Anxiety Disorders* **82**, 102442.
URL: *https://www.sciencedirect.com/science/article/pii/S088761852100089X*

Öhman, A. and Soares, J. J. F. (1994), '"Unconscious anxiety": Phobic responses to masked stimuli.', *Journal of Abnormal Psychology* **103**(2), 231–240.
URL: *https://doi.apa.org/doi/10.1037/0021-843X.103.2.231*
ΩŠimić et al.

Šimić, G., Tkalčić, M., Vukić, V., Mulc, D., Španić, E., Šagud, M., Olucha-Bordonau, F. E., Vukšić, M. and R. Hof, P. (2021), 'Understanding emotions: Origins and roles of the amygdala', *Biomolecules* **11**(6), 823. Publisher: MDPI.

Appendices

Appendix A

Study 1: Neurophysiological Experiment on Fear

A.1 Ethics Forms

PROJECT INFORMATION



University of Nottingham
UK | CHINA | MALAYSIA

Date: 20/12/2022

Project: A study on the physiological understanding of fear, using a variety of different biodata readers

School of Computer Science Ethics Reference: CS-2022-R39

Funded by: EPSRC / Horizon CDT

Purpose of the research. The aim of this study is to collect physiological data whilst a user is engaged in a fear-based virtual reality environment. This will consist of a series of 3 calming videos and 3 horror videos, designed to induce fear within an individual and calm an individual for comparability. The aim of this study is to understand which biodata readers will be best used for a personalised virtual reality horror experience. The biodata readers to be used within this study are:

- Octamon – functional near infrared spectroscopy (fNIRS) (brain data)
- Nexus-10 Mk1 – heart rate, skin conductance, temperature, respiration

These will be attached to the participant whilst they are engaged with the experience. Application can be done by the participant or study convenor.

Nature of participation. Participation in this research is voluntary but is reliant on the user being monitored and providing preliminary data about fear in an interview stage before the experiment begins and throughout the study.

Participant engagement. By taking part in the research, the participant will be required to carry out an interview about their response to fear before being able to partake in the experiment directly. They will then be placed into each virtual reality experience with a Nexus-10 Mk1 device and fNIRS device attached to their person which will monitor their brain activity, heart rate, skin conductance, temperature and respiration throughout the experience. Individuals will be recorded whilst taking part in the virtual reality experience. Additionally, throughout the study, the participants will be asked questions on their fears, what they have experienced and how the experience made them feel.

Benefits and risks of the research. This data can help us understand how we can create personalised experiences for users and adapt experiences dynamically for users, pathing the way for more personalised experiences in the future. As this is a horror experience, there will be risks of stress and anxiety induced by the surroundings and interactions, but this should be no more than playing a horror game or watching a horror movie.

Use of your data. The data gathered will be used and analysed within project meetings and reports for the purposes of the research. All data will be anonymised before use where possible. The data may be used within academic papers and within the PhD thesis.

Future use of your data. The data will be archived after use within this project and stored securely on an encrypted hard drive disconnected from any computer network. The advantage of storing such data is to provide value towards future research within a similar field of study.

Procedure for withdrawal from the research. You may withdraw from the study at any time and do not have to give reasons for why you no longer want to take part. If you wish to withdraw please contact the researcher who gathered the data. If you receive no response from the researcher please contact the School of Computer Science's Ethics Committee.

Contact details of the ethics committee. If you wish to file a complaint or exercise your rights you can contact the Ethics Committee at the following address: cs-ethicsadmin@cs.nott.ac.uk

CONSENT FORM

University of Nottingham
UK | CHINA | MALAYSIA

Date: 20/12/2022

Project: A study on the physiological understanding of fear, using a variety of different biodata readers

School of Computer Science Ethics Reference: CS-2022-R39

Funded by: EPSRC / Horizon CDT

Please tick the appropriate boxes	**Yes**	**No**
1. Taking part in the study		
a) I have read and understood the project information sheet dated 20/12/2022, or it has been read to me. I have been able to ask questions about the study and my questions have been answered satisfactorily.	☐	☐
b) I consent voluntarily to be a participant in this study and understand that I can refuse to answer questions and I can withdraw from the study at any time, without having to give a reason.	☐	☐
c) I understand that in taking part in the study there is a potential risk of stress and anxiety induced by the surroundings and interactions	☐	☐
d) I understand that taking part in the study requires me to provide data and that this will involve a video recorded interview about my thoughts on fear as well as the collection of brain activity data and physiological data throughout the experiment	☐	☐
2. Use of my data in the study		
a) I understand that data which can identify me will not be shared beyond the project team.	☐	☐
b) I agree that the data provided by me may be used for the following purposes:		
– Presentation and discussion of the project and its results in research activities (e.g., in supervision sessions, project meetings, conferences).	☐	☐
– Publications and reports describing the project and its results.	☐	☐
– Dissemination of the project and its results, including publication of data on web pages and databases.	☐	☐
c) I give permission for my words to be quoted for the purposes described above.	☐	☐
d) I give permission for my visual image contained in photos or video gathered during the research to be used for the purposes described above.	☐	☐

Please tick the appropriate boxes	Yes	No

3. Reuse of my data

a) I give permission for the data that I provide to be reused for the sole purposes of future research and learning.	☐	☐
b) I understand and agree that this may involve depositing my data in a data repository, which may be accessed by other researchers	☐	☐

4. Security of my data

a) I understand that safeguards will be put in place to protect my identity and my data during the research, and if my data is kept for future use.	☐	☐
b) I confirm that a written copy of these safeguards has been given to me in the University's privacy notice, and that they have been described to me and are acceptable to me.	☐	☐
c) I understand that no computer system is completely secure and that there is a risk that a third party could obtain a copy of my data.	☐	☐

5. Copyright

a) I give permission for data gathered during this project to be used, copied, excerpted, annotated, displayed and distributed for the purposes to which I have consented.	☐	☐
b) I wish to be publicly identified as the creator of the following works - Video recording of interview	☐	☐

6. Signatures (sign as appropriate)

Name of participant (IN CAPITALS)	Signature	Date

If applicable:

For participants unable to sign their name, mark the box instead of signing ☐

I have witnessed the accurate reading of the consent form with the participant and the individual has had the opportunity to ask questions. I confirm that the individual has given consent freely.

