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Designing Digital Vertigo Experiences

A thesis submitted in fulfilment of the requirements for the degree of Doctor of Philosophy

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I would like to dedicate this thesis to my family. Thank you for everything.

Declaration

I certify that except where due acknowledgement has been made, the work is that of the author alone; the work has not been submitted previously, in whole or in part, to qualify for any other academic award; the content of the thesis is the result of work which has been carried out since the official commencement date of the approved research program; any editorial work, paid or unpaid, carried out by a third party is acknowledged; and, ethics procedures and guidelines have been followed.

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Richard Byrne
May 7, 2018

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Abstract

Many people enjoy "vertigo" sensations caused by intense playful bodily activities; examples of such activities include spinning in circles, riding fairground rides, and driving fast cars. Game scholar Caillois calls the associated experiences "vertigo play", elucidating that these enjoyable activities are a result of confusion between sensory channels.

In Human-Computer Interaction (HCI), designers often attempt to avoid causing sensory confusion as it can be associated with a negative user experience. I believe this has led to a lack of understanding surrounding how to transition and extend Caillois' thinking from analogue games and play to the digital realm. However, with more digital games focusing on the body through technologies such as motion sensors and head mounted displays, an opportunity to understand how to design digital vertigo games has arisen. Understanding this will allow designers to create novel and intriguing digital bodily experiences inspired by traditional vertigo play activities. This thesis explores this opportunity by answering the research question: "How do we design digital vertigo experiences?"

I developed and studied three different experiences to answer this research question. The first game, "Inner Disturbance", is a single player game where sensory confusion is facilitated by manipulating a player's vestibular sense of balance through Galvanic Vestibular Stimulation (GVS). The second game, "Balance Ninja", uses GVS to extend sensory confusion across two players through a feedback loop, whereby the lateral movements of each player affects the GVS system of the opposing player. In the final game, "AR Fighter", Head Mounted Displays confuse players' visual sense as a result of the opposing player's movements.

Studies of the player experience of the three games led to the development of the Digital Vertigo Experience Framework. This framework, which presents designers with the first understanding of how to design digital vertigo experiences, contains two axes: amount of surrendered body agency, and extent of facilitated sensory confusion. The framework is split into four digital vertigo user experience areas: more daring, more overwhelming, more predictable, and more nauseating. Designers are encouraged to stay within these areas to avoid causing one of four possible risks to players: risk of physical

injury, sensory overload, boredom, and nausea.

With this work, I aim to bring the excitement of traditional vertigo play experiences to the digital world, guiding designers in their creation. Offering an increased understanding of digital vertigo play experiences will allow designers to create more engaging and exciting body-based games, and provide players with more possibilities to enjoy novel and exciting bodily-play experiences.

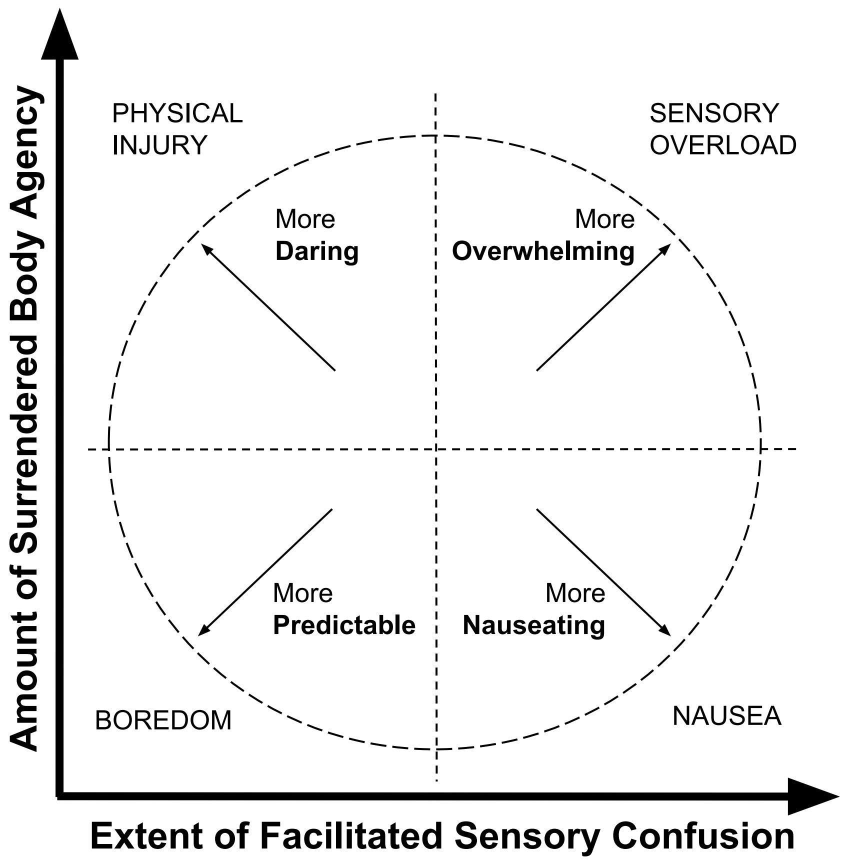

Fig. 1 The Digital Vertigo Experience Framework.

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Chapter 1

Introduction

Voluntarily experiencing confusion between bodily senses can be exciting, thrilling, and enjoyable. For instance, some sports professionals such as skiers and racing drivers battle against the intense sensory confusion induced from fast movements to remain balanced and in control. Theme parks, too, are home to rides designed to purposefully create intense and powerful sensory confusion in riders, all for the sake of providing riders with a thrilling experience.

Activities and methods of purposefully confusing our senses are all around us. Have you, for example, ever spun around in circles on the spot for the simple joy of doing so? Rolled down a hill? Consumed alcohol to excess? Or perhaps you are even an avid theme park goer or thrill seeker? Whatever your preference, the chances are that at some point in your life you have chosen to experience an enjoyable form of sensory confusion.

Game sociologist Roger Caillois calls such activities "vertigo games", and states that vertigo games *"consist of an attempt to momentarily destroy the stability of perception and inflict a kind of voluptuous panic upon an otherwise lucid mind"* (Caillois, 1961). Simply, they are activities where a player's senses are affected (altered perception, lucidity) such that the player has an enjoyable experience (voluptuous). Caillois uses sports and activities such as rock climbing, dancing, and skiing to help illustrate his definition, and sports psychologists have long suggested that "the pursuit of vertigo" is indeed the main attraction behind many of these popular sports (Alderman, 1974; Kenyon, 1968).

Despite the suggested allure of the pursuit of vertigo, the purposeful design of digital equivalents has been under-explored in Human-Computer Interaction (HCI) and game design work to date, although recently designers have begun to create digital facsimiles of vertigo experiences. For example, several recent digital games allow players to traverse climbing routes within a Virtual Reality (VR) space (Crytek, 2016; Dufour et al., 2014). However, some designers have argued that Caillois' vertigo definition of confusing the senses is perhaps not well suited to digital game design, and even goes beyond the boundaries of such games (Salen & Zimmerman, 2004, p.289).

Often, the advice provided by game and VR designers is not to cause too much sensory confusion in case it leads to negative experiences such as motion sickness (Sharples, Cobb, Moody, & Wilson, 2008). Although, some game scholars do contest this guidance, suggesting that vertigo elements could help to enhance digital games (Bateman, 2006). Rutter and Bryce (2006), for instance, describe how the disorientating speed in which Sonic the Hedgehog (Team Sonic, 1991) moves can create a pleasurable vertigo sensation for the player, due to the disorientating nature of Sonic's fast movements through the game world (Rutter & Bryce, 2006, pp. 79-80).

Therefore the core research question of this thesis is:

> *"how do we design digital vertigo experiences?"*

With this work I address the gap in knowledge concerning the design of digital vertigo experiences by presenting a design-led exploration of creating digital vertigo experiences.

In the following sections I explain "digital vertigo experiences", before providing an overview of the thesis structure.

1.1 Vertigo Experiences

What is a vertigo experience? To understand this let us first consider vertigo as it is commonly understood. In the medical world, for example, vertigo has been described as *"a sensation of spinning or whirling motion. Vertigo implies a definite sensation of rotation of the subject (subjective vertigo) or of objects about the subject (objective vertigo) in any plane"* (Dorland, 1901). Intuitively it may seem as though designers would want to avoid such sensations in digital game design. However, I argue that these sensations can be the basis of engaging bodily-play experiences (play which involves using the whole body), as vertigo games could allow players to experience and overcome sensations that are unexpected, different, and even exaggerated, challenging their own perceived sense of "normality".

Stevens suggests that games of vertigo, which allow players to experience sensations beyond their normal day to day activities, could even allow players to *"more fully be themselves"* (Stevens, 2007). Caillois suggested that such games could also be *"of merit in furnishing admirable witness to human perseverance, ambition and hardiness"* (Caillois, 1961). The possibility to stretch and challenge one's own bodily limitations are clearly desirable to thrill seekers and adrenaline junkies, and it is reasonable to assume that, for some, being able to push themselves beyond their normal bodily abilities would be a desirable game experience - an experience of which could be afforded by vertigo experiences.

Further supporting the attraction of challenging the body through experiencing vertigo is the fondness people have for the fair ground. Fair ground rides, or "powerful machines" as Caillois calls them (Caillois, 1961, p.26), have been entertaining people since the Nineteenth Century. The *Haunted Swing* Illusion (Wood, 1895), for example, is one of the earliest examples of a mechanical ride designed to induce sensory confusion by tricking riders into thinking they are swinging a full 360 degrees around a bar. In actual fact, the riders are near stationary and the room the swing is placed in rotates around them, creating confusion between what riders see, and what their vestibular sense of balance is telling them.

Within the field of exertion games, designers have investigated various ways of challenging player's bodily abilities through digital, full body games (Marshall, Linehan, & Hazzard, 2016; Mueller et al., 2011). Benford et al. (2012) have even considered how digital stimulation can be used to purposefully induce different uncomfortable sensations in players, to create various entertaining outcomes. In the work of Tennant et al. (2017) the authors were inspired by the *Haunted Swing* to create a digital version, where players wearing a Head Mounted Display (HMD) swing on a real, physical swing, and have their sense of movement within a virtual environment exaggerated through the visual feedback.

Such work as that of Benford et al. (2012) suggests that vertigo experiences, which could also result in uncomfortable or unusual bodily sensations, could be equally entertaining. As digital technology has improved, it is now possible for designers to illicit greater control over how to digitally induce peculiar sensations in players (as illustrated by Tennant et al. (2017)). Contrastingly, however, researchers have generally used digital devices such as HMDs to augment and update *existing* ride experiences (Merlin Entertainment Group, 2016; Schnädelbach et al., 2008; Walker et al., 2007). Designers have also explored making the experience more immersive (Eidenberger & Mossel, 2015; Inition, 2014a, 2014b) through dampening any sensory confusion that may be indirectly induced in players, rather than using the technology to purposefully exaggerate such sensory confusion, and thus creating dedicated vertigo experiences. Other designers choose to augment existing experiences with digital technology such as accelerometers, projectors, and augmented reality with the aim of improving performance in sports related activities (Bächlin, Förster, & Tröster, 2009; Daiber, Kosmalla, & Krüger, n.d.; Pijnappel & Mueller, 2014; Ruttkay, Zwiers, van Welbergen, & Reidsma, 2006; Spelmezan, Schanowski, & Borchers, 2009).

This thesis argues that there exists an opportunity not to err on the side of caution and dampen the experience, but instead to embrace the opportunity digital technology affords us to explore the varying ways in which such technology can be harnessed and embraced to induce purposeful sensory confusion in players. Doing so, I believe, can help HCI and game designers to create exciting, novel, and playful vertigo experiences independent of complicated ride machinery and infrastructure, expanding the range of games that we currently play.

1.2 Digital Vertigo Experiences

Vertigo is a game characteristic that Caillois presents as one of four main categories of games and play: games of Competition (Agôn), Chance (Alea), Simulation (Mimicry) and finally, Vertigo (Ilinx). Caillois (1961) explains the reasoning for naming the vertigo classification as "ilinx", stating that: *"for a disorder that may take organic or psychological form, I propose using the term* ilinx*, the Greek for whirlpool, from which is also derived the Greek word for vertigo (*ilingos*)"* (Caillois, 1961, p.24).

Caillois extends his definition by explaining how two different types of experience may exist at the extreme dimensions of vertigo. The first of these experiences he calls "paidia", and describes it as a completely unstructured and spontaneous activity such as improvised play (i.e. are playful). The second, opposite end of the scale, he describes as "ludus", representing activities that have explicit rules (i.e. are gameful). Although Caillois does consider certain activities to be either more playful or more gameful, I argue that in the digital world the use of paidia and ludus extremes seems slightly redundant. To clarify, mountain climbing is considered by Caillois as more gameful in nature and therefore bound by strict rules. Although this can be the case, it can also be playful in nature, e.g. overcoming a climbing route because it is difficult (Suits, 2014). Similarly, waltzing is described by Caillois as being more of a playful activity, however, if one were waltzing in a dance contest there would clearly be strict rules to adhere to. Researches have also suggested that designers leave their designs less rigid in order to allow for playful experiences to emerge (Kirman, 2010). Therefore in this thesis I apply the term "Digital Vertigo Experiences" to encompass all different types of vertigo experience (playful or gameful) that are achieved through digital means.

The confusion over whether vertigo is gameful or playful could help to explain why little has been articulated about how to design digital vertigo games until now. Game designers have even suggested that Caillois' vertigo category may go beyond a description of digital games, saying that the classification falls outside the boundary of digital games (Salen & Zimmerman, 2004, p.289). This inspired me to research the area of vertigo experiences since I believe that vertigo *can* be a powerful gameplay element in digital games and play if designed correctly.

Game scholar Chris Bateman (2006) agrees that *"little has been written about the ilinx (vertigo) of video games"*, and argues that artificially induced states of vertigo could enhance the enjoyment for players in certain "vertiginous" games like snowboarding and car racing games (Bateman, 2006). Importantly, these *"vertiginous experiences"*, Bateman notes, are not *"the nausea inducing kind"*, but rather enjoyable and fun ways of extending what is happening to an avatar on screen to the player in the real world, achieved through digitally induced sensory confusion.

The idea that vertigo games should be enjoyable is true to Caillois' sentiment that players should experience a *voluptuous* panic (i.e. a pleasurable experience) when playing vertigo games. I discuss different types of user experience in this thesis, and present tactics for designers to help them achieve these experiences. Exploring the design of vertigo games with a digital perspective lends itself to this aim, since the digital aspect presents an opportunity to finely control the vertigo experience for designers, through the use of novel digital technologies. For example, a system could detect if players appear to be losing their sense of balance, and any stimulation that is inducing this loss of balance can be immediately reduced by the system.

Using digital technology that can induce sensory confusion in players affords designers with unique design opportunities, such as the ability to share one player's sensory confusion with another (e.g. sense when one player looses their balance, and make another player lose their balance in the same way). However, until now there has not been an attempt to articulate how digital vertigo experiences should be designed.

In the following section I describe my core research question and objectives, and present an overview of how I answered the question through the exploration of four case studies.

1.3 Thesis Statement

In this thesis I address the core research question:

How do we design digital vertigo experiences?

To answer the question, I followed a design-led process including a design workshop, and the development of three digital vertigo experiences. Designing and studying these games has allowed me to explore a range of digital vertigo experiences. Through a reflection on these experiences I created the Digital Vertigo Experience Framework (figure 1.1). Overall, this work aims to inspire designers to explore vertigo in their games by illustrating the range of potential vertigo experiences which can be created with digital technologies, and the design opportunities afforded by them. In addition, each study served as a research vehicle to derive design tactics that aim to provide clear guidance for the design of engaging digital vertigo experiences.

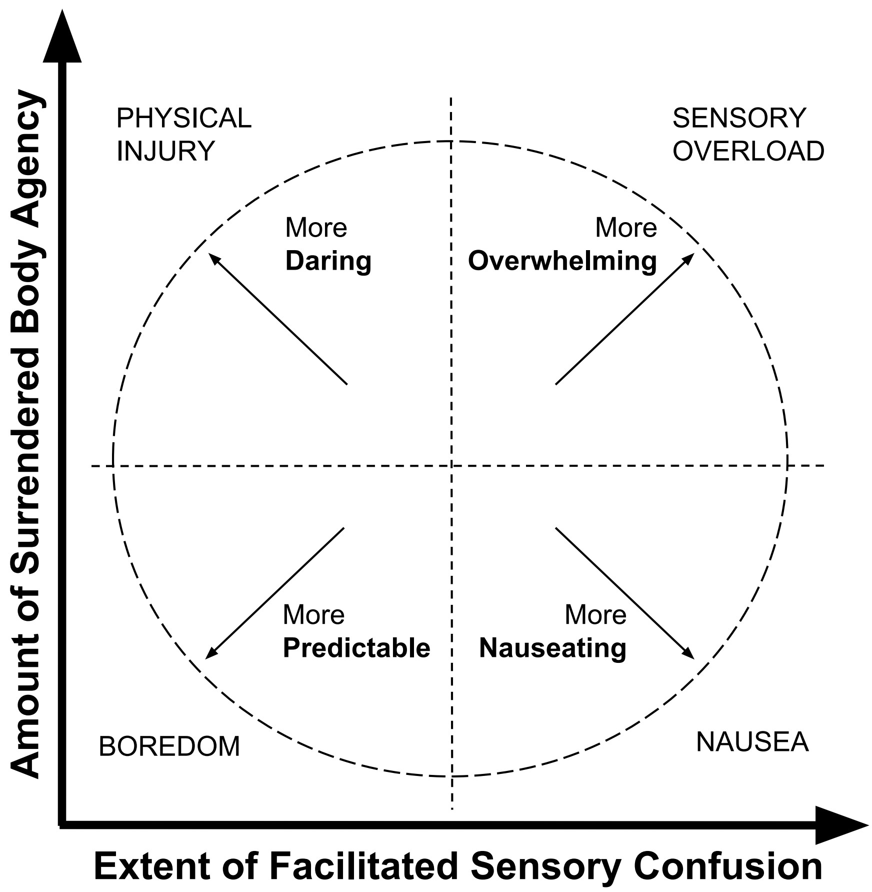

Fig. 1.1 The Digital Vertigo Experience framework.