Name of witness (IN CAPITALS)	Signature	Date

I have accurately read out the information sheet to the potential participant and, to the best of my ability, ensured that the participant understands to what they are freely consenting.

Name of researcher CALLUM BERGER Signature Date

7. Researcher's contact details

Name: Callum Berger

Phone: 07501768896

Email: callum.berger@nottingham.ac.uk

Provide the participant with a copy of the completed form either by email or hard copy as they prefer.

A.2 Questionnaire Data

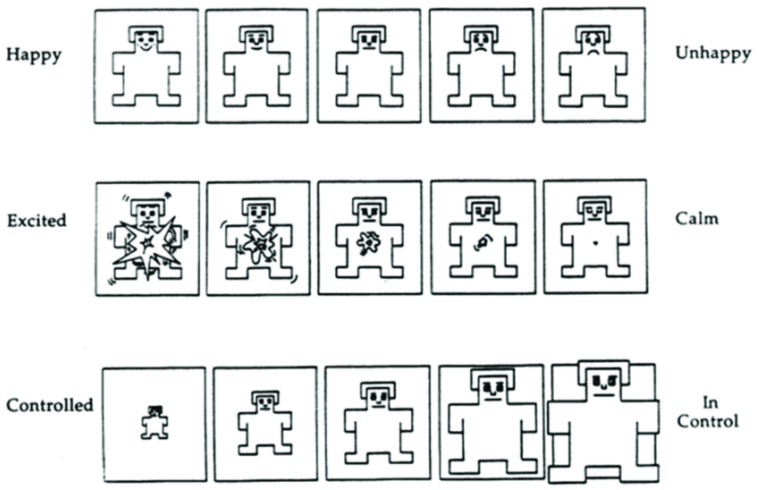


Figure A.1: The Self-Assessment Mannequin used within the VE. The top row refers to valence, the second row refers to arousal, and the bottom row refers to dominance.

Appendix B

Study 2: Defining the Horror for Adaptation - Horror Filmmaker Interviews

B.1 Ethics Forms

PROJECT INFORMATION



University of Nottingham
UK | CHINA | MALAYSIA

Date: 19/10/2023

Project: Study 2: Horror Film Maker Interviews into Design and Creation of Horror and Potential Directions for Adaptation

School of Computer Science Ethics Reference: CS-2022-R39

Funded by: EPSRC / Horizon CDT

Purpose of the research. The aim of this study is to interview film makers focused on the horror genre. We hope to gain insight into the language and grammar that is in use, the tools and structures put in place, and the thinking and design that goes into the creation of a horror film. We wish to bridge the gap between the technical and creative sides of horror film creation.

Interviews will also delve into the film makers thoughts on the use of adaptation for horror, whether this would be a useful application and the implications adaptation may have on the narrative and creative aspects.

Nature of participation. Participation in this research is voluntary but involves the interviewing of participants, recording the audio throughout.

Participant engagement. By taking part in the research, the participant will be asked a variety of questions relating to the creation of horror films from a design perspective as well as their thoughts on the use of real-time adaptation for use within horror films and experiences.

Benefits and risks of the research. This data can help us understand how we can create an adaptive horror experiences for user, the tools and structures to doing so and the correct way to express the grammar and language used within the industry.

Use of your data. The data gathered will be used and analysed within project meetings and reports for the purposes of the research. Data will be anonymised upon request before use where possible. The data may be used within academic papers and within the PhD thesis. Data may also be used for promotional purposes upon request. Audio used for promotion refers to use of audio that relates to views on adaptation within the horror genre.

Future use of your data. The data will be archived after use within this project and will be securely stored on the University of Nottingham OneDrive. The advantage of storing such data is to provide value for future research within a similar field of study.

Procedure for withdrawal from the research. You may withdraw from the study at any time and do not have to give reasons for why you no longer want to take part. If you wish to withdraw please contact the

researcher who gathered the data. If you receive no response from the researcher please contact the School of Computer Science's Ethics Committee.

Contact details of the ethics committee. If you wish to file a complaint or exercise your rights you can contact the Ethics Committee at the following address: cs-ethicsadmin@cs.nott.ac.uk

CONSENT FORM

University of Nottingham
UK | CHINA | MALAYSIA

Date: 20/12/2022

Project: Study 2: Horror Film Maker Interviews into Design and Creation of Horror and Potential Directions for Adaptation.

School of Computer Science Ethics Reference: CS-2022-R39

Funded by: EPSRC / Horizon CDT

Please tick the appropriate boxes	**Yes**	**No**
1. Taking part in the study		
a) I have read and understood the project information sheet dated 20/12/2022, or it has been read to me. I have been able to ask questions about the study and my questions have been answered satisfactorily.	☐	☐
b) I consent voluntarily to be a participant in this study and understand that I can refuse to answer questions and I can withdraw from the study at any time, without having to give a reason.	☐	☐
c) I understand that taking part in the study requires me to provide data and that this will involve an audio recorded interview about my thoughts on the horror genre and the use of adaptation within horror.	☐	☐
2. Use of my data in the study		
a) I understand that data which can identify me will not be shared beyond the project team.	☐	☐
b) I agree that the data provided by me may be used for the following purposes:		
– Presentation and discussion of the project and its results in research activities (e.g., in supervision sessions, project meetings, conferences).	☐	☐
– Publications and reports describing the project and its results.	☐	☐
– Dissemination of the project and its results, including publication of data on web pages and databases.	☐	☐
– Promotion of future works relating to adaptation of horror experiences using audio collected throughout the interview. Audio used would be focused on how adaptation may a useful or interesting concept within the horror genre	☐	☐
c) I give permission for my words to be quoted for the purposes described above.	☐	☐
d) I give permission for my visual image contained in photos or video gathered during the research to be used for the purposes described above.	☐	☐