1.3.1 Research Objectives

In order to answer the core research question the work presented here addresses four key objectives:

1. **Understand the role of vertigo in games, and its relationship to bodily interaction in HCI and play**. This objective was achieved through my exploration and discussion of related work (chapter 2). Through understanding and drawing upon existing theory I was able to plan where to begin with regards to exploring digital vertigo experiences.

2. **Develop an appropriate method of investigating the core research question**. Following my exploration of related work I investigated what research methodology would assist me in answering my research question. I discuss my chosen research methodologies in chapter 3.

3. **Explore the design space of digital vertigo games**. In chapters 4 through 7 I explore the design space of digital vertigo games through conducting a design workshop, and the study and evaluation of three digital vertigo experiences.

4. **Create a theoretical design framework concerning digital vertigo experiences**. Through achieving the above objectives I was able to create my Digital Vertigo Experience Framework (chapter 8). This framework was derived from the evaluation of all four studies I conducted, and the recurring design themes concerning the user experience of playing the games, and tactics for designers of digital vertigo experiences which I uncovered through my evaluation of the study data.

1.4 Research Scope

In order to provide a focused and precise contribution as described above, the scope of the research is limited as follows:

- The work of this thesis considers *Vertigo* as a game classification as defined by Caillois (Caillois, 1961). Therefore, this thesis is not concerned with "medical vertigo" or associated conditions such as acrophobia (a fear of heights). This work instead considers digital vertigo experiences: games which induce sensory confusion to facilitate engaging experiences.

- As this is an initial exploration into designing digital vertigo play experiences, I have considered two main interfaces for creating induced vertigo: Galvanic Vestibular Stimulation (GVS) and Head Mounted Displays (HMDs). GVS systems directly affect the balance organs of the inner ear through the stimulation of a small (< 1.5 mA) current applied to the mastoid bones behind the ear. This can create sensory confusion in players since their visual perception indicates that they are standing upright, but their balance senses are reporting something different. The result is that players often lean toward the side which is being stimulated. GVS is explained in greater detail in chapter 4.

  HMDs create sensory confusion in almost the opposite way - the visual senses can be placed in conflict with the balance senses, but this time by affecting what players see, rather than what their balance senses report.

  It is possible that designers could explore other technologies to create sensory confusion in players. For instance, in the HCI space there have been other examples of technologies that could create sensory confusion in players. Electric Muscle Stimulation (Lopes, Ion, Mueller, & Hoffmann, Daniel and Jonell, Patrik and Baudisch, 2015) for example can move a player's body based on electrical impulses applied to the muscles. Designers could use such a technology to create sensory confusion by making the movement of one limb control the movement of another.

  Additional methods of creating sensory confusion are not wholly considered in this thesis, but are certainly encouraged as future work.

- Some body-based games have shown success in also being used as training tools to improve players' performance in certain sports or activities. For example the work of Kajastila, Holsti, and Hämäläinen (2014) explores whether a trampoline game is useful in allowing players to improve their trampoline performance whilst playing a game that translates their jumps to an avatar moving through a platforming game. Similarly, the work of Jensen, Rasmussen, and Grønbæk (2014) uses a custom 360-degree play space to improve players' soccer skills, through requiring the players to kick a soccer ball at a highlighted area within the space, scoring higher points for greater accuracy. The main focus of this research does not consider the utility of training players of vertigo games to, for example, improve their balance or improve their ability to not experience disorientation.

- The digital vertigo experiences presented in this work are designed to induce sensory confusion in players, but were not designed to purposefully induce motion sickness or make players ill. Although I present tactics to help designers of future vertigo experiences dampen these effects, I have not directly studied whether my games and tactics help to reduce motion sickness in players, instead leaving this as future work.

1.5 Case Studies

To answer my research question I conducted four case studies in order to help create the Digital Vertigo Experience Framework. In the following sections I briefly describe each case study, along with the sub-research question they were designed to answer.

1.5.1 Case Study 1 - Design Workshop: (Chapter 4)

Fig. 1.2 Case Study 1 - Design Workshop

This first case study asked the question: *"What factors are important to begin creating digital vertigo games?"*

To answer the question I held a design workshop with nine game design students over a period of three hours. During the workshop the participants were invited to design and build lo-fidelity prototypes of vertigo games (figure 1.2) in order to explore the topic of vertigo as a design resource in bodily play (play involving the body) (Byrne, Marshall, & Mueller, 2016b). Participants also had the opportunity to experience and use a Galvanic Vestibular Stimulation (GVS) system as a technology probe (Hutchinson et al., 2003).

In four groups the participants described five potential vertigo games in total which, following analysis of transcriptions of the group discussion, led to the creation of five recurring design themes for designers of digital vertigo experiences. This case study helped me to narrow the focus of my exploration through highlighting not only that GVS was a valid sensory confusion technology, but that the amount of bodily control surrendered by players, vs. the affect on a players balance can be key factors in developing digital vertigo experiences.

1.5.2 Case Study 2 - *Inner Disturbance*: (Chapter 5)

Fig. 1.3 Case Study 2 - *Inner Disturbance*.

Inner Disturbance (figure 1.3) is a digital vertigo experience designed for one player. The game challenges players to remain balanced whilst an induced internal force, via my GVS system, affects their sense of balance. In exploring this case study I addressed the sub-research question: *"What kind of experience is created when affecting a player's sense of balance with digital stimulation, such as GVS?"*

In *Inner Disturbance* a player stands on one leg whilst GVS is applied in an oscillating, pre-programmed, pattern to the player. A player battles against this stimulation to remain balanced. Placing their raised foot back on to the floor causes the player to lose that particular round. Each round (up to a maximum of five) increases the level of simulation applied, making it increasingly more difficult for players to remain balanced. Participants were allowed to rest between rounds for up to a minute before proceeding to the next round. Each round increased the difficulty by increasing the amount of stimulation. This amount was derived during an initial calibration stage up to an absolute total maximum of 2.5 mA. Music signified when the systems were active and a gameplay round was being played, and a "losing" sound played to signify when players lost a round.

An analysis of semi-structured interviews of ten participants uncovered four design themes for the development of digital vertigo play experiences as derived from the data. These insights, along with those of the initial exploration, informed and framed the development of case study 3. For example, some players found the game to be less challenging at lower levels of stimulation, and also found the pattern became predictable and easy to overcome. In *Balance Ninja* I redesigned how the GVS systems worked so that this was no longer the case.

1.5.3 Case Study 3 - *Balance Ninja*: (Chapter 6)

Balance Ninja (figure 1.4) is a two-player vertigo game where two players battle against both their own sense of balance and the sensory confusion induced via a GVS system that is controlled by the opposing player. The main objective of the game is to cause the opposing player to lose their balance first and score a point. The first player to five points wins the game. The study allowed me to answer the sub-research question of: *"What is type of vertigo game that emerges when a player has to both experience sensory confusion and actively participate in the vertigo experience?"* Players stand facing each other on wooden boards, which I call balance boards, placed on a wooden beam. Each player is attached to his or her own GVS system and has a mobile phone attached to his or her chest. Players compete to score a maximum of five points by getting the other player to touch their balance board to the floor. Players achieve this by leaning from side to side. The direction and amount that the player leans is recorded by the phone and activates the opposing player's GVS system, such that their balance is affected in the opposite direction. For example, if player 1 leans to the right then player 2's GVS system activates on the left, causing their balance to be affected in that direction. Observing the

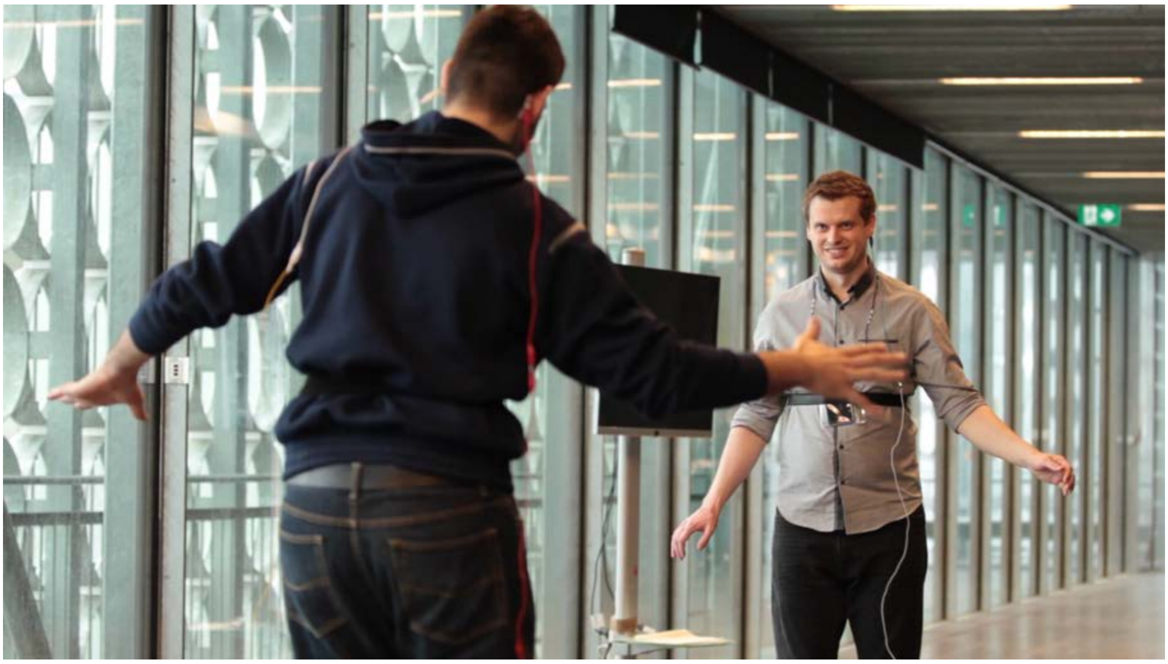

Fig. 1.4 Case study 3 - *Balance Ninja*.

gameplay can appear as though the players are mirroring one another's movements. By battling in this way players have to strategically choose when they can lean and when they need to fight the GVS stimulation affecting their own sense of balance, as caused by the opposing player's movement.

The first player to cause their opponent to lose five times through touching their balance board to the floor wins the game. The score was displayed on a TV, which was visible to both players and spectators, and music and voice-overs indicate when the game is playing and when a player scores a point.

An analysis of *Balance Ninja* further refined the design themes and accompanying design tactics. Some of these findings correlate with those that emerged from the previous case studies as well as suggesting that another type of vertigo game to consider could make use of a form of visual stimulation, instead of GVS. These findings encouraged the development of the final case study and further refined the Digital Vertigo Experience Framework.

1.5.4 Case Study 4 - *AR Fighter*: (Chapter 7)

AR Fighter (figure 1.5) has a similar premise to *Balance Ninja* - requiring players to try and make their opponent lose their balance first and thus win themselves a point - but uses

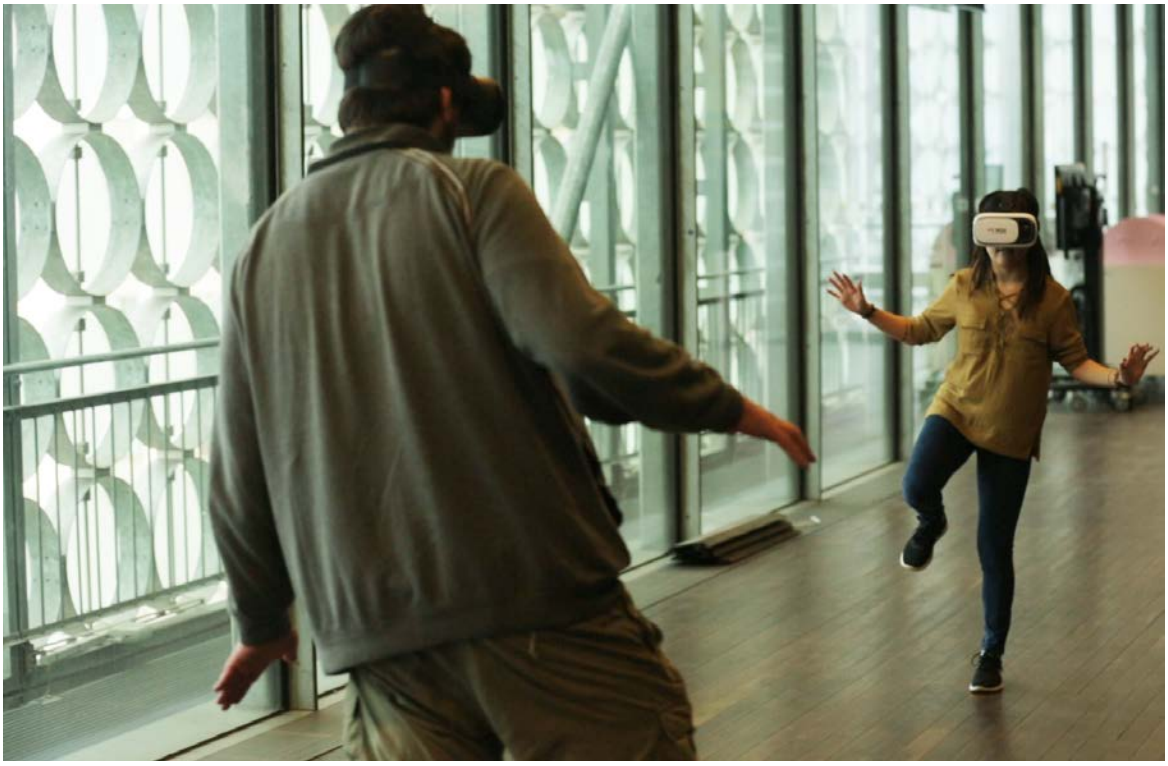

Fig. 1.5 Case study 4 - *AR Fighter*.

Head Mounted Displays (HMDs) to induce sensory confusion in the players instead of GVS systems. The sensory confusion in *AR Fighter* is a result of players' visual perception being manipulated by the HMDs, which is in conflict with their sense of balance. From the results of the previous case studies and design workshop, I opted to experiment with affecting players' visual perception in order to answer the sub-research question of: *"How does using a different method of facilitating sensory confusion, such as an HMD, change or support what I have understood so far about designing digital vertigo play experiences?"*

Players of the previous games had suggested that when playing *Inner Disturbance* closing their eyes made the game harder, and in *Balance Ninja* focusing on visual points of reference was considered a winning gameplay tactic. Therefore, I thought that if I could use a visual method of inducing sensory confusion it could lead to intriguing insights for the framework as it allowed me to explore an additional method of inducing sensory confusion in players. The goal of *AR Fighter* is similar to the game's predecessor, such that players battle to keep their own balance, whilst attempting to cause the opposing player to lose theirs and thus score a point in the process. Once again, the first player to score five points wins the game. Due to the limited field of view when wearing an HMD *AR Fighter* does not use the balance boards used in *Balance Ninja*. Instead, players stand on one leg in much the same way as *Inner Disturbance*. Players stand facing each other on one leg when the rounds start. As one player tilts their head the horizontal perspective of the opposing player is altered to match the head tilt of the first player. For example if player 1 tilts their head to the right, then the view of player 2s HMD is mapped to that same angle, creating the impression that they are leaning. This creates sensory confusion in the players as their visual perception communicates that they are leaning, but in reality they are not. Results of the interviews from *AR Fighter* allowed me to consider the previously discovered design themes and tactics and see how they differed when the stimulation method was altered from GVS to visual. The results from this study, in conjunction with the previous studies, allowed me to refine the digital vertigo play experience design space and fully develop the Digital Vertigo Experience Framework.

1.6 Contributions

This work makes the following contributions:

1. This research contributes to design knowledge by providing details on the implementation of, and insights gained from, the design and evaluation of three digital vertigo play experiences. The case studies and game prototypes demonstrate how digital games can be created and designed with vertigo in mind.

2. This research contributes to design knowledge through the provision of a conceptual understanding of the role vertigo can provide in body based games and HCI.

3. The research presents the Digital Vertigo Experience Framework. It is the first theoretical conceptualisation of how to design for vertigo experiences from a digital perspective, and along with practical examples and design tactics guides designers in developing their own novel digital vertigo play experiences. The framework was derived through the findings of the four case studies. Each case study consists of recurring design themes, as uncovered from the qualitative analysis of the user experience of playing the games. These insights and quotes provided a high level understanding of the experience of playing each of the digital vertigo experiences. These themes informed the design tactics, also present in each case study, which serve as practical examples for designers to develop digital vertigo experiences and achieve the desired user experience as explained in the themes.

1.7 Related Publications and Presentations

A significant portion of my research through the development of this thesis has been peer-reviewed, published, and presented to the wider HCI audience. My paper reporting the study of *Balance Ninja* also won the Best Paper Honourable Mention Award at CHI Play 2016.