Please tick the appropriate boxes	Yes	No

3. Reuse of my data

a) I give permission for the data that I provide to be reused for the sole purposes of future research and learning.	☐	☐
b) I understand and agree that this may involve depositing my data in a data repository, which may be accessed by other researchers	☐	☐

4. Security of my data

a) I understand that safeguards will be put in place to protect my identity and my data during the research, and if my data is kept for future use.	☐	☐
b) I confirm that a written copy of these safeguards has been given to me in the University's privacy notice, and that they have been described to me and are acceptable to me.	☐	☐
c) I understand that no computer system is completely secure and that there is a risk that a third party could obtain a copy of my data.	☐	☐

5. Copyright

a) I give permission for data gathered during this project to be used, copied, excerpted, annotated, displayed and distributed for the purposes to which I have consented.	☐	☐
b) I wish to be publicly identified as the creator of the following works - Video recording of interview	☐	☐

6. Signatures (sign as appropriate)

Name of participant (IN CAPITALS)	Signature	Date

If applicable:

For participants unable to sign their name, mark the box instead of signing ☐

I have witnessed the accurate reading of the consent form with the participant and the individual has had the opportunity to ask questions. I confirm that the individual has given consent freely.

Name of witness (IN CAPITALS)	Signature	Date

I have accurately read out the information sheet to the potential participant and, to the best of my ability, ensured that the participant understands to what they are freely consenting.

Name of researcher CALLUM BERGER Signature Date

7. Researcher's contact details

Name: Callum Berger

Phone: 07501768896

Email: callum.berger@nottingham.ac.uk

Provide the participant with a copy of the completed form either by email or hard copy as they prefer.

B.2 Questionnaire Data

B.3 Horror Filmmaker Interview Questions

B.3.1 Introduction

- Do you consider yourself as a horror film director?
- How long have you been making horror films?
- Have you ever made films within different genres?
- What interests you about horror films?

B.3.2 Interpreting the Horror Genre

- What makes a horror film?
- What elements are important when creating an effective horror film?
- What tools and structures of the horror genre do you use?
- Are there tools and structures from outside the horror genre that you employ?
- Have you ever experienced Virtual Reality and/or considered creating a Virtual Reality horror film?

B.3.3 Understanding the Audience

- Are there other outside influences that limit your ability to create the horror you would like to?

- How do you know if you've made an effective horror film for your audience?
- Do you have a set creative process that you follow?
- Who is your audience? How do you define the audience for your film?
- How do you gauge the horror limitations of your audience? (e.g., do you hold back?)

B.3.4 Audience Journey and Engagement

- Do you consider the audience's journey?
- When do you consider the audience's journey and with whom?
- How would you differ the audience journey you create for a horror film as opposed to other genres?
- What is your priority of the audience's journey with respect to other aspects of film making? (e.g., tone, plot, budget)
- As a director, which departments do you interact with to ensure the audience journey is kept in focus?

B.3.5 Adaptation of Fear

- Have you ever made a film that you wish you could show multiple versions of? (e.g., Director's cut, Extended cut, Theatrical cut, and cuts for different countries)
- How would you feel about the use of real-time adaptation in horror films? (e.g., changing the visuals and audio to induce or reduce fear in a viewer)

- How would you feel about watching a horror film that could sense when you're afraid and adapt to that?
- What impacts do you think adaptation could have on a viewer's experience?
- What impacts do you think adaptation would have on your process of the design and creation of horror films?
- What would you consider are the barriers to making adaptive horror movies?

Appendix C

Study 3a: Evaluation of A Place For Everyone: In the Wild

C.1 Ethics Forms

School of Computer Science
University of Nottingham

Section B. Information to be provided to research participants

PROJECT TITLE: Study 3a: A Place for Everyone – Public Study

1. The research
a) Aims and objectives of the research
Controlled Lab Study This study involves watching a horror VR experience that adapts in response to the fear processing called 'A Place for Everyone'. The experience will consist of watching 2 repeated short virtual reality adaptive horror experiences. These experiences will range from 5 – 9 minutes in length totalling a 30-minute experience. You will be taken through a narrative that involves violence, death, and strong language. As so it will be limited to an 18+ audience. A demographic questionnaire will be completed prior to participants undergoing the experience. This will be anonymous and collect Age, Gender, and Ethnicity. This data will be used to evaluate potential links between brain activity data and GSR data throughout the experience in relation to the demographics collected. Before the experience starts, a calibration phase will understand your threshold to fear through you watching a series of repeated fear videos in VR. These are designed to understand your tolerance to fear so that the experience adapts correctly. The first repeated scene will be adaptive in both viewings to understand whether the second viewing produces a different experience. The second repeated scene will initially be non-adaptive and then adaptive on the repeat viewing. This is designed to see if the adaptive version of the scene alters the experience as opposed to the non-adaptive version. As an adaptive horror experience, elements will be altered in real-time within the experience based upon fear processing feedback from an fNIRS brain scanner. Alterations include visuals and audio in response. The experience is outright designed to push participants to experience fear, but not beyond their own limit. Once fear is inferred within an individual, no further increase in adaptation will occur. GSR data will be collected to understand if this data could be applied alongside the fNIRS data in the future to get a more accurate depiction of an individual's fear state. fNIRS data will be collected to ensure that the experience is behaving as intended and validate the use of adaptation. You will also be asked to fill in a presence questionnaire and soma trajectory mapping after each scene. These will be introduced and explained in detail before the experience starts. There will also be an interview after the experience to engage with your thoughts and ideas on the experience and understand ways in which the experience could be improved and further developed.

Collected physiological data (Brain data and GSR) will be anonymous, identified by an ID only. Audio data will be anonymised once transcribed. Any audio data containing identifying data (e.g. names) could be used to identify an individual and are therefore advised not to use.

Collected data will be anonymous.

Performance Led Study

This study involves watching a horror VR experience that adapts in response to the fear processing called 'A Place for Everyone'.

The experience will consist of watching the virtual reality adaptive horror experience. The study should take around 60 minutes in length. You will be taken through a narrative that involves violence, death, and strong language. As so it will be limited to an 18+ audience.

A demographic questionnaire will be completed prior to participants undergoing the experience. This will be anonymous and collect Age, Gender, and Ethnicity. This data will be used to evaluate potential links between brain activity data and GSR data throughout the experience in relation to the demographics collected.

Before the experience starts, a calibration phase will understand your threshold to fear through you watching a series of repeated fear videos in VR. These are designed to understand your tolerance to fear so that the experience adapts correctly.

As an adaptive horror experience, elements will be altered in real-time within the experience based upon fear processing feedback from an fNIRS brain scanner. Alterations include visuals and audio in response. The experience is outright designed to push participants to experience fear, but not beyond their own limit. Once fear is inferred within an individual, no further increase in adaptation will occur.

You will then be interviewed after the experience to engage with your thoughts and ideas on the experience and understand ways in which the experience could be improved and further developed.

Collected data will be anonymised. Any audio data and bio data will be stored anonymously and audio data will be transcribed.

Audio will be recorded using a mobile recording device. Audio data will then be uploaded to the OneDrive for storage before being wiped from the personal device. Google Recorder will be used for this and ensures no third-party data sharing. This also encrypts data and allows permanent deletion.

b) Funder information

N/A

c) Governance

This research has been approved by the School of Computer Science Research Ethics Committee (CS REC), ethics application ID: CS-2023-R10

2. Taking part in the research

Participants will watch a 30-minute adaptive VR experience around climate change.

Participant interview recordings will be anonymised through transcription. Audio data can be identified if names are used and are therefore advised otherwise.

Individual participant data will be connected through a secure key to ensure that the data can be withdrawn if requested without removing anonymity.

Interviews involve a series of questions about the experience and the use of real-time adaptation.

3. Risks of participation

a) Risks

There is always a risk of unauthorised access to data.

b) Mitigation of risks

See section 5 for the measures we put in place to mitigate the risk of unauthorised access.

Participants can withdraw from or pause the interview at any time.

A mapping of the participant identifiers will be securely stored on the OneDrive. This allows for anonymisation of all data with a link between different participant data without easy identification of a participant's collected data. This mapping will be removed on 01/12/2024, when writing of study results begins and the mapping is no longer needed.

The participant is not required to give a response to any question if they feel uncomfortable to do so.

4. Purpose of data processing

a) Data collected

We collect the following categories of data during your participation in the research:

fNIRS Activity Data
Galvanic Skin Response Data
Audio recordings of the interviews

b) Specific purposes for which the data are processed

Data collected during the research that identifies you may be:

- Analysed to meet the aims and objectives described in Section 1.

- Reviewed and discussed in supervision sessions between researchers and their supervisors or in research meetings between members of the research team, including project partners.
- If audio recordings are collected during the research, these will be transcribed and made anonymous. Anonymous quotations of your spoken words may be used in scientific works, including presentations, reports and publications stored in databases and posted online, and in marketing materials that promote the research and its findings.

c) Automated decision-making and profiling

N/A

d) Legal basis for processing your data

We collect personal data under the terms of the University of Nottingham's Royal Charter and in our capacity as a teaching and research body to advance education and learning. We thus process your data on the legal basis that our research is in the public interest, we have legitimate interests and / or that you consent to data processing in freely and voluntarily participating in our research activities.

5. Storage and retention of your data

a) Data protection measures

We put the following organisational and / or technical safeguards in place to protect your data and your identity to the best of our ability:

i) All data will be securely stored on the University of Nottingham OneDrive.

b) Retention period

Data protection law allows us to retain personal data for an indefinite period and use it in future for public interest, scientific or historical research purposes or statistical purposes, subject to the implementation of technical and organisational measures that safeguard your data, your legal rights and your freedoms. These safeguards include the storage measures described above to protect your data against unauthorised access, and de-identification (anonymisation or pseudonymisation) of your data wherever possible and practicable. Data that identifies or could identify you will not be made public without your consent.

6. Third party recipients, services and data transfers

a) Project partners

Data will not be shared with others

b) Third-party services

N/A

c) Data transfers

Data will not be transferred to another country

7. Your legal rights

Data protection rights (Data Protection Act 2018)

You have the right:

- To be informed about the collection and use of personal data (as per this document).

- To access and receive a copy of your personal data, and other supplementary information, on request.
- To object to and restrict data processing if you think we are not complying with data protection law, and to rectify inaccuracies.
- To be forgotten, i.e., to have your personal data erased.
- To data portability and to obtain your data in an accessible and machine-readable format if appropriate, or to transfer your data to another organisation if technically feasible.
- To complain to about the way we process your personal data to our ethics committee (cs-ethicsadmin@cs.nott.ac.uk), our Data Protection Officer (dpo@nottingham.ac.uk) or the Information Commissioner's Office (https://ico.org.uk/make-a-complaint).*

Joint authorship in copyright works (Copyright, Designs and Patents Act 1988)

Joint authorship applies if participants are actively engaged in making original works as part of the research. The key criteria for determining joint authorship are 1) that original works created during the research could be copyright protected;[1] 2) that participants collaborate in their creation; 3) that participants make a contribution to the work's creation that a) cannot be distinguished from the contribution of any other 'author' involved (if their contributions can be distinguished then two or more separate works exist) and b) the work's creation relies on participants' skills and labour. If *all* of these criteria apply, then participants are joint authors and should be offered the opportunity to be acknowledged as such.