My work has been presented at several academic venues throughout the duration of my candidature. A list of these publications can be viewed below. Publications and reports of my research progress can also be viewed online at `richbyrne.co.uk/publications`.

1.7.1 Peer Reviewed Publications

Full Papers

- **Byrne, R.**, Marshall, J., and Mueller, F. (2016). Balance Ninja: Towards the Design of Digital Vertigo Games via Galvanic Vestibular Stimulation. In *Proceedings of the 2016 Annual Symposium on Computer-Human Interaction in Play* (CHI PLAY '16). ACM, New York, NY, USA, pp. 159-170. **Best Paper Honourable Mention**.

- **Byrne, R.**, Marshall, J., and Mueller, F. (2016). Designing the vertigo experience: Vertigo as a design resource for digital bodily play. In *Proceedings of the TEI '16: Tenth International Conference on Tangible, Embedded, and Embodied Interaction* (TEI '16). ACM, New York, NY, USA, pp. 296-303

- Hämäläinen, P., Marshall, J., Kajastila, R., **Byrne, R.**, and Mueller, F. F. (2015). Utilizing gravity in movement-based games and play. In Proceedings of the 2015 Annual Symposium on Computer-Human Interaction in Play, CHI PLAY '15, ACM, New York, NY, USA, pp. 67–77. **Best Paper Honourable Mention**.

- **Byrne, R.** and Mueller, F. F. (2014). Designing digital climbing experiences through understanding rock climbing motivation, *Entertainment Computing–ICEC 2014*, Springer, pp. 92–99.

Short Papers

- **Byrne, R.**, Marshall, J., and Mueller, F. (2016). Inner Disturbance: Towards Understanding the Design of Vertigo Games through a Novel Balancing Game. In *Proceed-*

ings of the 28th Australian Conference on Computer-Human Interaction (OzCHI '16). ACM, New York, NY, USA, pp. 551-556.

- **Byrne, R.** (2016). Designing digital vertigo games. In *Proceedings of the 2016 ACM Conference Companion Publication on Designing Interactive Systems* (DIS 2016). ACM, New York, United States, pp. 25-26. (Doctoral Consortium Submission.)

- **Byrne, R.** (2015). Vertigo as a design resource for bodily play. In *Proceedings of the 2015 Annual Symposium on Computer-Human Interaction in Play* (CHI PLAY 2015). ACM, New York, NY, USA, pp. 399-402 (Doctoral Consortium Submission.)

- Finnegan, D. J., Velloso, E., Mitchell, R., Mueller, F. and **Byrne, R.** (2014). Reindeer & wolves: exploring sensory deprivation in multiplayer digital bodily play, in *proceedings of the first ACM SIGCHI annual symposium on Computer-human interaction in play* (CHI PLAY 2014), ACM, pp. 411–412.

1.7.2 Public Presentations

- Presented an invited talk on my research at The University of Melbourne's Interaction Design Lab in March 2017.

- My first case study was presented as a short paper at the 28th Australian Conference on Human-Computer Interaction (OzCHI).

- My Second Case study was presented on my behalf as a full paper at the 2016 Annual Symposium on Computer-Human Interaction in Play (CHI PLAY), (Byrne, Marshall, & Mueller, 2016a).

- Presented Doctoral Research at the ACM Conference Companion Publication on Designing Interactive Systems (DIS) Doctoral Consortium, in Brisbane, Australia.

- Presented full paper on workshop findings and Case Study 1 system *Inner Disturbance* at demo session of the ACM International conference on Tangible, Embedded and Embodied Interaction (TEI) 2016, in Eindhoven, Netherlands (Byrne et al., 2016b).

- Presented Doctoral Research at the ACM SIGCHI Annual Symposium on Computer-Human Interaction in Play (CHI PLAY) Doctoral Consortium, in London, UK.
  My joint research with other universities was also presented here, including an

Honourable mention paper (Hämäläinen, Marshall, Kajastila, Byrne, & Mueller, 2015), and a work in progress paper (Alavesa, Schmidt, Fedosov, Byrne, & Mueller, 2015).

- My work was presented as a talk and full paper to game and HCI researchers and designers at the International Conference on Entertainment Computing (ICEC) 2014, in Sydney, Australia (Byrne & Mueller, 2014).

1.8 Thesis Structure

The document structure of the thesis is described in table 1.1.

Thesis Structure

Chapter 1	Introduction: An overview of the research and thesis statement.
Chapter 2	Related Work: Presents my review of relevant background and related work.
Chapter 3	Methods: Describes the research methods followed throughout the thesis.
Chapter 4	Case Study 1: Design Workshop Describes the initial design workshop.
Chapter 5, 6 and 7	Case Studies *Inner Disturbance, Balance Ninja,* & *AR Fighter*: Details the development and evaluation of three vertigo play experiences and studies to explore my core research question.
Chapter 8	The Digital Vertigo Experience Framework: Details the development of the digital vertigo play experience framework.
Chapter 9	Conclusion and Future Work: Concludes and summarises the thesis. I also discusses future work as part of this chapter.

Table 1.1 Outline of thesis.

1.9 Summary

In this chapter I have presented an overview of my research topic. In the next chapters I go into more detail as I first describe related work to help illustrate the research gap, before detailing the study and evaluation of my case studies. Finally I bring the thesis to a close with the presentation of the Digital Vertigo Experience Framework, and a discussion on the future of the research topic.

Chapter 2

Background and Related Work

2.1 Introduction

The focus of this thesis is to understand the design of digital vertigo experiences, therefore I begin by defining what a “vertigo experience” is; then I describe relevant prior literature. In undertaking this work, I build on digital game studies research, Human Computer Interaction (HCI) work on bodily interaction and bodily-play, and experience design work studying thrilling and uncomfortable experiences. I finish the chapter by describing the research opportunity and revisiting my core research question.

2.2 Vertigo Experiences

The description of vertigo in games was first presented by the sociologist Roger Caillois, in his 1958 book, *Les jeux et les hommes*, later translated to English as *Man, Play and Games* (Caillois, 1961). In his work, Caillois defines four main game classifications in total, games of Competition (Agôn), Chance (Alea), Simulation (Mimicry) and finally, Vertigo (Ilinx). Caillois explains that vertigo games consist of *“an attempt to momentarily destroy the stability of perception and inflict a kind of voluptuous panic on an otherwise lucid mind"* (Caillois, 1961, p.23). It is for this reason that he also uses the term “ilinx”, stating that *“for a disorder that may take organic or psychological form, I propose using the term* ilinx*, the Greek for whirlpool, from which is also derived the Greek word for vertigo (ilingos)”* (Caillois, 1961, p.24). Caillois provides examples of playful vertigo experiences such as children spinning in circles until they fall over, tightrope walking, falling and the pleasure experienced through the acceleration of vertilinear movement (straight, upward movement) (Caillois, 1961). One thing that these examples have in common is that the whole human body plays a role in the experience through one's own proprioceptive movements, and sports psychologists have even suggested that the *"pursuit of vertigo"* (Alderman, 1974) is the main attraction for bodily experiences such as rock climbing (Alderman, 1974; Kenyon, 1968).

A possible reason for players enjoying the allure of vertigo is that players of vertigo games can experience an altered perception as they are *"surrendering to a [. . .] shock [. . .] which destroys reality"* (Caillois, 1961). This shock that players experience as a result of sensory confusion could result in *"intoxicating physical sensations of instability and distorted perception"* (Stevens, 2007), which perhaps explains why vertigo experiences can be enjoyable. Stevens suggests that the "shock" or sensory confusion that Caillois describes, can be created in a variety of ways, including affecting the inner ear, and also through inducing feelings of scale, speed and traction (Stevens, 2007) that players are not normally used to, and thus leading them to feel as though they are experiencing something of an altered perception.

One main methods of achieving this state of altered perception is through the purposeful confusion of two or more bodily senses (Caillois, 1961). Creating sensory confusion in players can make use of extreme forces or motions (as Stevens says: concerning vertigo of intense scale, speed and traction (2007)), and such experiences require the use of large, specialised equipment, (such as rollercoasters).

Medically speaking vertigo has been described as *"a sensation of motion [...] in which the individual or the individual's surroundings seem to whirl dizzily"* (Dorland, 1901). Although this definition is not always agreed upon (Blakley & Goebel, 2001) the common basis of the definition tends to relate to the patient having their vision or vestibular balance affected in a way that is unusual and even disorientating. Intuitively, therefore, it may seem as though designers would want to avoid inducing such sensations in players of their digital games. However, I argue that these sensations can be the basis of enjoyable bodily-play experiences. For example, many people enjoy the experience of being pushed down a hill in an inflatable ball - an activity known as "Zorbing" - and other similar bodily experiences, which can make you extremely dizzy.

Despite the enjoyable nature of these games it has been argued that Caillois' vertigo game classification is difficult to situate within digital game design (Salen & Zimmerman, 2004). Salen and Zimmerman (2004), for example, discuss vertigo as a game design element, but suggest that Caillois' vertigo examples *"fall outside the boundaries of games" and that Caillois' vertigo classification also goes "beyond a description of games"* (Salen &

Zimmerman, 2004, p.308).

However, Rutter and Bryce (2006) suggest that vertigo can actually be a dominant play category in digital games, referring to *Sonic the Hedgehog* (Team Sonic, 1991) as one example of an early game with an effective use of vertigo. The authors suggest that Sonic's momentum can be fast enough to *disorientate* the player and that his speed is clearly attributed to the vertigo classification of games, rather than chance, mimicry or simulation (Rutter & Bryce, 2006, pp.79-80). Sonic's quick movements through the game world are a core part of the game, and although some designers may argue that causing disorientation should not be part of a games design (Salen & Zimmerman, 2004), this mechanic of speed in Sonic is an early suggestion that this is perhaps not always true.

Some designers have suggested that technological limitations may be the reason as to why vertigo is not represented as well in game design literature, (unlike Caillois' other three game categories). Game scholar Chris Bateman, for example, reports on the "Joy of Ilinx" (2006), and considers that the possible absence of vertigo elements in games could be down to the limited graphical power available to designers in the past, but suggests that newer, more powerful technologies may now afford the opportunity to design for vertigo based games. Bateman also notes a lack of design consideration regarding vertigo games, despite alluding to a growing popularity as a result of technological advancements: *"very little has been written about the ilinx of videogames, despite the fact it is an increasingly potent force in popular games"* (Bateman, 2006).

These works suggest that game designers have considered vertigo when designing digital games, whether intentionally creating it in their games (Sonic) or as a complement to other game elements. Limited technological power has been blamed as a potential reason that designers have not explored the vertigo game classification as fully within their games, whilst other designers have suggested that Caillois may be incorrect in categorising some games as "vertigo". Either way, there is a limited understanding of how to design digital experiences based on vertigo, and this thesis attempts to address this.

Digital technology, I argue, can enable novel ways of facilitating engaging vertigo experiences and I expand on this later. In the next section I explain what I learned from my research concerning the body as play, which was important to understand before considering how to digitally create sensory confusion in players.

2.3 The Body as Play

In HCI, an interaction between people and objects within the physical world has been explored through embodied interaction (Dourish, 2004). Embodied interaction considers a phenomenological approach to tangible and social HCI design. The consideration of the tangible space concerns several perspectives of HCI design related to design for and with the lived body in mind (Svanæs, 2013). These works consider how players perceive and physically respond to digital sensory stimulation. In HCI exploring how the body responds to the digital world has also been investigated through tangible interactions (Ishii, Lakatos, Bonanni, & Labrune, 2012; Ishii & Ullmer, 1997), proxemics (Hall, 1963, 1966) and whole body interaction (England, 2011; Tholander & Johansson, 2010). Both game and HCI designers can draw inspiration from these works, and with the continuing advancement in digital technology, take advantage of combining these teachings with new experiences that can, for example, encourage seeing the *body* as a form of *play* in and of itself.

Exploring ways to include the body in games as an input instead of using a simple controller has been explored commercially, with one of the more popular examples being that of the Nintendo Wii, and the Microsoft Kinect. Within the HCI research domain using the body as an input mechanic for games has been considered (Larssen, Loke, Robertson, Edwards, & Sydney, 2004), and designers have also explored the explicit development of "Exertion Games", i.e. games that require and encourage physical exertion to play (Nijhar, Bianchi-Berthouze, & Boguslawski, 2012).

The HCI community have created play experiences based on challenging the body (Marshall, Rowland, et al., 2011; Mueller et al., 2011), and researchers have also described that these games can be engaging for the joy of movement alone (Márquez Segura, Waern, Moen, & Johansson, 2013). With their work, Márquez Segura et al. (2013) explain how they see the body as being central to the experience and enjoyment of body-based games, rather than in the traditional videogame setup where the movement of the body is often accidental, for example, when leaning the body as you turn a tight corner in a racing game. Digital vertigo experiences can also be enjoyable due to the movement involved to create sensory confusion in players.

Mueller et al. (2012a) describe an exertion game where players physically hold on to a metal bar whilst dangling above a projected river beneath them. The "river" contains planks of wood which are spaced out to allow the player to rest between hanging periods, and these rest periods get periodically shorter requiring the player to hang by their arms for longer. In this example, player fatigue is the desired outcome and the game will not stop until the player eventually lets go of the bar. Mueller and Isbister (2014) suggest that games can be designed with an outcome in mind to make them more engaging, i.e. hanging by one's arms for a long time is tiring, so make that part of the challenge. With digital vertigo experiences designing for the specific outcome of sensory confusion is important, and this work highlights that at times, what may be considered a negative coincidental side effect of playing a game, can actually be designed for from the start. Further, it encourages designers to question what players may actually want to experience through questioning what should be considered as a "negative" experience.

2.3.1 Uncomfortable bodily-play experiences

With that being said, there is a body of work in the HCI community concerning the study of uncomfortable interactions (Benford et al., 2012). Uncomfortable interactions are described by Benford and colleagues are interactive experiences aimed at creating a deliberate and powerful cultural experience for players (2012). Such interactions are intended to cause a degree of suffering to the user, and are designed to facilitate feelings of sociality, entertainment or enlightenment in those who experience them. These games which deliberately cause some form of discomfort in their players in order to create entertaining experiences, have encouraged other designers to create their own uncomfortable interaction games, such as a two player game where one player is shut inside a real physical coffin (Brown, 2015).

The work of Huggard et al. (2013) exploits another fear of players through creating discomfort in the form of social interactions requiring players to tightly embrace strangers in order to move a game character on screen. In each of these examples, the players found the games engaging and fun to play, despite the initial trepidation of being shut inside a coffin, or hugging strangers. With digital vertigo experiences it is possible that players are hesitant to play the games initially and this work helps to illustrate that this is not necessarily a problem, but something that can be factored into the design.

For instance, Benford et al. (2012) describe that their experiences could be embedded into a larger narrative through the use of Freytag's pyramid (Freytag, 1863) where players can be eased into the experience on the rising action, reach a climax of interaction at the peak, before recovering on the falling action. Digital vertigo experiences expand this work since they too could cause apprehension in players initially, and using a similar narrative structure can serve to introduce players to the experience and to prevent their senses from becoming too overwhelmed by allowing them to also recover.

Intense bodily-play interactions have also been explored by Marshall and Benford (2011), who discuss how intense experiences can be created through the use of fast interactions. In their work the authors introduce a system which plays a poem to participants, but the entire poem is only heard if participants constantly increase their movement speed. This means that users cannot remain still and are encouraged to run faster and faster in order to hear the entire 90-second poem. The studies discovered that terrain, novelty of setting and speed, as well as the level of exertion, provided different results to the experience. What is interesting about this work, is that the combination of speed, terrain, etc. blurred the participant's senses such that they could not remember the poem, resulting in a gradually more intense experience. This shows that designers can orchestrate how an experience can unfold and is useful for digital vertigo experiences as it suggests that the sensory confusion should be induced over time, rather than all at once. Doing so could potentially facilitate the emergence of a constant challenge.

As has been shown by the exploration of uncomfortable interactions within the HCI community, players can find unusual games and experiences engaging, and I suggest that digital vertigo experiences – which are playful experiences that involve players experiencing sensory confusion - are also worth exploring in the HCI community.

2.4 Learning how to induce sensory confusion

Creating artificial sensations of vertigo can be an unwanted side effect in some games and can result in a form of digitally induced motion sickness referred to as "simulator sickness" (Kennedy, Lilienthal, Berbaum, Baltzley, & McCauley, 1989). Simulator sickness, although less severe than motion sickness (Kennedy, Lane, Berbaum, & Lilienthal, 1993), *"occurs when physically stationary individuals view compelling visual representations of self-motion"* (Hettinger & Riccio, 1992). Simulator sickness has also been reported in VR due to the same reason (Sharples et al., 2008), i.e. a player is stationary and their vestibular sense reports this, but their visual sense reports that they are moving. This can be disorientating for the player if it is not the desired result of the game.

Similarly individuals can experience vertigo sensations due to sensory confusion as a result of looking down from extreme heights, where a sensory mismatch occurs as visual information is in contrast to their proprioceptive and vestibular senses (Brandt, Arnold, Bles, & Kapteyn, 1980). This "distance vertigo" (Brandt et al., 1980) is not quite the same as acrophobia, which is the fear of heights, although some work has considered that acrophobia may be a result of an individuals over reliance on their visual senses to assist their sense of balance (Whitney et al., 2005). This effect is exaggerated at extreme heights as it becomes difficult for the eyes to make sense of the distance and focus on one spot. This feeling of sensory confusion due to extreme heights is the type of vertigo immortalised in Hitchcock's famous 1958 film of the same name (Hitchcock, 1958), and is perhaps one of the reasons that people confuse vertigo as being a fear of heights (Bradford, 2016).