You may, if you wish, be acknowledged and publicly identified as joint author of the interview recording of the involvement in the experiment for 'A Place for Everyone'. **Affirming your right to be acknowledged as joint author may affect your anonymity.**

8. Your ethical rights

a) Right to withdraw

You have the right to withdraw from the research at any time without explanation. You also have the right to request that your data be deleted if you do withdraw. Please note that I will begin amalgamating and writing up the study findings from 01/12/2024. At that point I will not be able to remove your data so I will not be able to fulfil a request to withdraw.

b) Handling of 'mixed' data

If the data is 'mixed' data – i.e., if it involves other people (not including the researchers), e.g., a conversation or video of multi-party interaction – it cannot be deleted unless **all parties** request it. However, any mixed data involving you will be redacted wherever possible, with the exception of scientific works produced prior to your notification of withdrawal.

c) Withdrawal procedure

If you wish to withdraw, please notify ***researcher insert your name and email address***

If you do not receive confirmation of withdrawal from the research, please email cs-ethicsadmin@cs.nott.ac.uk

* Our DPO's postal address is Data Protection Officer, Legal Services, A5 Trent Building, University of Nottingham, University Park, Nottingham NG7 2RD.

[1] Copyright protected works include literary works (webpages and computer programs as well books, etc.); databases, whether paper or electronic; dramatic and musical works; artistic works (including photographs and maps); typographical arrangements; sound recordings; films, videos and broadcasts. Copyright covers every medium in which work exists, including the Internet. Copyright does not cover ideas, products or processes (see IP law instead).

9. Consent to participate	
a) I consent to participate in the research and my signature or mark confirms the following: • I understand the aims and objectives of the research • I understand what the research requires me to do • I accept the risks of participation • I understand what data will be collected and the purposes for which the data will be used • I understand safeguards will be put in place to protect my data and my legal rights • I understand I will not be identified unless the use of identifiable data has been requested and I consent to it • I understand that I can withdraw at any time without explanation • I have been able to ask questions about the research, my participation, and my data and my questions have been answered satisfactorily • I agree to participate and my participation is voluntary	***Signature or mark:***
b) Opt out. I do not consent to use of my interview recording data in scientific works or materials that promote the research and its results	
c) Opt in. I wish to affirm my right to be acknowledged as joint author of original works created in this research and understand this may affect my anonymity	

Name of participant(s)	
Date	
Witness *If participant(s) cannot sign*	*In signing I confirm the participant(s) named above have been fully informed about the research, have been able to ask questions, and consent freely.*

C.2 Questionnaire Data

C.3 A Place for Everyone - In Situ Questionnaire

1. How did you find it?
2. Are there any key moments that stood out to you?
3. Would you consider this a horror experience?
4. Did you feel it was effective as a horror?
5. Would you consider yourself as a consumer of horror?
6. Did you notice the changes caused by adaptation?
7. How did the adaptation effect your experience?
8. When something changed, did the changes increase the amount of fear you experienced?
9. How do you think an adaptive system could be used?
10. How could an adaptive system be negatively used / abused?
11. How did you feel your brain data was being used?

Appendix D

Study 3b: Evaluation of A Place for Everyone: Controlled Lab Study

D.1 Ethics Forms

School of Computer Science
University of Nottingham

Section B. Information to be provided to research participants

PROJECT TITLE: Study 3: A Place for Everyone VR Experience – Controlled Lab Study

1. The research
a) Aims and objectives of the research
Controlled Lab Study This study involves watching a horror virtual reality (VR) experience called 'A Place for Everyone' whilst measuring fNIRS brain activity and GSR. It's likely this will take around 50 minutes for the whole study and you will be offered a £10 amazon voucher for your help with this research. The research is aiming to investigate how we can understand the effectiveness of Functional Near-Infrared Spectroscopy (fNIRS) and Galvanic Skin Response (GSR) in a virtual reality horror experience. fNIRS is a brain scanner used to measure oxygenation in the brain, while GSR is used to measure changes in skin conductance in the hand The experience will consist of two parts. Part 1 will be a calibration phase, where you will watch 4 VR horror clips (30 seconds) and rate each one on a fear scale of 1 – 5. After this you will rank the videos in order of fearfulness and chose one that best represents a level of fear for you. This then leads into part 2, where you experience a VR horror experience. This consists of watching 6 scenes. These scenes will range from 2 – 8 minutes in length totalling a 30-minute experience. The experience will involve taking the viewpoint of different characters in a post-climate crisis world, taking you through a narrative that involves violence, death, and strong language. As so it will be limited to an 18+ audience. FNIRS and GSR data will be collected to understand your fear within the experience and see if it's possible to get an accurate depiction of an individual's fear state. fNIRS is a brain scanner used to measure oxygenation in the brain, while GSR is used to measure changes in skin conductance in the hand. The equipment used for this will be an Octamon fNIRS headset, SHIMMER GSR device and Oculus Quest 3 VR headset. You will also be asked to fill in a presence questionnaire and fear trajectory mapping after each scene. The presence questionnaire asks a series of questions to measure your sense of presence within the virtual environment. Fear trajectory mapping asks the participant to map their fear (y axis) over time (x axis) throughout the scene just watched. This data is used to provide instant feedback on each scene. These will be introduced and explained in detail before the experience starts. There will also be an interview after the experience to engage with your thoughts and ideas on the experience and understand ways in which the experience could be improved and further developed.

Audio will be recorded using a mobile recording device. Audio data will then be uploaded to the OneDrive for storage before being wiped from the personal device. Google Recorder will be used for this and ensures no third-party data sharing. This also encrypts data and allows permanent deletion.

Collected data will be anonymous.

b) Funder information

N/A

c) Governance

This research has been approved by the School of Computer Science Research Ethics Committee (CS REC), ethics application ID: CS-2024-R25

2. Taking part in the research

You will have a 20-minute calibration session followed by a 30-minute VR horror experience around climate change.

FNIRS and GSR data is collected and anonymised

Your interview recordings will be anonymised.

Interviews involve a series of questions about the experience.

Demographic data will be collected through an anonymous questionnaire

3. Risks of participation

a) Risks

There is always a risk of unauthorised access to data.

When inside the experience, there is possibility for motion sickness and disorientation. The following steps will be taken to mitigate this:

- You may pause or stop the experience and remove the head-mounted display without withdrawing at any time
- I will be near to you in order to assist you if required
- A bucket will be within the room in case you are feeling unwell
- There will be minimal movement involving only head orientation and hands/arms due to you being sat down

In order to mitigate potential stress and anxiety, you have the right to withdraw at any given time within the study and are also briefed before starting the study that they will be taking part in an adaptive experience that aims to alter visuals and audio to induce fear. You will be taken through a narrative that involves violence, death, and strong language. As so it will be limited to an 18+ audience. No rests are scheduled as part of the study, but the experience does contain moments of rest.

b) Mitigation of risks

See section 5 for the measures we put in place to mitigate the risk of unauthorised access.

You can withdraw from or pause the interview at any time.

A mapping of the participant identifiers will be securely stored on the OneDrive. This allows for anonymisation of all data with a link between different participant data without easy identification of a participant's collected data. This mapping will be removed on 01/03/2025, when writing of study results begins and the mapping is no longer needed.

The participant is not required to give a response to any question if they feel uncomfortable to do so.

4. Purpose of data processing

a) Data collected

We collect the following categories of data during your participation in the research:

fNIRS Activity Data

Galvanic Skin Response Data

Audio recordings of the interviews

Participant Demographics through an anonymous questionnaire

b) Specific purposes for which the data are processed

Data collected during the research that identifies you may be:

- Analysed to meet the aims and objectives described in Section 1.
- Reviewed and discussed in supervision sessions between researchers and their supervisors or in research meetings between members of the research team, including project partners.
- If audio recordings are collected during the research, these may be transcribed and made anonymous. Anonymous quotations of your spoken words may be used in scientific works, including presentations, reports and publications stored in databases and posted online, and in marketing materials that promote the research and its findings. Audio used for promotion refers to use of audio that relates to the VR horror experience.

c) Automated decision-making and profiling

N/A

d) Legal basis for processing your data

We collect personal data under the terms of the University of Nottingham's Royal Charter and in our capacity as a teaching and research body to advance education and learning. We thus process your data on the legal basis that our research is in the public interest, we have legitimate interests and / or that you consent to data processing in freely and voluntarily participating in our research activities.

5. Storage and retention of your data

a) Data protection measures

We put the following organisational and / or technical safeguards in place to protect your data and your identity to the best of our ability:

i) All data will be securely stored on the University of Nottingham OneDrive.

b) Retention period

Data protection law allows us to retain personal data for an indefinite period and use it in future for public interest, scientific or historical research purposes or statistical purposes, subject to the implementation of technical and organisational measures that safeguard your data, your legal rights and your freedoms. These safeguards include the storage measures described above to protect your data against unauthorised access, and de-identification (anonymisation or pseudonymisation) of your data wherever possible and practicable. Data that identifies or could identify you will not be made public without your consent.

6. Third party recipients, services and data transfers

a) Project partners

Data will not be shared with others

b) Third-party services

N/A

c) Data transfers

Data will not be transferred to another country

7. Your legal rights

Data protection rights (Data Protection Act 2018)

You have the right:

- To be informed about the collection and use of personal data (as per this document).
- To access and receive a copy of your personal data, and other supplementary information, on request.
- To object to and restrict data processing if you think we are not complying with data protection law, and to rectify inaccuracies.
- To be forgotten, i.e., to have your personal data erased.
- To data portability and to obtain your data in an accessible and machine-readable format if appropriate, or to transfer your data to another organisation if technically feasible.
- To complain to about the way we process your personal data to our ethics committee (cs-ethicsadmin@cs.nott.ac.uk), our Data Protection Officer (dpo@nottingham.ac.uk) or the Information Commissioner's Office (https://ico.org.uk/make-a-complaint).*

Joint authorship in copyright works (Copyright, Designs and Patents Act 1988)

Joint authorship applies if participants are actively engaged in making original works as part of the research. The key criteria for determining joint authorship are 1) that original works created during the research could be copyright protected;[1] 2) that participants collaborate in their creation; 3) that participants make a contribution to the work's creation that a) cannot

* Our DPO's postal address is Data Protection Officer, Legal Services, A5 Trent Building, University of Nottingham, University Park, Nottingham NG7 2RD.

[1] Copyright protected works include literary works (webpages and computer programs as well books, etc.); databases, whether paper or electronic; dramatic and musical works; artistic works (including photographs and maps); typographical arrangements; sound recordings; films, videos and broadcasts. Copyright covers every medium in which work exists, including the Internet. Copyright does not cover ideas, products or processes (see IP law instead).

be distinguished from the contribution of any other 'author' involved (if their contributions can be distinguished then two or more separate works exist) and b) the work's creation relies on participants' skills and labour. If *all* of these criteria apply, then participants are joint authors and should be offered the opportunity to be acknowledged as such.