Hitchcock achieved his effect with the now well-known "dolly zoom" (Wickman, 2014), which first created the illusion of vertigo on the cinema screen. Interestingly VR work has explored helping people overcome their fear of heights through VR treatment (Emmelkamp et al., 2002). This work suggests that technology can be used to induce vertigo sensations, and I propose with my work that digital technology could be used to help control how much sensory confusion is experienced by players, and could perhaps even help in avoiding simulator sickness, or alternatively exaggerating the disorientating effects. My framework is a contribution to this end.

2.4.1 Learning from machines that can create sensory confusion

Creating vertigo-type experiences can be achieved through the confusion of two or more bodily senses, and fair grounds, which actively design for such experiences, have been entertaining people in this way since the Nineteenth Century. The Haunted Swing Illusion (Wood, 1895), for instance, is one of the earliest examples of a mechanical ride designed to induce sensory confusion by tricking riders into thinking they are swinging a full 360 degrees around a swing. In actual fact, the riders are near stationary and the room the swing is placed in rotates around them (see figure 2.1). Riders experience "vertigo" due to the confusion of their visual sense and their vestibular sense. Inspired by this work, Tennent et al. investigated purposefully developing HMD experiences where the visuals were not synchronised to the body's real world movement (Tennent et al., 2017). Their version of the swing amplified a riders swinging motion and lead to players feeling as though they were swinging further than they really were, and is another interesting example of creating sensory confusion in riders to create an entertaining experience.

Researchers have also investigated how digital technology could be used to allow riders to control a ride based on their own bodily data. Marshall et al. (2011) used a breathing sensor to detect when a rider was breathing in and out, and used this body data to spin the very ride the rider was sitting on. The ride, a mechanical "bucking bronco" system, translated the rider's breathing into directional input, turning the bronco anti-

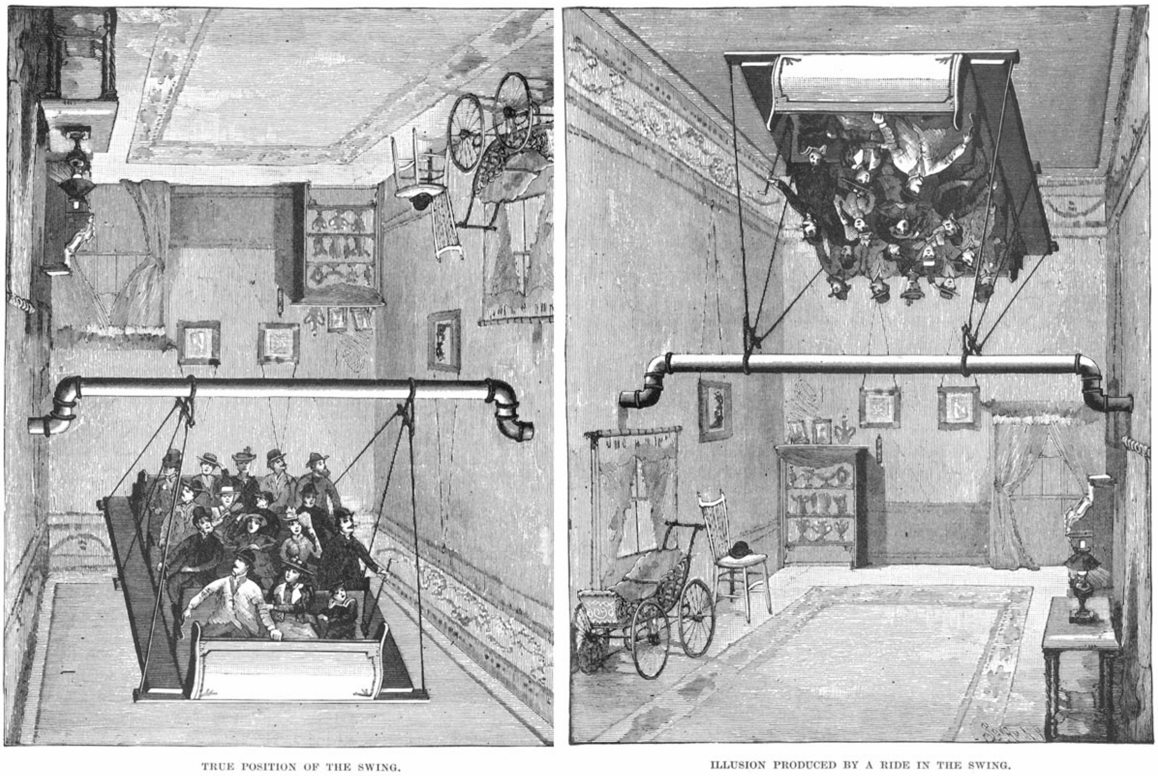

Fig. 2.1 The Haunted Swing Illusion, adapted from Jastrow (1897, pp. 92-93). The left image shows the true position of the swing, whereas the right image shows how the riders perceive what is happening.

clockwise when breathing out and clockwise when breathing in. The speed of breathing controlled the speed of rotation of the ride. In order to maintain a level of progression the ride also got gradually more difficult by increasing the rotation speed, before adding the "bucking" motion to the bronco in later levels. Studies revealed that allowing the user to feel a gradual loss of control improved the experience. Additionally the ride was deliberately made difficult in the latter stages to encourage participants to fall off and thus feel a full loss of control.

One of the most alluring reasons for my interest in exploring vertigo games, was that Caillois highlighted in his work the creative measures needed as one ages to experience vertigo sensations, such as inducing high speeds by driving sports cars around corners, the thrill of downhill acceleration through sports such as skiing, and, in particular, by using "powerful machines" (Caillois, 1961, p.25). Caillois uses theme park and fair ground rides as examples of these powerful machines, stating that *"these machines would obviously surpass their goals if it were only a question of assaulting the organs of the inner ear, upon which the sense of equilibrium is dependent. But it is the whole body which must* *submit to such treatment as anyone would fear undergoing*" (Caillois, 1961, p.25). Today, thanks largely to advances in digital technology, these powerful machines are not necessarily the only method of creating vertigo sensations. In the next sections I describe the two methods of inducing sensory confusion in players that I used throughout the course of my research: Galvanic Vestibular Stimulation, and Head Mounted Displays.

2.4.2 Learning about Galvanic Vestibular Stimulation

Galvanic Vestibular Stimulation (GVS) is an electronic stimulation system that is described by Fitzpatrick and Day (2004) as both a simple and safe method of eliciting vestibular (balance) reflexes. GVS is an application of small (< 5 mA) electrical currents attached to the skin via electrodes on the mastoid bones behind the ears, directly over the vestibular system. When current is applied a vestibular response is triggered and people who wear the system often feel their balance affected in the direction of the positive electrode. Traditionally, GVS has been used in medical fields such as physiology and psychology to, for example, investigate how walking patterns change when GVS is applied (Fitzpatrick, Wardman, & Taylor, 1999), or as a way of treating neuropsychological disorders (Utz, Dimova, Oppenländer, & Kerkhoff, 2010).

Even though GVS originated in the medical community, some HCI designers have appropriated GVS systems for entertainment purposes. For example, Nagaya et al. (2006) investigated a novel way of experiencing music, where a person's perception, balance and vision become affected based on the beat and rhythm of a music track, through the application of GVS stimulation in time to the music. Further describing the potential of this technology, Maeda, Ando, Amemiya, et al. (2005), created a GVS system that allowed an individual to alter the balance of another user via remote control, effectively altering the controlled user's walking direction. Maeda and colleagues found that participants were *"not distracted by the stimulation"* (2005) and were not aware that their altered balance behaviour was a result of the system stimulation. Additionally the work described another prototype in the form of an adapted car racing game that caused a player to feel "centrifugal force" whenever a car turned a corner in the game, adding an extra layer of reality to the racing game by extending the experience directly to the body. This work is interesting as it has demonstrated how digital technology could be used to directly, and explicitly, confuse a player's senses, and does so subtly enough that players are not aware that they are being affected.

Affecting one's sense of self-motion has also been explored in work that combined

GVS with VR games Maeda, Ando, and Sugimoto (2005). In this work Maeda et al. compared the sense of proprioception (self-motion) experienced in VR to that felt from GVS. The authors found that when VR is combined with GVS, negative effects such as motion sickness, which were previously experienced by participants, were reduced. This work supports mine, as it states that systems designed to induce sensory confusion can be digitally controlled such that the sensory confusion experienced by players can be exaggerated or dampened to help change the experience that they have.

Technology like GVS affords designers an unique opportunity to finely control player's bodily responses, and in fact this has been demonstrated by Moore, Dilda, and MacDougall (2011). In their work, Moore and colleagues adapted GVS for use by astronauts as a practical training tool, allowing trainee astronauts to familiarise themselves with the possible effects they may experience during and after flights. This obviously requires a fine range of control to carry out, and serves to highlight the control afforded to designers by this type of technology. The fact that GVS has been considered as both a practical and entertainment tool also suggests its applicability towards being used in digital vertigo experiences, where controlling a player's sensory confusion is imperative to the experience the designer wishes the player to have. The appropriation of existing electronic systems like GVS, and how to design vertigo experiences with them which do not make players nauseous has not been articulated previously, and my thesis addresses this absence to also contribute towards filling this gap in design knowledge.

Learning about Head Mounted Displays

As discussed earlier, the "pursuit of vertigo" can be the main attraction behind many popular extreme sports such as rock climbing (Alderman, 1974; Kenyon, 1968), and designers have experimented with creating digital and simulated versions of these experiences. One such technology that has allowed designers to achieve this are HMDs. For example, several HMD games have been designed to allow players to simulate the traversal of popular climbing routes within a virtual space (Crytek, 2016; Dufour et al., 2014). In prior investigations of virtual spaces, researchers have suggested that players can potentially experience a sense of vertigo within the virtual space due to the inherent sensory confusion afforded by the HMDs, i.e. the player moving in the virtual world but being stationary in the real, physical, world (Meehan, Insko, Whitton, & Brooks Jr, 2002; Sharples et al., 2008).

Whereas sensory confusion of this kind can be considered to be the cause of motion sickness or a way of inducing nausea in players (Sharples et al., 2008), recent work contests that embracing this confusion can lead to more immersive vertigo experience simulations, such as simulating death-defying tightrope walks. The design studio Inition, for example, challenged players to walk across a real world plank whilst wearing an HMD which depicted the plank as being suspended high above the ground between two buildings (Inition, 2014b). Similarly, for the film *"The Walk"*, Sony Entertainment created a companion application that allowed players to virtually traverse the same route as the lead character in the film – a tightrope walk between the Twin Towers over a 1974 representation of New York City (Sony Pictures Home Entertainment, 2016).

These experiences focus on distance vertigo (Brandt et al., 1980), and the sensory confusion induced when one's vestibular and visual senses are not able to compensate for the (simulated) height as the player's eyes find it hard to focus on the a spot in the distance. For some players, this may exploit their underlying acrophobia (their fear of heights), which in turn could create feelings of unpleasant and nausea inducing vertigo (a disorientation that occurs in those who suffer from acrophobia).

Height induced vertigo is an effect that can be exploited with HMDs because designers can control what the player sees and to what extent their vision is affected. Players of VR games have even said that they have experienced height-related vertigo when playing certain VR games (Meehan et al., 2002). Usoh et al. (1999) explored the feeling of immersion in VR spaces and found that when players were exploring a VR space by walking in the real physical world, that a virtual hole in the floor (in the VR space) created an exaggerated feeling of vertigo in players when the hole was deeper and wider.

Designers have also explored combining HMDs with large-scale equipment in order to create more intense simulations, such as simulating the feeling of wing-suit flying (Inition, 2014a), or skydiving (Eidenberger & Mossel, 2015). Building on such work, theme parks have looked to digital technology to renovate old rides or to breathe new life into the experience of riding them. On the Galactica rollercoaster (Merlin Entertainment Group, 2016), for example, riders wear HMDs to experience a virtual spaceflight which moves in response to the real rollercoaster. Similarly, researchers have also postulated adapting waterslides in waterparks to allow riders to wear HMDs to alter the experience while sliding down the slides (Raffe et al., 2015), which could potentially lead to sensory confusion in the form of making the riders visually see something in conflict with their movement down the slide. These works suggest that digital technology like HMDs could be a viable way of achieving vertigo play experiences, since these "vertigo" experiences have already made use of HMDs to alter and enhance existing experiences. Wearing HMDs on a rollercoaster for example offers designers a unique challenge since the riders motion is always the same, but the visual sense of motion can be exaggerated, or placed in direct conflict (e.g. the ride goes left but the visuals go right).

Steam's *HTC Vive* system allows players to be tracked whilst playing HMD games in their living room (Vive.com, 2017), and researchers have also investigated affordable ways of allowing players to experience immersive VR environments in their own private spaces. Greuter and Roberts (2014) for example detail a custom built system, *SpaceWalk* which uses a *Microsoft Kinect* sensor for position tracking, and the Oculus Rift to create a custom game environment within any real world space. What is novel about this system is that it utilises low-cost and mobile hardware, negating the need for custom built environments or large motion-capture rooms. The system allows any room to host a simulated space, encouraging players to get up and move around their game environment, facilitating the emergence of vertigo experiences whereby a player's walking movements can be placed in contrast to their visual senses.

2.5 Learning from Existing Bodily Interaction Frameworks

In HCI, frameworks can be used to obtain a better understanding of systems or the user experience of using the systems (Hornecker, 2010). Many frameworks, however, do not offer step-by-step guidance on the design process of creating such systems (Hornecker, 2010). In practice-based research this has been an issue for researchers (Olsen Jr, 2007), who have since investigated possible ways of closing this gap to support designers in the design process (Antle, 2009; Hornecker, 2010). This has often taken the form of a design framework supported with design guidelines (Mueller & Isbister, 2014), strategies (Pijnappel & Mueller, 2014) or sensitivities (Jensen et al., 2014). The contribution of my work will be in the form of a theoretical design framework, and I have considered relevant related works in order to guide me in the design of this framework such that it will be useful for designers in creating their own Digital Vertigo Experiences. I describe these works below.

The "Exertion Framework" (Mueller et al., 2011) explores the body as play, and presents an investigation into how digital technology can be used in order to design and extend Exertion Games through four key lenses. These lenses consider the body as more than a single space to consider when designing Exertion Games, suggesting up to four spaces should be considered: The Responding Body, The Moving Body, The Sensing Body and the Relating Body.

Each space progressively increases in distance from the central body, i.e. The Responding Body is inside the body, with the Relating Body considering how one body relates to another person in an environment. Though this work does not directly explore the role of vertigo in games the spaces described by the Exertion Framework do highlight that digital, body-based games should consider the placement of digital technology within these spaces. For example, there could be up to three spaces that are particularly relevant to consider when designing for digital vertigo experiences: the responding body (how the body is affected by the vertigo experience), the moving body (placement of wearable technology for vertigo experiences and the game space) and the sensing body (support the vertigo experience when players use external technology). This work considers bodily interactions as desirable in games, and further, accentuates that when supporting the body with digital technology there is more than one bodily space to consider. The work of this thesis draws from the exertion framework as it illustrates what different factors can be altered (e.g. the level of facilitated sensory confusion), to create different types of digital vertigo experience. Additionally the two example technologies used in this thesis - GVS and HMDs, help to illustrate which lens relates to which technology (e.g. GVS affects balance internally, whereas HMDs affect the visual senses externally).

The Taxonomy of Thrill (Walker, 2005), presents a design taxonomy to determine how thrilling an experience can be by scoring it based on Walker's formula (2005). Walker later extended this work with design strategies for augmenting theme park rides (2007) in order to support designers in creating thrilling experiences. Schnädelbach et al. (2008) extend this work in their digitally augmented theme park ride research, and reflect on their design experience in the form of a design discussion. These works illustrate how a design framework, or taxonomy, along with relevant design tactics can lead to researchers creating their own experiences based on the prescriptive advice of the framework.

Considering how to design for the spectator experience, Reeves, Benford, O'Malley, and Fraser (2005) present a taxonomy that describes how different HCI experiences can be more magical, more expressive, more secretive, and more suspenseful. The authors provide a description of what constitutes each type of experience and what designers need to do to create experiences within these spaces. Marshall, Dancu, and Mueller (2016) draw on movement based interactions, such as proprioceptive interaction (Lopes et al., 2015), to present a taxonomy for use by designers interested in creating mobile interaction systems for use by a user who is in motion at the time of using it. The authors present a design space similar to that presented by (Reeves et al., 2005) in that it is split into four distinct experience areas, and the authors also provide design strategies to address the different dimensions of their taxonomy and how future designers can design their interactions based on each of these spaces. I lean on these examples in my own work by also contributing four user experience areas for the design of digital vertigo experiences, and also combine my framework with prescriptive examples in the form of design tactics designers can consult when creating their own digital vertigo experiences.

I consider the works here as inspiration for my own Digital Vertigo Experience Framework, as they serve as examples of how designers can not only communicate their findings to other designers, but also how they can provide future designers with examples and tactics to follow in the creation of their own novel systems.

2.6 Research Opportunity and Research Question

Caillois alludes in his work that if sufficiently advanced technology existed, then "powerful machines" would no longer be the only way of creating vertigo experiences (Caillois, 1961, p.26). I believe that with todays advances in digital technology it is possible to create digital vertigo experiences, and the works described above help to illustrate this point.