If you collect interview data, whether recorded on audio or video, joint authorship applies.[2]

If joint authorship applies to your research, delete this guidance and add the following boilerplate text:

You may, if you wish, be acknowledged and publicly identified as joint author of the *insert name for the work(s) participants are joint authors of in this research (e.g., the interview recording or video of the involvement in an experiment)*. **Affirming your right to be acknowledged as joint author may affect your anonymity.**

Then add an Opt-in to Section 9 underneath the Opt-out and insert the following boilerplate text:

c) Opt in. I wish to affirm my right to be acknowledged as joint author of original works created in this research and understand this may affect my anonymity

Don't forget to leave space for their signature or mark.

Joint authorship applies to all forms in which an original work exists (e.g., audio recording, transcript, research reports, presentations, publications, etc), which means that joint authors should be acknowledged in all forms in which an original work exists. Add the names of any participants who do affirm their right to be acknowledged as joint author in the **Acknowledgement section** of any written works.

8. Your ethical rights
a) Right to withdraw
You have the right to withdraw from the research at any time without explanation. You also have the right to request that your data be deleted if you do withdraw up until 01/03/2025, when writing of the study results begins and the mapping of participant ID to data is no longer needed.
b) Handling of 'mixed' data
If the data is 'mixed' data – i.e., if it involves other people (not including the researchers), e.g., a conversation or video of multi-party interaction – it cannot be deleted unless **all parties** request it. However, any mixed data involving you will be redacted wherever possible, with the exception of scientific works produced prior to your notification of withdrawal.
c) Withdrawal procedure
If you wish to withdraw, please notify ***Callum Berger, callum.berger@nottingham.ac.uk*** If you do not receive confirmation of withdrawal from the research, please email cs-ethicsadmin@cs.nott.ac.uk

9. Consent to participate	
a) I consent to participate in the research and my signature or mark confirms the following: • I understand the aims and objectives of the research • I understand what the research requires me to do • I accept the risks of participation • I understand what data will be collected and the purposes for which the data will be used	***Signature or mark:***

[2] https://www.copyrightuser.org/educate/the-game-is-on/episode-3-case-file-27

• I understand safeguards will be put in place to protect my data and my legal rights • I understand I will not be identified unless the use of identifiable data has been requested and I consent to it • I understand that I can withdraw at any time without explanation • I have been able to ask questions about the research, my participation, and my data and my questions have been answered satisfactorily • I agree to participate and my participation is voluntary	
b) Opt out. I do not consent to use of my visual image in scientific works or materials that promote the research and its results	
c) Opt in. I wish to affirm my right to be acknowledged as joint author of original works created in this research and understand this may affect my anonymity	
Name of participant(s)	
Date	
Witness *If participant(s) cannot sign*	*In signing I confirm the participant(s) named above have been fully informed about the research, have been able to ask questions, and consent freely.*

D.2 Questionnaire Data

D.3 A Place for Everyone - Controlled Lab Questionnaire

D.3.1 Horror Experience

- Would you consider this a horror experience? (yes or no, why?)
- Do you feel it was effective as a horror?
- How did you find it?
- Are there any key moments that stood out to you?
- Were any scenes more fearful?
- Would you consider yourself as a consumer of horror?

D.3.2 Adaptation

- Did you notice any changes within the scenes in relation to the environment and audio? (proceeded by an explanation of the adaptation)
- How did the adaptation effect your experience?
- When something changed, did the changes increase the amount of fear you experienced?
- Do you feel that adaptation reflected your fear level?
- Which calibration clip best reflected the fear level the experience gave you?

D.3.3 Critical Thinking

- How do you think an adaptive system could be used?
- How could an adaptive system be negatively used / abused?
- How did you feel your brain data was being used?
- Would you want to know that an experience is adaptive?

D.4 A Place for Everyone - Presence Questionnaire

1. How much did the visual aspects of the environment involve you?
2. How much did the auditory aspects of the environment involve you?
3. How natural was the mechanism which controlled movement through the environment?
4. How compelling was your sense of objects moving through space?
5. How much did your experiences in the virtual environment seem consistent with your real-world experiences?
6. How completely were you able to actively survey or search the environment using vision?
7. How well could you examine objects from multiple viewpoints using vision?
8. How compelling was your sense of moving through the environment?
9. How closely were you able to examine objects?

10. How well could you identify sounds?

11. How well could you localize sounds?

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

13. How well could you ignore distractions in the virtual environment?

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

D.5 Practitioner Guide to Implementing the Adaptive Horror Toolkit

The following section details a guide for practitioners on how to implement the adaptive horror toolkit developed in Section 5 and detailed in the Table 5.4. This will include using the Refugee scene from 'A Place for Everyone' as an example implementation, mentioning how the scene followed the toolkit. Throughout the process of script writing for an experience, it is key to identify the key moments and audiovisual stimuli you wish to include within the experience, including when and where these occur. For 'A Place for Everyone', I examined each of the six scenes during their conceptualisation and writing phase to establish these key moments and audiovisual stimuli.

D.5.1 Step 1 - Establishing Key Moments and the Combined Canonical Fear Trajectory

It is key at the start of the adaptation process to first understand where and when adaptation may take place. This allows you to target audiovisual stimuli based on certain events. Within a 'A Place for Everyone',

AlbinoMosquito and I determined what the key moments of each scene were during the conceptualisation and writing phase of the experience. In accordance with the toolkit, the aim of adapting to key moments is to maintain narrative coherence whilst being synchronised with the emotional beats of the story.