My exploration of related work highlights a gap in understanding of how digitally induced sensory confusion could be viewed as a design opportunity to create digital vertigo play experiences, and what type of experiences could be created by controlling the sensory confusion felt by players. In this thesis, I address this gap in design knowledge by answering the research question:

> *how do we design digital vertigo play experiences?*

Chapter 3

Methods

3.1 Introduction

This chapter describes the research methods I have used throughout the development of this thesis in order to help me answer my research question. I describe the methods I followed below.

3.1.1 Ethics Approval

All of the studies in this thesis received Ethics Approval from RMIT University's College of Human Ethics, under the reference number of: 0000019016-10/14. My study of the game *Balance Ninja* also received ethics approval from the School of Computer Science at the University of Nottingham, UK (reference numbers are not provided by this University).

3.2 HCI and Research through Design

Throughout my exploration I leant on design theory from the fields of HCI (Rogers, 2004, 2012) and Research Through Design (RtD) (W. Gaver, 2012; Koskinen, Zimmerman, Binder, Redstrom, & Wensveen, 2011). RtD is popular within the field of HCI as it is a method that encourages researchers to focus on "research of the future" (Zimmerman, Stolterman, & Forlizzi, 2010). RtD is also an iterative and reflective practice where thinking and research outcomes become apparent through the direct process of prototyping. Designing in this way allows for interaction designers to evaluate their prototypes by examining the process, invention, relevance and extensibility of their design (Hartmann et al., 2006; Zimmerman, Forlizzi, & Evenson, 2007). With this approach, the design is also not necessarily as important as how it is adopted in context (Zimmerman et al., 2007), where design artefacts become outcomes that can "transform the world from its current state, to a preferred state" (Zimmerman et al., 2007). In RtD, therefore, designers are not necessarily interested in releasing a fully developed system with some kind of cultural impact, but are concerned with the why and the how of users interaction with the artefact (Fallman, 2003).

To achieve this, Cross (2006) explains that designers need to consider the question of "How would you design an <X>?". For this thesis I can extend this statement to include my own research question: *how would you design digital vertigo experiences?*.

To answer this question, I used a RtD approach to develop three prototype systems to investigate novel ways of designing digital vertigo games. This method ensured that the developed systems were iteratively developed based on participant feedback. Such a cycle follows standard game development and testing practices (Fullerton, 2008; Schell, 2003) as well as RtD principles. Additionally game design researchers have utilised this approach in order to generate theoretical contributions based on their designs, for example in the form of theoretical design frameworks (Mueller et al., 2011) or via design strategies and sensitivities to guide designers of related future systems (Jensen et al., 2014). With this thesis I contribute to design theory with the presentation of my Digital Vertigo Experience Framework.

3.3 Qualitative Study Methods Used

As the primary research goal was to create a design framework that guides designers of digital vertigo experiences, I followed a predominantly qualitative research approach (Anselm & Corbin, 1998; Bryman & Burgess, 1999). As qualitative research can be advantageous when understanding technology as experience (McCarthy & Wright, 2004) I considered it to be the most appropriate method, since a deeper understanding of the quality of the vertigo game experience was necessary in the development of the design framework. Qualitative research involves the collection of subjective - yet open ended - data in order to develop a set of common and recurring themes (Creswell, 2003). To gather these themes I followed the data collecting practice of conducting semi-structured interviews about the experience of playing each of the case studies presented throughout this thesis.

3.3.1 Data Collection: Playtesting and Semi-Structured Interviews

In order to garner an understanding of the experience participants have when playing the games, I first made use of playtesting (Fullerton, 2008), before asking players about their experience in semi-structured interviews.

Semi-structured interviews (Wengraf, 2001) are often used to understand user interactions with given systems. The interviews can provide more in-depth insights on user experience and how it perhaps felt to interact with systems, something that standard quantitative data (such as recording system information) cannot reveal. I opted to use semi-structured interviews since this afforded the opportunity for follow up questions, which as Neuman (2006) explains, supports a deeper elucidation of participants' responses and thinking processes. Such an approach complemented my research approach by allowing me to gain a deeper understanding of how users interacted with and felt about the digital vertigo experiences they played.

To support the semi-structured interviews and playtests I took my own paper notes and also digitally recorded audio and video data of the interviews and playtests. I chose to record this data in each case study as related work indicated this was a good approach for research which involves body movement and digital play (Larssen et al., 2004; Moen, 2006; Mueller, Agamanolis, & Picard, 2003) since it is possible to support what a player says in the interviews, along with the digital recording of the play experience. For example, if a player said they particularly enjoyed when x happened, I was able to check this in the playtest video and see the player smiling, validating what they had said.

I describe my data-analysis approach in the next section.

3.3.2 Data Analyses: Inductive Thematic Analysis

The main method for data analyses I followed throughout the case studies was inductive thematic analysis (Braun & Clarke, 2006). This form of analysis is similar to grounded theory Anselm and Corbin (1998) in that the inductive approach means the themes identified are strongly linked to the data themselves (Patton, 1990) and thus, allows for data-driven coding to occur (Braun & Clarke, 2006).

Braun and Clarke (2006), suggest that thematic analysis offers an accessible and theoretically flexible approach to analysing qualitative data allowing the themes themselves to be grounded in the data and ensures that important themes are not missed.

The inductive thematic analysis in this thesis was achieved in the following way in each case study:

- The interview data was first transcribed.
- Two researchers independently coded the transcripts.
- We grouped the codes together in meetings held either in person or over Skype. The groupings were then translated into recurring design themes.

3.3.3 Likert Questionnaire

In *Balance Ninja* and *AR Fighter* I also employed the use of a five-point Likert scale questionnaire (Allen & Seaman, 2007) in order to gain some quantitative data about players' perception of playing the game.

3.4 Study Design and Methods Used

Following a research through design approach allows designers to adapt systems in an iterative manner, based on experience gained from not only the evaluation stage but also the design stage. This allows for the creation of new design artefacts previously not considered during the conceptualisation of the initial systems (W. Gaver, 2012). Throughout the development of the thesis several systems were iterated on to improve their usability and to alter or adapt their functionality based on the user feedback. The study design and research methods used for each case study are presented in the following sections.

3.4.1 Case Study 1: Design Workshop

The workshop followed a rapid prototyping structure. Rapid prototyping has been used in HCI (Dey, Abowd, & Salber, 2001) and game design (Lopez & Wright, 2002) successfully as a way of quickly ideating and testing ideas. Rapid prototyping can be achieved with lo-fidelity paper prototypes as well as hi-fidelity more realised concepts. As this was an exploratory workshop in order to gain design ideas through participatory design I elected to use lo-fi paper based prototyping, which has been shown to lead to similar results at the conceptualisation stage (Sefelin, Tscheligi, & Giller, 2003). This allowed for all of the participants to take an active role in building or playing with the provided equipment (paper, notepads, stationary, poster tubes, stickers, etc.), without any need for special expertise. The games were then presented and discussed, and I transcribed the presentation and discussions to uncover several initial themes and design ideas for the development of digital vertigo experiences.

3.4.2 Case Study 2: *Inner Disturbance*

My first digital vertigo experience was developed following the findings from the design workshop, which is detailed in Case Study 1 (see chapter 4). The workshop suggested that the GVS technology probe (Hutchinson et al., 2003) was something that participants enjoyed experiencing and experimenting with. I developed a simple game with a custom built GVS system that altered player balance from left to right whilst they tried to remain standing on one leg. The purpose of this study was to see how the system would be perceived and if players would actually enjoy using it in a game context. Thematic analysis was used on the recorded interview data, and allowed me to derive four recurring design themes and accompanying design tactics. The full details of this investigation are presented in Chapter 5.

3.4.3 Case Study 3: *Balance Ninja*

Balance Ninja (see chapter 6) investigated how players would feel when the GVS system directly controlled one player based off feedback from another (in a closed-feedback loop), rather than from a computer. A thematic analysis of the study data allowed me to derive three design themes and accompanying design tactics. I also used a five-point Likert scale in this study to gather some quantitative information about the players' experience of *Balance Ninja*.

3.4.4 Case Study 4: *AR Fighter*

AR Fighter built on the prior case studies by using a Head Mounted Display (HMD), instead of Galvanic Vestibular Stimulation, as the primary method if inducing sensory confusion in players. The goal of this work was to see what type of experience would be created by using a different stimulation technology, and if it was still a digital vertigo experience. In evaluating this study I once again made use of a five-point Likert scale and inductive thematic analysis to refine the themes and associated design tactics I had previously uncovered. I also discovered new tactics related solely to HMD based digital vertigo experiences.

3.5 Summary

In this chapter I have presented an overview of the main research methods I used throughout the thesis. Each individual chapter contains a more detailed description of how the design, development, and evaluation of each study was undertaken. Primarily, iterative design, research through design and inductive thematic analysis were the methods I followed throughout every case study, and through invoking these research methods I was able to derive my Digital Vertigo Experience Framework.

Chapter 4

Case Study 1: Design Workshop

4.1 Introduction

In this chapter I detail an my first case study: a design workshop through which I explored how designers may approach the topic of designing digital vertigo experiences. The intention of this workshop was to provide a starting point for the work by involving potential designers in the design of imagined vertigo experience systems, which related work has suggested is a valuable process to follow in the early design stage (van Turnhout et al., 2014). In this workshop nine people who were taking part in a university game design module participated in total.

The main purpose of this workshop was to address the 1st objective of my core research question: "What factors are important to begin creating *digital* vertigo games?" In the following chapter, I address this question through the presentation of the workshop process and structure, before describing the workshop findings and possible vertigo experience ideas that emerged. This work helped to inform an understanding of how designers may approach the design of digital vertigo experiences, and helped to provide ideas for the system development of the case studies which follow in later chapters. An analysis of the workshop presentations allowed me derive five recurring design themes from the participants' discussions, as well as ideas as to how the themes could be used to design vertigo experiences in the future. These too are discussed in more detail below.

4.1.1 Related Publication

Work in this section has also been peer reviewed and reported on in a full conference paper (8 pages) entitled: "Designing the Vertigo Experience: Vertigo as a Design Resource for Digital Bodily Play" (Byrne et al., 2016b), which was presented at The ACM International conference on Tangible, Embedded and Embodied Interaction (TEI) 2016 in Eindhoven, Netherlands. The paper is available to view at `http://www.richbyrne.co.uk/publications/`.

4.2 Workshop Design

Fig. 4.1 Workshop participants during initial ideas stage of the workshop.

The workshop followed a rapid prototyping structure. Rapid prototyping has been used in HCI (Dey et al., 2001) and game design (Lopez & Wright, 2002) successfully as a way of quickly ideating and testing ideas. Rapid prototyping can be achieved with lo-fidelity paper prototypes as well as hi-fidelity more realised concepts. As this was an exploratory workshop in order to gain design ideas through participatory design I elected to use lo-fi paper based prototyping, which has been shown to lead to similar results at the conceptualisation stage (Sefelin et al., 2003). This allowed for all of the participants to take an active role in building or playing with the provided equipment (paper, notepads, stationary, poster tubes, stickers, etc.), without any need for special expertise.

The workshop lasted a total of three hours, and followed an iterative process of ideation, prototyping and discussion. The nine participants were split into teams of two (one team of three due to the uneven number) creating four groups in total and over the three hour period they were challenged with conceptualising and rapidly lo-fidelity prototyping a vertigo game. To help with this, the participants were given Caillois' vertigo definition at the start of the workshop and asked to initially consider what they thought was meant by "designing games of vertigo".

Fig. 4.2 Workshop participants prototyping their design ideas.

Additionally, after the first thirty minutes, participants were provided with several possible vertigo characteristics that had been derived from related work. These characteristics were in the form of dimensions (main word), and the extremes of these dimensions (brackets): Mechanic (Gameful/Playful), World (Real/Virtual) and Affect (Obvious/Subtle). These themes were offered as a guide and the participants were told that they were free use or ignore them as they wished, as were primarily there to support the participant's ideation. This approach was in part inspired by related work, which suggested the use of *design lenses* (Mueller et al., 2011; Schell, 2014) and *design cards* (Flanagan, Belman, Nissenbaum, & Diamond, 2007; Hornecker, 2010; Lucero & Arrasvuori, 2010), as being valuable ways of further enhancing the ideation process.

In addition to the design characteristics and the vertigo definition I also provided three identical Galvanic Vestibular Stimulation (GVS) systems (explained further below) that I had custom built for the workshop. Their development is explained below and their use by the participants was optional.

Finally, through feedback sessions over the last 45 minutes of the workshop, each group presented their design idea and paper prototype to the rest of the group. This presentation session facilitated group discussion and the entire session was both video and audio recorded to allow for data analysis at a later stage.

4.3 GVS as a Technology Probe

As discussed in related work, Caillois suggested that affecting the inner ear (i.e. the vestibular system) directly could help to create vertigo games that do not require large machines or infrastructure. GVS is an electrical stimulation technology which does directly affect the vestibular system; it is a simple and safe way of affecting one's balance by applying a small current (+/- 2.5mA) to one's vestibular system (Fitzpatrick & Day, 2004), and is reported to have no lasting negative effects from repeated use (Wilkinson, Zubko, & Sakel, 2009). Electrodes placed behind each ear deliver a current across the ears, which in turn stimulates the balance organs of the inner ear. The result is that wearers feel a *pull* or *sway* towards the positive electrode, or experience a perception of leaning when they are in fact standing still (see figure 4.3).

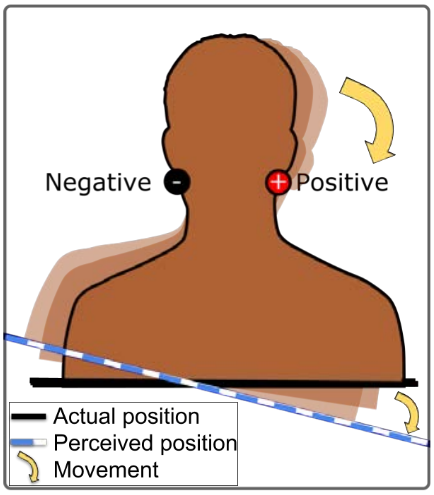

Fig. 4.3 When GVS is applied, one feels as though their perception of balance (black line) is altered towards the positive electrode, and compensates for the adjustment (blue dotted line), causing a lean towards the positive electrode.

Controlling GVS through digital means offers some unique play abilities for designers, and in related work I have already discussed several of these, including remotely controlling another person's walking behaviour (Maeda, Ando, & Sugimoto, 2005), or internally creating vestibular sensations to support the feeling of racing fast cars in racing games

(Nagaya et al., 2006).

The use of a technology as a facilitator for ideation has been suggested to allow researchers to plan and create new technologies through co-designing with users (Hutchinson et al., 2003). Therefore, instead of allowing groups to ideate solely without using any technology, I felt it was beneficial to offer the groups an opportunity to gain familiarity with a possible digital vertigo experience for themselves.

It is important to note that the goal of the workshop was not to evaluate the performance of the GVS system itself, but to encourage discussion of designing digital vertigo games by allowing the groups of participants to experience vertigo sensations within the constraints of the workshop room. Participants were not required to use the system, but as Shusterman (2014) and HCI designers explain, when designing interactions for the body, it is important to know how the body moves and feels when experiencing that interaction (Fogtmann, Fritsch, & Kortbek, 2008; Höök, Jonsson, Ståhl, & Mercurio, 2016; Höök & Löwgren, 2012). Therefore participants were informed that the systems were there to help with the ideation of vertigo games, by allowing them to experience an artificially induced sense of vertigo if they so desired.

4.3.1 GVS System

Initially I investigated the possibility of using an off-the-shelf GVS system, however they are not readily available. Therefore I built my own from scratch, looking to related work for inspiration for the system. The basic system requires a 9V battery, a current of between 0.5-3 mA and an ability to alternate the positive electrode from left to right, and vice versa.

The GVS systems used in the workshop can be seen in figure 4.4a and figure 4.4b).

Each system consisted of an H-bridge built from four NPN transistors to change the current direction, two push buttons to activate the H-bridge and a current meter. The system was powered by a single 9V battery and self-adhesive electrodes (attached via crocodile cables) allowed for easy attachment to the mastoid bones behind each ear. The system also made use of a 5K potentiometer to allow for system calibration, and guard resistors for safety reasons such that the current output by the GVS system could not go above a maximum of 2.5 mA. This value was chosen since related work indicates good performance from 1 mA - 2.5 mA (Fitzpatrick et al., 1999; Nagaya, Sugimoto, Nii, Kitazaki, & Inami, 2005), and is far less than the recommended maximum of 5 mA, which has been suggested as causing discomfort if exceeded (Curthoys & MacDougall, 2012).

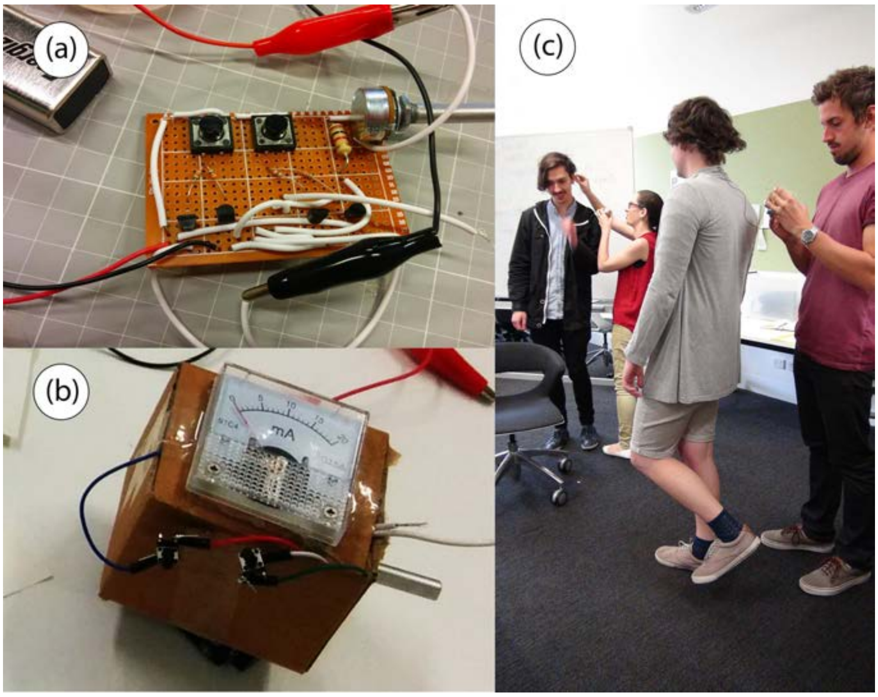

Fig. 4.4 (a) the system circuit (a), (b) how it looked to participants, and (c) GVS application and use. The player on the right controls another, whilst the group in the background applies the electrodes before using the system.