Taking Refugee as an example, this scene is broken down into 7 key moments:

- Start
- Lana & Sophia
- Start of the family chat
- Argument in the family
- Billboard of Alistair
- Henry welcoming the group
- End

With these key moments identified, we moved to establishing the combined canonical fear trajectory. Each key moment within each scene was assigned a fear level, indicating the anticipated level of fear for the participant, as measured by James Geer's fear scale, which ranges from 1 (none) to 7 (terror) (Geer, 1965). This fear level described the intended level of fear of the scene without adaptation. For the Refugee scene, as seen in table 6.1, without adaptation, the scene starts at 1, before escalating to 2 at 'Argument in the family', there is another increase to 3 at 'Billboard of Alistair', after which the scene remains at 3 until the end. For scaling this with adaptation, a zero or one was chosen to show adaptation as active (1)

or inactive (0). Active adaptation aims to increase fear, and as seen within 'Argument in the family', adaptation becomes active here (1) and remains active until the end. Combining the fear level of each key moment with whether adaptation is active or not produces a heightened fear trajectory overall. For Refugee this can be seen in Figure 6.4

D.5.2 Step 2 - Identification of Audiovisual Stimuli

Having established the key moments and combined canonical fear trajectory for each scene, the next step is to identify the audiovisual stimuli to be used. These stimuli can be virtual objects, sound, lighting, and atmosphere. As per the toolkit, the stimuli must aim to evoke tension while allowing flexibility in themes, in addition to being digitally driven to allow for content reuse. Below is a list of the audiovisual stimuli used within Refugee and the justification for each:

- Colour treatment can be applied to the billboard of Alistair to alter the colour of Alistair's hologram. Colour changing applies a red tone to the existing visual as an element of foreboding towards the evil intent of the character.
- Music cues for altering the music present within the current moment. Cues include effects such as rising tone and sudden sounds. These aim to play on themes of fearful music commonly found in horror scores.
- Sound design can include distant screams, whispers into the ear of the viewer, and noises of machinery. The screams are designed to provide a sudden fright to the player. The whispers and machinery

are aimed to provide suspense and a feeling of unease as to what is to come.

- Environmental changes can include the sudden appearance of bodies at the side of the road, Silhouettes in building windows, changing the scene from day to night, flickering lights, and the changing of road detritus to human bodies. These environmental changes can be accompanied by the screams and other sound design adaptations to create a greater combined effect.

As shown in the list of audiovisual stimuli, each stimulus chosen has an intent to play into the scene, either as foreboding or as a characteristic of horror. Some elements are designed to work collaboratively with others for a combined effect.

D.5.3 Step 3 - Defining the Stages for Adaptation

With a list of audiovisual stimuli available, the next step is to develop stages of adaptation. As listed within the toolkit "Adaptive horror system should incorporate a fear modifier which alters the audiovisual intensity in key moments based on a viewer's state". For 'A Place for Everyone', 3 adaptive stages were chosen for each scene, as this provided a suitable variability in audiovisual content. Higher stages are additive to previous stages and therefore don't overlap or disrupt them. There is no strict limit of 3 stages; however, fewer stages may provide less variability in audiovisual content, and more fear stages will require a greater level of audiovisual changes. The number of stages included should be determined by the amount of audiovisual content available and the depth of adaptation intended for the experience. For Refugee, the following list describes each stage and its

content:

- Stage 1: Slight introduction of the altered horror music as well as silhouettes in the windows of buildings, turning the scene to night, and the colour treatment of the billboard of Alistair. These subtle effects should create a gradual increase in fear as the viewer walks through the scene. This shouldn't instantly frighten the viewer, but may put those more easily scared into a fearful state.

- Stage 2: Further introduction of the altered horror music, replacement of road detritus with human remains and the flickering of lights. There can also be the inclusion of whispers and faint machinery noises. This stage aims to apply a more apparent increase in fear as there is plenty of debris scattered throughout the scene, with the aim of leaving a majority of viewers within this stage.

- Stage 3: Take over from the previous music into the altered horror music, bodies at the side of the road, as well as screams to be heard and an increase in volume of machinery noises. This final stage aims to push the remaining viewers to feel fear, combining all previous stages. This is much more intensive and directed at the viewer.

D.5.4 Step 4 - Implementation of Adaptive System into the Experience

This step is key to bringing the adaptation into the experience. This step occurs once the experience has been designed/filmed/developed and is ready for adaptation to be edited into the experience. For this step, I will describe the system logic for integrating adaptation using 'A Place for Ev-

eryone' as an example. The general process for this is input - comparison - rules

Firstly, you must establish your input that will cause the adaptation to come into effect. For my case, real-time fNIRS data was used to establish an inference of a viewer's fear state. Secondly, you must determine what this input is compared to for adaptation to increase or decrease. In 'A Place for Everyone', the comparison is a calibrated threshold established before the experience begins. Finally, you must identify the rules for adaptation. For 'A Place for Everyone', three rules were used:

- Rule 1: if a user's fear state established from fNIRS is below the calibrated threshold, increase the adaptive stage
- Rule 2: if a user's fear state established from fNIRS is within $\pm 10\%$ of the calibrated threshold, maintain the current adaptive stage
- Rule 3: if a user's fear state established from fNIRS is above the calibrated threshold, decrease the adaptive stage

With the input, comparison, and rules defined, it is now appropriate to add in the audiovisual stimuli and stages within each scene, triggering in time with the adaptive moments defined in the combined canonical trajectory.

D.5.5 Step 5 - Evaluate and Iterate

With an integrated adaptive system in the experience, it is useful to test, evaluate, and iterate on the implementation. As the adaptation is digitally driven, it can be altered as seen fit to either add more content and remove/alter existing content to produce the final experience.

D.5.6 A Place for Everyone Example

An example of a Place for Everyone with a complete run through can be found through the following link: https://youtu.be/KTCIXKLzgEU.