The procedure for using the GVS system was as follows:

- The electrodes were attached securely behind each ear.
- The potentiometer was set to its highest resistance before the participant holding the device pressed one of the electrode buttons.
- The current was slowly increased by manually decreasing the potentiometer resistance until the participant wearing the electrodes felt an effect such as a tingling or their balance being affected.

4.4 Workshop Games

The workshop concluded with a discussion about the design process and the participants' thoughts about using vertigo as a design resource for bodily play. Here I articulate the game ideas in order to provide a greater context to the design themes I discuss later.

Of all four groups who took part in the workshop, at least one person from each group chose to wear the GVS system in order to experience the effect. Figure 4.4c and figure 4.5

Fig. 4.5 The player in the front smiles as he experiences the GVS sensation for the first time. The player behind laughs as he realises his button presses are affecting the player in front.

show participants testing the GVS systems. Each participant who wore the system said that they lost their balance in different ways when using it. Some participants simply stood on one leg, whilst others walked around the room whilst their partner pressed the buttons to alternate the GVS stimulation from the left to the right. This response suggested that the GVS technology created a sense of sensory confusion strong enough that it caused players to lose their balance.

Along with these experiences, the groups designed their own vertigo experiences, resulting in five different types of game discussed in total (one team presented two different ideas). As part of the presentation the groups also discussed how they imagined their prototype games would integrate with digital technology if they were able to develop them beyond this preliminary workshop. Participants were also invited to try out each others games (see figure 4.6).

Fig. 4.6 Two groups play another group's game.

The following sections present each game that was discussed and are supported with participants' design comments. Several of the presented game ideas can also be seen in figure 4.7.

Group One - Bouncing Interactions

The first group considered jumping and bouncing as their main gameplay mechanics, describing that they wanted players to wear "bouncy" shoes in order to move around their proposed game area. Players would be required to jump on a series of lights that would randomly illuminate on the floor (illustrated with stickers in figure 4.7b) in order to score points. The group explained that they wanted to use the shoes to make it difficult to remain in control *"while you're springing around trying to hit these goals, you're kind of going all over the place, so it makes it really hard and hap-hazard and crazy"* [Participant (P) 1]. Such gameplay would have the result of confusing the player's sense of balance, making it more difficult for them to achieve their objective of hitting the correct lights.

This group also stated that they found bouncing was a really *fun* aspect, demonstrating this in the workshop by using the bouncy nature of the office chairs to move around

Fig. 4.7 Several prototype games being described by participants: a) Cooperative Maze Escape, b) Bouncing Interactions, c) Blindfolded Obstacles.

the room. They explained that by trying out different ways of bouncing and from trying the GVS system, they could imagine different types of games based on the premise of bouncing, *"Yea it's a good framework here you can sort of add anything into it and it just sort of makes it more fun."* [P2]. They also emphasised how the body played a key part in their game design, *"Yea [we were] just trying to maximise enjoyment and the bodily kind of action."* [P1].

Group Two: Blindfolded Obstacles

The second group presented their concept as a cooperative experience where one blindfolded player wearing headphones would be guided through a world filled with both real and virtual obstacles, by another team of players providing audio directions to the individual player. Presented as a cardboard drawing (figure 4.7c) and acted out by the participants, they explained that the challenges they thought could be faced by the blindfolded player would include divulging a secret before being allowed to proceed further (creating a sense of panic), navigating dangerous terrain such as a bridge that would lose planks and using a swing whilst remaining blindfolded (challenging perception).

The participants suggested how they saw their game as more of an unstructured and spontaneous activity, *"there needs to be a lot of spontaneity and not too much structure of rules, because the spontaneity of a game like this and the activities create the thrills and the tension"* [P9]. The participants also explained how they considered anticipation to be a core mechanic of their game also, *"just, um the sense of apprehension, and expectation and anticipation that felt like, that was part of the fun"* [P3].

Group Three: Escape the Room and Inducing Fear

The third group described two different game ideas, one an escape the room game and the second a Vertigo Experience based on fear. The participants explained that they were influenced by the *strange* feeling the GVS effect induced in them, and spent time considering how that feeling could be incorporated into vertigo games. They described an escape the room scenario where GVS could attempt to *"replicate a supernatural sense of where things are"* [P5], where players would be subtly *drawn* towards specific objects that they would need in order to solve the puzzle in the room.

The second idea the group presented was a cooperative game where one player would secretly take the role of a horror figure in a fear experience, whilst other players were trying to get away from this player. However, again using GVS, the players would lose their sense of balance as the horror figure approached, making escape more difficult, *"so that experience of fearing that thing, almost as if it affected [you]...it felt like it affected you on a supernatural level and its coming from different wavelengths [it] could be a fun emotion to play along with"* [P6]. This game considers vertigo from the perspective of disorientating and affecting the player's perception, as well as inducing a sense of panic in the case of trying to run away from a horror figure.

Group Four - Cooperative Maze Escape

The final group described their game idea as a two-player game where one player would guide and control another player as they traverse a maze (shown in figure 4.7a). In the suggested game, one player would have a virtual birds eye view of the maze and is responsible for navigating both themselves and the other player through the space. Both players, the group explained, would experience the navigation effects via a GVS system, which would actually be controlled by the person behind (4.7a).

Initially the group experimented with the GVS whilst the player in the maze was blindfolded, but found that destabilising effect of GVS was heightened by adding a visual component, allowing for the player to see how they were falling, *"We realised while actually* *testing it out [GVS] we both presumed that by closing your eyes would make it easier to feel the impact of what direction to turn, but we soon realised that apparently, [P8] couldn't tell which direction [P8 was] falling in - so I was saying "Go left! Go left!" and [P8 wasn't] going left, so ... we decided to bring the visual aspect back into it and just have you see which direction you were falling*" [P7]. The group also favoured mixing real life and the virtual world by saying they imagined the visual aspect would appear via a virtual reality display, indicating that a combination of a VR game and a GVS system could create an intriguing and rich vertigo game, *"also the use of the natural vertigo that the [VR] creates and the like, I don't know if you guys have seen the roller coaster [VR] and people fall over? But the use of [GVS] to exploit that further or to control it, would be interesting*" [P8].

4.5 Recurring Design Themes

The discussion of the games was audio and video recorded for later data analysis. As described in *Methods* (chapter 3), I followed a qualitative approach to this data analysis. The audio and video information was imported into NVivo (International, 2012) data analysis software, where the imported files were then transcribed. I proceeded to identify five recurring design themes in total from the discussion and game presentations. The next section details these design themes.

4.5.1 Control in the Vertigo Game

Control in the Vertigo Game refers to several aspects of the game: Who is in control of the effect, the player or computer? Is it self-control or giving control to someone else? Is the player losing or attempting to maintain control? Each group (G1-G4 hereafter) considered the level of control in their games. G1 introduced an aspect that would reduce player's ability to remain in control of their movement through bouncing. G2 and G4 suggested that giving another person or group of people control of the player's body or actions would create an engaging vertigo game. G3 on the other hand indicated that enhancing control by offering players a sensing ability could create a novel experience by offering a sort of supernatural aspect to games of vertigo.

Losing Control

The loss of control seemed to be an intriguing theme for the participants with G2, G3 and G4 describing games that would result in some loss of control (losing control when a horror figure approaches for example). This attraction is supported by existing work (Benford et al., 2012; Marshall, Rowland, et al., 2011) that suggests a gradual loss of control, or surrendering control to a computer system, machine or other people can all be used to create engaging and exciting experiences. Flow theory (Csikszentmihalyi & Csikszentmihalyi, 1992) suggests that for an optimal experience to exist, players need to maintain a sense of control, such that the experience is not too easy to control, but is not *beyond* the control of the player, and in vertigo games it is reasonable to assume that a sense of remaining in control may be conductive to an enjoyable experience. Too greater loss of control and confusing the senses too greatly could make players potentially feel sick, for instance.

G2 and G4 did describe ideas that suggested giving self-control to another person could be an interesting aspect to consider in Vertigo Experiences. G2's game is reminiscent of popular 1980 and 1990s British game show *Knightmare* (Child, 1987) where one blindfolded player is tasked to navigate a virtual dungeon whilst being told what to do by a dungeon master and group of players, illustrating the appeal and entertainment value of being controlled by another person.

In the digital realm, controlling others digitally has been explored by Maeda, Ando, and Sugimoto (2005), who used a remote controlled GVS system to affect another person's sense of balance. Experiments with controlling proprioceptive motion through Electric Muscle Stimulation (Lopes et al., 2016, 2015) have also considered how to move another person's body through remote control (Pfeiffer, Dünte, Schneegass, Alt, & Rohs, 2015) remotely using EMS. Although these systems have investigated the novelty of controlling another person, there could be an opportunity in digital vertigo experiences for designers to consider these technologies to create complex and engaging vertigo games, by considering the stimulation method and how it affects the sensory confusion of a player in such a way that their bodily control is also affected.

Maintaining/Regaining Control

G1 suggested that the "fun" in their game would come from the players trying to maintain control and perhaps gain mastery over their environment, whilst bouncing around their imagined arena. The novelty of unfamiliar terrain can be seen from children's play areas where bouncy/jumping castles are a prominent feature, to large trampoline parks where the entire traversable surface is made up of trampolines. Kajastila et al. (2014) considered trampolines in their own work, where a player traverses a platform game on screen by jumping in the real world on a trampoline, they found that an engaging experience was created by players trying to maintain control of their actions during the gameplay. As Caillois describes, vertigo can be either gameful or playful (Caillois, 1961), and this theme suggests that how control is factored into the digital vertigo game design, can affect whether it is more playful or gameful in nature - do players lose it for sheer fun such as when Zorbing, or do they tactfully choose when to surrender and regain control?

4.5.2 Structure of the Vertigo Game

The structure of the vertigo game refers to whether the experience is more gameful or playful in nature. G1 and G4 described a gameful experience where there is a winning goal, (score the most points and escape the maze respectively), but G2 and G3 considered a mixture of both playful and gameful elements. G2 for example expressed how the spontaneous aspect of their game was important in ensuring Caillois' concept of "voluptuous panic" (Caillois, 1961, p.23), but they also employed rules in their game whereby the player would lose the game if they failed a task. Such gameful and playful constructs can create different types of vertigo experiences, such as spinning in circles (playful), or speed climbing (gameful).

Structure is important in all games, but for vertigo games there exists the opportunity to design the game in such a way that players are kept in an optimum state of sensory confusion, as chosen by either the designer or player. For example, in non-digital vertigo experiences if players spin too much they are out of action until their senses re-orientate. In digital vertigo experiences sensors could be used to detect this early on and perhaps lower the level of stimulation to allow players senses to become less confused, before inducing the confusion again later on.

4.5.3 Digitally altering player perception in the Vertigo Experience

This theme considers how digital technology can affect the player of the vertigo game.

Alter the player's perception directly, or indirectly through the environment

Digital technology could be used to directly affect a player's sense of perception, as seen with work by (Walker, 2015) and Tennent et al. (2017), which virtually alters a player's sense of motion in VR; designers could instead choose not to directly affect the player, but to use the digital to alter the environment around them requiring players to overcome tangible obstacles. For example G1's game would take place in the real everyday world, whereas G4 speculated that their game would combine both the virtual and the real, physical worlds. An example of this combination can also be seen in *Inition's* Digital Vertigo Experience (Inition, 2014b). In this example the player walks across a plank in the real physical world whilst large fans generate wind that the player feels as they traverse the plank, but the visual aspect of a large drop is only possible via the 3D VR headset that the player would have to wear.

With the GVS technology available to the participants in the workshop, the effect was exaggerated when the user was already off balance, i.e. standing on one leg or when walking. It would appear that another consideration of the technology is what the player needs to do initially in order to experience the effect created by the technology, e.g. does the player need to surrender some control initially through some bodily action to become more susceptible to the digital stimulation?

Reducing the player's sense of bodily control

G3's horror game idea illustrates how digital technology can directly affect the body to create a vertigo game that also takes place in the real world. When players try to escape from the "killer", technology like GVS could be used to force players to lose control of their balance, causing them to stumble as they try to get away.

G2 said that they considered both the real and virtual world as playing a part in their proposed game, by explaining they would design it so certain rooms would require different types of embodiment. Similarly G1's game causes players to indirectly lose control of their body in the real world where their walking actions would become exaggerated and result in greater difficulty traversing the game arena. Designers of vertigo experiences could consider how the design of the environment can be used and incorporated into the design of the game in order to cause the player to surrender bodily control early on, which in turn could potentially exaggerate the vertigo feeling. In my later case study *Balance Ninja* (chapter 6), I require players to stand on balance boards (wooden boards that wobble when you stand on them) whilst also battling against the sensory confusion induced through a GVS system. Getting the players to be initially off balanced helped to amplify the effect from the stimulation being applied.

4.5.4 Intentionally creating sensory confusion vs. accidentally creating sensory confusion

A key consideration of the participants was whether or not the sense of vertigo induced by the games should be intentional or accidental in nature. For example, intentionally causing a player to lose their balance (G2, G4) or to build slowly over time (G3's supernatural feeling).

Intentional

Intentional sensory confusion can be used to greatly alter the type of experience, for example, popular games like spinning races occur when a player spins in place for a set number of revolutions before trying to run to a marker on the opposite end of the room. Digital technology has the opportunity to create this intentional effect through technologies like GVS and by controlling what a player sees in a virtual setting. Designers can also lean on findings from Maeda, Ando, and Sugimoto (2005) and Pfeiffer et al. (2015) to explore the novelty of allowing a second person or spectators to control someone in a maze (as suggested by G2 and G4).

Accidental

G1 considered an accidental cause of sensory confusion by reducing the control players had when bouncing around their game world. Much like spinning around in circles it would be possible to maintain a level of control over one's actions until eventually the senses become too confused and overwhelmed. Experiences, such as the bucking bronco ride described by Marshall, Rowland, et al. (2011) achieve this by gradually increasing the speed in which a player is turned and by altering the action of the system causing the player to eventually become disorientated through increasing the game difficulty.

4.5.5 Immediacy of the Vertigo Effect

Finally, the last theme that emerged from my analysis of the data was the immediacy of the vertigo effect. G2 stressed that they enjoyed the sense of suspense and anticipation that was the result of waiting to experience a vertigo affect when observing their colleagues playing with the GVS system. They explained that this feeling of anticipation encouraged part of their design. When designers choose to trigger the effect should be carefully considered as it can, again, alter the experience greatly.

For example, interrupting a rock climber during a complex move could cause not just injury, but frustration. Altering the time between an effect being triggered and being experienced (subtle or intense) can offer designers of vertigo games a wide array of opportunities to create novel and interactive user experiences. For the design of digital vertigo experiences, this can be controlled by the technology, although an intense sensory confusion could lead to sickness, whereas it is possible that a subtle effect may not be very entertaining.

Subtle effect

Anticipation of vertigo effects is key to the design of theme park rides, from the design of queuing areas to show the most dramatic elements of the ride and heighten riders' fear, to the way that rides artificially go slowly upwards and then pause on the edge of the drop before releasing and racing to the ground (Rennick-Egglestone et al., 2011). G3 highlighted that fear is strongly linked to feelings of vertigo, and this suggests that delaying the effect could allow for interesting interactions in vertigo games, where the anticipation could be key to creating, for example, a sense of fear. This would be most useful in a horror game setting where the use of small amounts of induced vertigo to maintain an anticipation that the "killer" is going to appear, may create a heightened feeling of dread, similar to the way dramatic music can be used prior to an event in horror films. The technology employed by the game designer also needs to be considered, for example GVS suffers an inherent latency of >200mS (Fitzpatrick et al., 1999) from the signal starting to the wearer feeling an effect, and this delay could be incorporated into the game as a part of the narrative or as a gameplay mechanic, i.e. introducing ambiguity as to whether the system is working or not.

Intense effect

An intense effect could also at times be required, such as when directly controlling a player in real time. Additionally, if the setting of the vertigo game is in a virtual world, then immediate real world stimuli may be required when something happens on screen in order to ensure that the player remains immersed in the experience. It is perhaps therefore beneficial to induce an immediate effect in experiences where a high degree of player control is necessary. In this case, designers would need to consider how to time the events of the virtual world to allow the physical world movement to occur and appear in sync, i.e. be aware of the latency that may occur as a result of the technology (Mansley, Scott, Tse, & Madhavapeddy, 2004).

4.6 Inspiring the Framework

The work in this chapter represents the initial findings of my research. It was very interesting to see what factors contributed to the design of digital vertigo experiences, as described by the workshop participants.

These initial findings allowed me to begin constructing the basis of my framework based on what was observed and what the participants described. As the thesis progresses I will add to the framework depicted here, illustrating how it all comes together before presenting my final Digital Vertigo Experience Framework in chapter 8.

4.6.1 Surrendering bodily control

One of the primary findings of the workshop was that in all games the participants designed some way of making the players lose control. In *Bouncing Interactions* this was through the special shoes, in *Blindfolded Obstacles* the blindfold. The surrendering of bodily control was achieved in the GVS games through not only wearing the device, but people appeared to be more susceptible to its effects when standing on one leg and off-balance. This allowed me to consider the initial construction of the framework, as per figure 4.8, and wonder what other important factors may appear if I designed a dedicated digital vertigo experience within this space.

Therefore, at this stage of the work, it seemed appropriate that the next study should look at an experience which would allow players to lose bodily control, and that this could be achieved through directly affecting their vestibular sense of balance. Additionally the findings suggested that the intensity of the digital stimulation could lead to different types of vertigo experience, so in the next study I also focused on gradually increasing the intensity of the stimulation to see what sort of effect this had on the experience (represented by the “?” in the figure 4.8).

4.7 Summary

In this exploratory workshop I introduced nine participants to the definition of vertigo games as derived by Caillois (Caillois, 1961), and asked the participants, in groups, to consider how they may design their own vertigo experiences with digital technology.

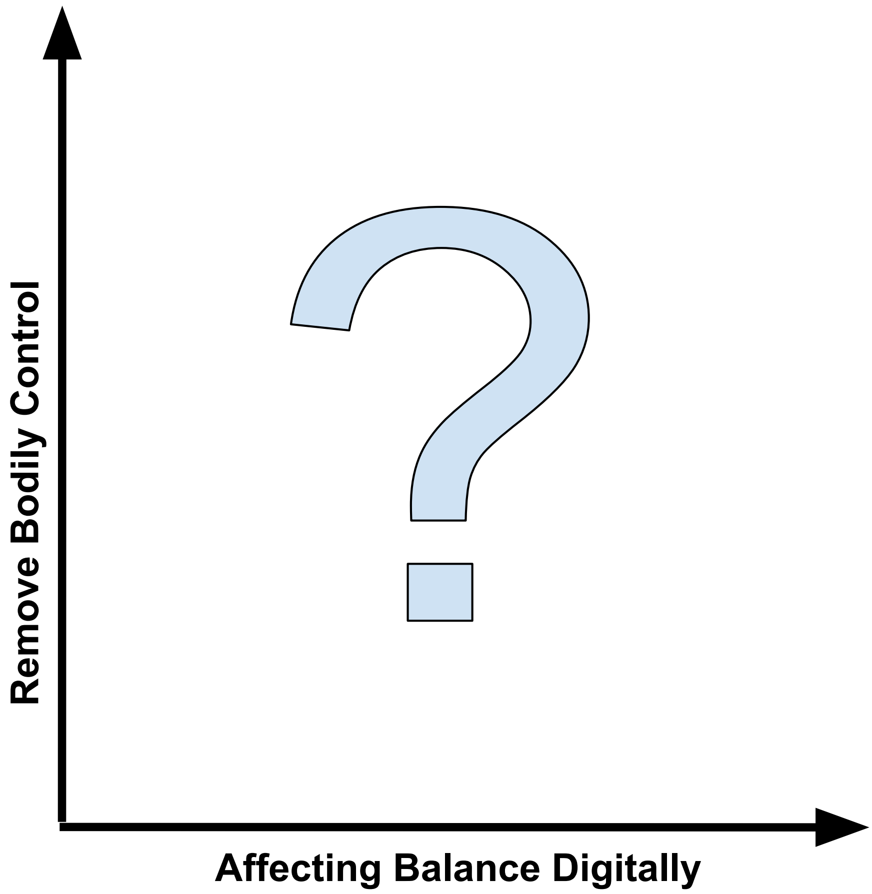

Fig. 4.8 First rudimentary framework, showing how affecting players' sense of balance could affect the amount of removed bodily control. Also interesting at this stage was what types of experience may be yielded within the inner design space (represented by the "?").

An analysis of data gathered during this exploration allowed me to derive five recurring design themes. This allowed me to begin constructing a rudimentary understanding of what a Digital Vertigo Experience Framework may look like. In particular, it seemed that losing bodily control through affecting players' sense of balance was a possible route to follow in continuing explorations.

Even though the effect or power of GVS was not directly evaluated during this study, participants' reactions to using the system and generated design ideas indicated that it could directly affect their sense of balance. With this in mind I developed my first game, *Inner Disturbance* with a digital GVS system as the main vertigo interface. This game and associated study are presented in the next chapter.

Chapter 5

Case Study 2: *Inner Disturbance*

5.1 Introduction

The findings from the initial workshop confirmed my idea that affecting a player's sense of balance through GVS was interesting, and highlighted a range of possible sensations that GVS could provide. With this in mind I designed my next case study: *Inner Disturbance*. *Inner Disturbance* is a one-player game where players are challenged to outlast the effects of GVS on their sense of balance. Players stand on one leg, and the GVS systems oscillate a stimulation signal from one side of the head to another. In this digital vertigo experience the GVS systems are controlled directly from a separate computer laptop (which I explain later in this chapter).

With this case study I explore my main research question through the sub-question of: *"What kind of experience is created when affecting a player's sense of balance with digital stimulation, such as GVS?"*

In the rest of the chapter I detail the new version of the GVS system used in this exploration, before describing the gameplay, set up, and study of *Inner Disturbance*. Finally I present the findings from the study and how they helped to further shape the Digital Vertigo Experience Framework.

5.1.1 Related Publication

The work presented in this chapter has been peer reviewed and presented at the Australian Conference on Human-Computer Interaction (OzCHI) 2016, in Launceston, Tasmania (Byrne, Marshall, & Mueller, 2016c). The paper, entitled: "Inner Disturbance: Towards Understanding the Design of Vertigo Games through a Novel Balancing Game" is available to view in the ACM Digital Library at: `https://dl.acm.org/citation.cfm?id=3010999&CFID=832584700&CFTOKEN=46126740` and also on my website: `http://www.richbyrne.co.uk/publications/`.

5.2 GVS System, Version 2

The GVS circuit used in this study evolved from that used in the original workshop described in chapter 4 (see figure 5.1).

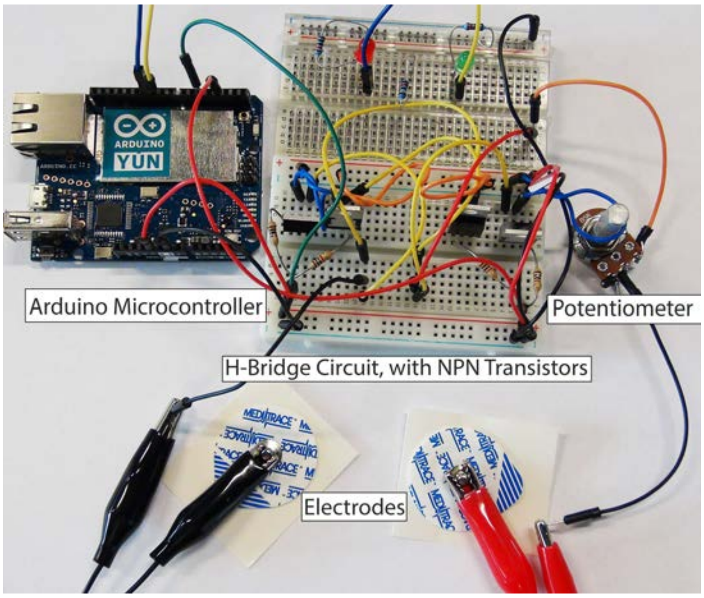

Fig. 5.1 The GVS system used in the study.

This version also consisted of an H-bridge built from four NPN transistors. The transistors allow the anode to be alternated from the left to right electrode (and vice versa). A 5K potentiometer was used to allow for system calibration, and guard resistors to ensure the current would not go over 2.5 mA. This version also used an Arduino Yún microcontroller to allow the GVS system to be activated from a separate computer instead of from the device itself (as in the workshop case study). The Arduino was controlled wirelessly from a laptop via a simple HTML web interface, which consisted of several hyperlinks and JavaScript commands to activate the Arduino microcontroller.

The Arduino GVS system used a 5V battery supply to power the Yún, and used Pulse Width Modulation (PWM) to control the current flow through the GVS system's H-Bridge. A standard 9V battery was used to supply power to the H-Bridge for GVS stimulation. The web interface allowed the system to be turned on or off, and for various pre-configured

PWM settings to be applied. By providing a different PWM level, a different amount of current would be allowed to pass through the H-Bridge, essentially affecting the level of stimulation that the player felt when wearing the GVS system. This allowed the possibility of five stages in the game, where, as described below, a percentage of the player's maximum calibration setting could be delivered over the five stages in twenty percent increments (20%, 40%, etc.).

As before, this GVS sensation was delivered to the player via two cables attached to a pair of electrodes placed on the player's mastoid bones behind the ears (figure 5.2).

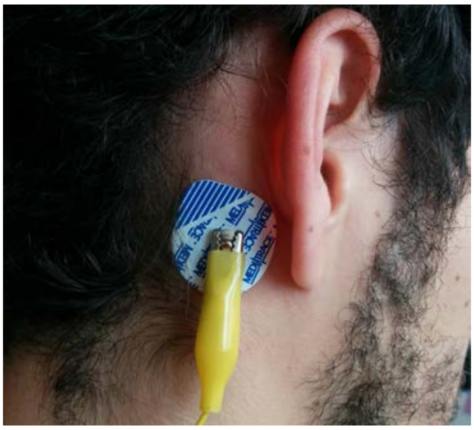

Fig. 5.2 Electrode position on the mastoid bone.

5.2.1 Safety Considerations

The GVS prototype was designed to be as safe as possible for use by the participants. Although the circuit is very simple, I took the following precautions when designing and building both the system and study:

- The maximum current that could be output by the system was 2.5mA. I chose this value since related work has shown good GVS performance from 1mA – 2.5mA (Fitzpatrick et al., 1999; Nagaya et al., 2005), and is far less than the maximum recommended comfortable setting of 5mA (Curthoys & MacDougall, 2012).

- As a further safeguard the GVS system was electrically isolated from the power supply required for the Arduino. This meant that the current of the GVS system was limited by the 9V battery that powered it.

- I ensured that there was plenty of space either side of the participants to allow them to balance and step sideways when losing their balance. When using this particular

GVS system participants do not tend to fall forward or backwards since there is no stimulation in that direction.

- I did not use crash mats or soft areas since I thought this could cause the participants to stumble when regaining their balance. I observed in my own tests that simply placing the foot back on solid ground was enough to regain balance and overcome the effect.

- The game was started and stopped from my laptop, (participants could also disconnect from the system at anytime by detaching the electrodes). I also had a stop button on my laptop which, when pressed, would immediately end the game and stop any stimulation being delivered to players if they felt uncomfortable, or in the event of an excessive stumble.

- The game, and hence stimulation, was stopped by myself as soon as participants placed their raised foot back on the ground.

The above safety considerations were implemented as an assumed precaution, however, during the study none of the participants lost their balance in a dangerous way or asked that the GVS system be turned off.

5.3 Study Procedure

Due to different levels of skin impedance, it was necessary to first calibrate the GVS system for individual players, since what may be a high stimulation for one player, may be a weak stimulation for another. To calibrate the system I attached the electrodes to the mastoid bones of each participant with the GVS system turned off. Participants were then asked to stand on one leg and, gradually, the level of stimulation was increased from it's lowest setting until either 1) the participant lost their balance, or 2) they felt the GVS sensation. The level of stimulation was altered during calibration via a potentiometer which would then remain set for the rest of that player's gameplay, setting the possible maximum level of stimulation that could be applied to that player. The maximum stimulation was only applied after this stage to players during game round 5. The stimulation level in each of the other rounds (1-4) was a percentage of this maximum from 20% to 80% respectively. The calibration stage also served as an extra safety precaution, since it ensured each player would not receive stimulation higher than his or her comfort level.

Fig. 5.3 A player smiles as he loses his balance during a level of the game.

Following the calibration stage the game began with round 1 (20% of maximum stimulation) and during the round the stimulation would increase from zero to 20% of the maximum stimulation over 5 seconds. The stimulation would then switch to the right hand side, again increasing from zero to 20% of maximum over 5 seconds, before repeating the pattern. The entire round would last for 30 seconds (so the pattern oscillated from side to side a total of 3 times). The rounds were over either when participant's placed their raised foot back on the floor or when the 30 seconds elapsed. After a short (1 minute) break, participants moved onto round two (40% of maximum, incremented over 5 seconds) and so on until round five (maximum stimulation for that player).

Other than raising one leg, I did not enforce any other rules about how to play the game. I did suggest to participants that if they found the balancing aspect of the game too easy that they were free to retry the round with eyes closed, nullifying their earlier attempt.

5.3.1 Participants

I recruited 10 post-graduate participants (two female, M=31, SD=6.7). Balancing ability was not a pre-requisite, however, I did ask that participants were comfortable standing on one leg for 30 seconds. Participants were recruited through the university mailing list and word of mouth.

5.3.2 Ethics Approval

I obtained ethics approval prior to running the study, (Reference Number: 0000019016-10/14) and precautions were taken to ensure safety to the participants as described earlier. Before taking part in the study each participant was thoroughly briefed before playing the game.

5.3.3 Data Collection

Audio and video recordings were taken throughout the study with participants' consent to help with the later data analysis stage. In total an hour and a half of audio was collected from the interviews.

Following each play session (which lasted typically no longer than six minutes), participants were invited to take part in a semi-structured interview about their experience of playing Inner Disturbance. The interviews lasted ten minutes on average and followed the schedule provided in table 5.1. The schedule is not an exhaustive list of all questions asked, but is the core list of questions I made sure to ask all participants (with follow up questions based on the participant's responses, which are not included in the table as they are different for each participant).

How did you find it?
Did you find the game difficult?
Was it comfortable?
Would you describe this as a vertigo game?
Did you feel in control?
How subtle was the sensation?
When/if you responded to the GVS sensation, how immediate was the response?
What was the best bit, and what was the worst bit for you when playing?

Table 5.1 Main questions asked in the *Inner Disturbance* interviews. Follow up questions to the above were asked based on participant responses and also contributed to the themes.

5.3.4 Data Analysis

To analyse the collected data I employed an inductive thematic analysis approach (Braun & Clarke, 2006). Transcripts of the audio interviews were read and coded independently by myself and another researcher. Once each of us had finished coding the transcripts we held an online meeting to refine the codes and derive several recurring themes from the transcripts. In performing the analysis, we considered each line of conversation to be "Units" and, (not including interviewer questions), there were a total of 145 Units. Each Unit could have multiple codes assigned if it described several different aspects of the experience and thus, from these Units we derived a total of ten code categories and four recurring design themes.

5.4 Results

In this section I describe the four overarching design themes that we derived from our analysis of the interview data: Vertigo and System Engagement, Inner Disturbance Challenges and Gameplay Strategies, Stories and Analogies and Varying Levels of Bodily Control. In the next sections I describe and explain these themes, supporting the findings with participant quotes.

5.4.1 Theme 1: Vertigo and Sensation

This theme is comprised of 65 of the 145 Units and is divided into two categories: Vertigo (32), and Sensation and Subtlety (44).

Vertigo

Participants expressed that through the game rounds they began to experience what they would consider to be vertigo, *"I started feeling after the first and second [round], and without [the] system a little unbalanced"* [Participant (P) 7]. *"What happens when you go one side to another side, that is just something weird that I cannot describe, its like falling but it does not feel like [...] its the same as losing the balance. So it's not a feeling it's an affect"* [P7]. They also explained how the game left them feeling vertigo for a small period after playing, *"so I think there's a little hangover, because you lose the kind of fixed ground, then I was a little shaky. A little unbalanced. As is true with vertigo"* [P7]. Players also expressed an uncertainty of when they started to feel a sense of vertigo *"I don't know, its something I* *would relate to vertigo, but its after, or in-between, but not in the game itself"* [P8]. By the end of the interviews no participants said that they were feeling any adverse effects from playing, with those who had experienced post-game "hangovers" saying that the feelings had passed. To note is that fairground rides, or even spinning in circles, also cause similar effects, suggesting to me that the game may have been causing some degree of vertigo game sensation in the participants.

When asked if the game had made participants feel sick, or dizzy, participants generally responded that they did not feel this way, *"not really, no"* [P1], *"nope"* [P3], and that it was actually quite a positive experience, *"no it did not - it actually made me feel alive and good!"* [P4]. One participant even compared the experience to drug taking, *"its like a drug you know [...] like a new experience of the senses, you know, and that's great"* [P2]. Considering the vertigo aspect of the game, participants had slightly mixed reactions. One participant for example said they *"sort of had that bit of an adrenaline rush [. . .] it was a bit of a thrill"* [P1], whilst another said that for them, the game *"was missing a bit of an adrenaline rush"* [P10], going on to explain that they were also *"missing visual stimulation"* [P10]. Possibly, this could be related to habituation, for example, the participant whom expressed a lack of "rush" explained to me that they were an avid rock climber, explaining that on a scale of one to five, their control in the *"early rounds was a 4, but with eyes closed 2 out of 5 in control"* [P10]. Possibly the change in perception (eyes shut) allowed a regular climber to also experience the game in the same way as a less experienced player. This suggested that perhaps different players of different abilities could play vertigo games, but that their previous skill may need to be taken into consideration during any calibration stages.

Asked if they would play the game again, or another game based on vertigo, participants generally responded positively, *"of course, absolutely [...] if you need another participant for the next iteration, let me know!"* [P2], and [P4] said: *"Yes definitely. There's so much scope for it"* [P4]. I was happy with this result, since there is a stigma of vertigo or causing disorientation to players, yet the participants responded well to the game and appeared eager to experience more.

Sensation and Subtlety

Participants found that the sensation of playing the game allowed them to imagine they were elsewhere, *"even though you close the eyes, even though I knew that if I take the example of the wire behind my ear, I knew it was two metres long and I knew I was not moving around more than a meter, I felt like I was still moving around and floating in* *space"* [P4]. Participant's found this sensation to be difficult to articulate, *"not dizzy, not sick, and when I closed my eyes it wasn't disorientation but I was kind of magnetically led to one side"* [P5], *"you could feel a little bit of something there. It was surprisingly, yea, powerful [...] the best [bit] is this invisible new sensation, [the] unfamiliarity of the sensation"* [P7]. Participants also found the sensation to be comfortable, *"[it was] fun, and wasn't uncomfortable at all"* [P8].

This was important since some participants appeared to be initially apprehensive of playing the game, as it involved novel technology attached to the body. However, immediately after experiencing the sensation for the first time I observed them laughing and smiling as they felt their balance being affected, *"it was actually funny sometimes" [P4], "the fun was there, [going] from one side to another"* [P7]. The same participant even expressed their unfamiliarity with the sensation as being the best part of the experience, *"the unfamiliarity of the sensation is the best thing, and to be able to feel it and to really see how powerful it is, I think that's very engaging, or interesting or fun"* [P7].

Some participants found the sensation subtle: *"I didn't really notice falling until I have already [fallen] [...] quite subtle I suppose"* [P10]. P1 said: *"it's pretty subtle as it ramped up over time yea it wasn't on and off"* [P1], and P5 agreed saying it was *"pretty subtle"* [P5].

This was a good result for the game since I was concerned that the feeling of GVS may be uncomfortable or that the sensation was too overpowering, however this appeared not to be the case.

5.4.2 Theme 2: Enjoyment, Challenge, and Gameplay Strategies

Units that discussed the challenges of playing the game, or gameplay strategies that evolved from playing the game are categorised by this theme. The theme is derived from 86 of the 145 Units and is divided into four categories: Challenge (18), Gameplay Strategies (10), Closing Eyes (29) and Enjoyment (29).

Challenge and Engagement

Participants explained that the game imposed a sense of challenge for them, *"my immediate reaction was how many levels I can go to, so there was a little bit of competency involved"* [P3]. They explained that *"this challenge to stand on one leg also added a mastery"* [P2], which lead to *"the desire to, [and motivation] to win. You know what I mean, to compete"* [P2]. The enjoyment of winning the game (lasting all of the rounds without putting the raised leg on the floor) was also present, *"I liked the challenge and I liked* *winning"* [P10], as was the irritation of losing, *"um, [laughing] the worst bit was losing!"* [P1].

Participants seemed to enjoy their experience with the system, saying that they found the game and system to be *"different, something I haven't tried much"* [P3] but fun, *"yeah it was great"* [P3]. Players described the game to be engaging, *"it was engaging. It was entertaining, definitely"* [P4], and even *"curious"* [P5]. Participants attempted to understand why it felt different, *"because you don't experience at least that sensation often, it's unusual. Um, and its unusual to be kind of um manipulated in such a way that it's not that obvious [. . .]. That kind of sensation is unusual, and I guess its interesting - especially as you have no visual indicator right, its all balance which is innate to us and just trying to adapt"* [P6].

Participants also experienced different amounts of difficulty in playing the game, *"yes it was difficult, probably for the first 10 seconds, but then the next 20 seconds was very difficult"* [P4], *"initially [the game was] very difficult it really threw me off. I don't think I have the greatest balance"* [P6]. For some players, it seemed already being off balance and then being hit with the GVS stimulation greatly confused their sense of balance making them lose the game round.

Gameplay strategies to overcome the sensory confusion

Participants experienced different levels of challenge when playing *Inner Disturbance*, and some appeared to adapt to the challenge as they got used to playing the game,*"you start using everything you can, flexing, breathing, fixing sight, are strategies if you want, so it gets easier"* [P7], finding that as the game progressed they had to adapt their winning strategies, *"round 1 [. . .] was no sensation at all, and I found [round] three and four I could feel oscillations strongly and the first time it was significant was [in round] two, I was like oh, I understand what is happening here, and by the end I wasn't aware of it anymore, my focus was elsewhere. Your body sort of tunes into something else, like what my foot was doing"* [P8].

Participants found that different approaches also worked for them, with some concentrating their vision on something fixed, such as the horizon, *"I looked at the horizon"* [P5], concentrating on the sensation, "I was just like, concentrating on that balancing part" [P1], and even dancing *"I focused on dancing [to the game music] as it distracted me from focusing on the sensation. I can override it"* [P5].

However, for other participants, lack of concentration and allowing the mind to wonder appeared to work in their favour, *"I was like, losing my balance a bit, when I was fo-*

cused on something whereas if I wasn't concentrating on it, it was maybe a bit easier." [P1], *"I tried to feel the balancing senses somehow differently, and particularly in your body in senses that you usually don't use for balancing, you know, you have to take different senses to experience, or to, to compensate for the [game], and this is very interesting"* [P2]. These findings were intriguing as they suggest ways in which players may be able to overcome the stimulation, and for digital vertigo experiences this could possibly "break" the experience.

Closing Eyes exaggerated the sensory confusion

As players became more used to the sensation I suggested that participants try to play the rounds with their eyes shut if they wanted to. I did not enforce this rule but all participants chose to do so, sometimes of their own accord before I suggested to do so, and often, the participants found the effect became exaggerated,*"whenever my eyes were closed I concentrated on eyes closed, it was a more intense experience, I really felt like these parks where you walk on a [tight] rope I felt like that basically, like, whoa!"* [P9]. Participants also found the game harder to play with their eyes shut, *"when I closed my eyes and didn't have a point of reference it became infinitely harder because I um, deprived myself the sense of orientation"* [P6].

It is worth noting that closing ones eyes when balancing inherently makes balancing more difficult since you are only relying on the vestibular sense and no visual indicators (Era & Heikkinen, 1985). With GVS the vestibular system is affected, so the effect becomes exaggerated, which was noticed by the players: *"I don't know why but when [the] eyes are open with a fixed point in the distance it makes it easier. Because the longer I stood with [my] eyes open I felt this imbalance, but it is so different with eyes closed"* [P9]. This often led to participants expressing that they enjoyed losing control in this way, *"I wish I would have closed my eyes for the whole thing"* [P5], even when at first it was difficult, *"I challenged myself by closing my eyes and trying to balance, and then I realised very quickly that it was just too hard, but then there were times when I was just shutting my eyes and letting it swing me around"* [P6].

The exaggerated effect suggests that perhaps there is a benefit in incorporating vision tasks into vertigo games, allowing orientation and perspective, and thus perception, to be altered in an exaggerated way. Some participants even voluntarily attempted closing their eyes as a way of beating the game, *"when I began to feel that tipsy sensation I was sort of, oh that's not good. How can I stop this...and that is when I began to fight it and then I was like I'll close my eyes and see what that's like - not good [...] you can see in the* *video I was like close my eyes, open, close, open and I'm like, trying to adjust, and after that I'm like well I'm not going to do it anymore because its going to make my task harder"* [P6].

Enjoyment of experiencing sensory confusion

Participants explained how they enjoyed *Inner Disturbance*: *"it was pleasurable just to give into it as a game"* [P5], *"I find it very interesting, because it is a physical exploration of the body, because it enforces a force on you, which, uh, is interesting to expose yourself to an outer force, so, this is the main thing that I find good, or interesting [...] I would actually like to try this again, without standing on one leg, just to experience the feeling, to purely experience [the feeling]"* [P2]. P4 also commented on how the game was strange and made them think about their own body: *"it's about balancing at least with this particular game and I wasn't in control of my body, even though I knew the body was mine"* [P4].

Players also explained that the *"best bit was trying a new experience"* [P3], and that the game also had an element of surprise to it, *"what surprised me, which was really nice was when I [went] to the left because there's the added barrier of having my leg in the way of balance as [the GVS effect] had to be strong enough, to pull me over my support leg. I quite liked that because it's a more difficult physiological task to do, so I liked having the experience both sides [leaning left and then leaning right]"* [P5].

This was interesting since experiencing sensory confusion could have been an uncomfortable or negative user experience, yet players actively engaged with the game rather than rejecting it. As Suits describes "playing a game is a voluntary attempt to overcome unnecessary obstacles" (Suits, 2014), and the players seemed to embrace this by playing with the game as they became more used to it, such as dancing: *"I played more dancing"* [P5] and hopping: *"I kept hopping back and forth"* [P10].

For some players, the early levels of repetitive nature of the gameplay was predictable: *" if there was an anticipation, so if there could be anticipation and surprise, expecting [the stimulation] but it turned out to be something different"* [P3],

5.4.3 Theme 3: Stories and Analogies

Participants often compared the experience to something else they were familiar with. This was discussed in 22 of the 145 Units, and during the analysis these Units were classified as a single category: Story/Analogies/Ideas (22).

Participants tried to relate the experience to something that they were familiar with, such as tight rope walking, *"so one reference I was mentioning, was [tight] rope walking,* *where I grew up, there were a lot of people who used to show those demos, so it was like they would walk on the poles and try to balance each other"* [P3], and sailing, *"because it was behind the ears and the only time I've done that, is that I've stuck sea sickness stickers behind my ears um, so I can maintain concentration during overnight sailing. So I just kind of associated it with that"* [P5]. Participants on several occasions likened the game feelings to the effects of alcohol: *"It reminded me of when you have too much to drink and you hit that point where your body is starting to compensate"* [P6], *"with my eyes closed [it was] extremely difficult. I think worse than being drunk!"* [P9].

Participants were also forthcoming with suggestions for future vertigo games, in particular they suggested combining the game with a Head Mounted Display, or combining with music: *"I can see really cool applications in combination with VR. Yeah I think if there is a connection with audio/visual input, it would be cool, it would be fun"* [P3], *"I'd love to see it linked to an Oculus Rift. I think then you have the possibility, as a designer as well, to put the system to black, there's the fantastic opportunity for you to play with musical accompaniment, a beat and rhythm in relation to the pulses"* [P8]. Additionally participants suggested different types of games, such as controlling other people, or fighting against the game, *"one [game could] steer a person to fall to the left or right, to actually give a stimuli to the [other] person [. . .] or the other is to fight [the stimulation] - like this game was more a 'fight the stimuli' or 'go with the stimuli' and I think both are very interesting ideas, and directions"* [P2]. Interestingly, these suggestions have been explored to some degree as discussed in chapter 2, for example Maeda, Ando, Amemiya, et al. (2005) explored remote control of another person via GVS and Nagaya et al. (2006) have explored combining the beat of music with GVS. Despite these explorations designers have not actively continued to explore designing games that purposefully induce sensory confusion in this way, and *Inner Disturbance*, which was in part inspired by these earlier works, extends these prior works by supporting that the gameplay induced through GVS can be engaging for players.

5.4.4 Theme 4: Surrendering and Regaining Bodily Control

Participants talked frequently about their experience of being in control, losing control and voluntarily surrendering bodily control. This theme encompasses these discussion points, and is derived from two categories: Feedback and Control (18) and Conscious Control vs. Lack of control (27).

One participant described the game as *"a submission thing [...] maybe you can explore* *this game as a submission under physical forces"* [P2]. Participants explained how they gave into the sensation: *"I had to allow [GVS] to take control. It was kind of like passing my mind over to the sensation"* [P5]. *"opening up, I think I was trying to gain control, not to gain control, but expecting to experience a loss of control. So I was opening up"* [P2]. The experience was also described as fascinating, *"the best thing was actually when I failed, and I actually felt I am exposed to an outer force, to a force beyond myself, this was the decisive thing of the game, and you will see this on the video, that the people, when this happens, they start to get amazed, because its fascinating, yeah to really submit yourself under another control, this is great"* [P2], *"I had to allow that [GVS] to take control. It was kind of like passing my mind over to the sensation"* [P5].

Participants explained difficulty in understanding the loss in their balance control *"it was a shift, a momentary shift, when, after I passed the first ten seconds of comfortable time, [...] I go into this uncomfortable area, which is fun again. But, yeah, this is when I found this drastic shift of my perception being disrupted"* [P5], *"I just felt a kind of random force controlling me, and I had no control over that and I had no understanding of any pattern"* [P7]. They also wondered about how the change from side to side may affect their ability to remain balanced, *"all you're thinking about is the anticipation of that change, then its a little more difficult and you don't feel as in control"* [P8].

5.5 Tactics for the Designing Stimulation to Create Sensory Confusion in Digital Vertigo Experiences

Here I articulate three design tactics that were informed from participant feedback and articulated using the recurring themes outlined above. These tactics are presented here to assist designers of future digital vertigo experiences.

5.5.1 Tactic 1: Alter a player's sense of bodily control to keep the experience from being too challenging or too boring through the level of stimulation applied

In *Inner Disturbance*, the GVS system is pre-programmed and repeats each round, albeit at a higher level of stimulation. Players had the ability to learn this stimulation pattern as a result of playing the game multiple times. Consequentially players were able to anticipate a) when the stimulation would be applied, and b) which side they were going to be pulled towards (as reported in theme 2). The higher amount of stimulation applied in the later game levels helped to combat when players were used to the sensation, or found it easy to balance (theme 1).

On the other hand, when players voluntarily reduced the control they had by closing their eyes (and relying solely on the visual sense) or when they allowed the GVS to take over (theme 4), the stimulation from the GVS system created a larger degree of sensory confusion. At lower game levels this was still quite enjoyable (theme 1 + 2) but did become quickly overwhelming at higher levels.

Designers have a difficult task in working out how much control to remove and how much stimulation to apply. On the one hand designers need to remove some control in order for players to start experiencing vertigo through the induced sensory confusion, on the other if they remove too much the game will finish too quickly or players may become overwhelmed making the game too difficult to play. If not enough control is removed then the game could also become boring or predictable. One way of combatting this is to allow players autonomy over the loss of control. In *Inner Disturbance* some players found they had to focus on surrendering control to the GVS as they got used to playing in order to experience the feeling of sensory confusion, such as by closing their eyes. However, players who did this sometimes found that the sensory confusion quickly intensified forcing them to open their eyes again almost immediately.

In the exertion game "Reindeer and Wolves" (Finnegan, Velloso, Mitchell, Mueller, & Byrne, 2014) a blindfolded player (the wolf) has to find the other players (the reindeers) within a gameplay area and within a limited period of time. If the wolf finds a reindeer they are out of the game. Reindeers are tasked with "eating" to score points and make a sound when they are eating. As the wolf's visual sense is removed moving around to find the reindeers can quickly become disorientating, but they are free pause and concentrate on the sounds of the reindeers moving around them in order to get their bearings. If the wolf player pauses for too long the other players win (as they have eaten all of the food). In this game the designers force the wolf to remove some control by requiring them to wear the blindfold, but the penalty for pausing is that the reindeers may have chance to win, however this is left up to the player to decide whether they want to keep going or get their bearings back.

Varying how the stimulation is controlled has advantages and disadvantages; for example, completely removing a player's bodily control would also increases the game's level of difficulty. On the other hand allowing a player to remain in control of when the stimulation is applied with no negative consequence would make the game too easy. Designers should therefore design the digital vertigo experience to remove control, but implement a way players can regain some if needed. For instance they could be permitted a number of "lives" where they can pause for only a maximum number of turns. The body-based exertion game "Hanging off a Bar" (Mueller, Toprak, et al., 2012b) implements this type of gameplay by allowing players to rest from hanging on a bar for increasingly shorter periods of time represented by planks of wood projected on the floor beneath them, giving players the choice: rest frequently at the start of the game or strategically space the breaks out? These rest periods can also be anticipated and players can use them to their advantage.

For digital vertigo games these periods could be controlled through the level of stimulation applied. For instance, if players are doing well the stimulation could be increased, if players are struggling then the game could automatically reduce the stimulation to allow players to recover. Players could also signal to the game to allow them to recover some bodily control by stopping the stimulation altogether for a limited period of time.

Completely removing a player's ability to control the game and when the stimulation is applied may increase the anticipation of when the stimulation will affect them, but could make the game too difficult to play as players do not have an opportunity to prepare for the sensation. Conversely, giving players too much choice over when the stimulation is applied (such as only inducing high levels of sensory confusion when they close their eyes) could make the experience too easy.

The challenge for designers is in choosing the trade off between the experience they want to create and keeping players engaged. Designers should therefore incorporate a method of altering the level of stimulation to avoid the sensory confusion either being too little (boring) or too intense (difficult).

5.5.2 Tactic 2: Incorporate the use of an unfamiliar interface to create sensory confusion into the gameplay

Several participants were initially apprehensive of playing *Inner Disturbance*, having never used any such stimulation devices before. However, all participants enjoyed the game and said that they would play it again, often being surprised with how they felt whilst playing (theme 2).

Designers could choose to embrace this apprehension and anticipation of administering the sensory confusion for the first time, creating a moment of suspense before even playing the game. Alternatively designers could choose to gently ease players into the experience. Marshall, Walker, et al. (2011) embrace the discomfort of their breath sensing system which is incorporated into a gas mask as a method of creating “fearsome" interactions. These games purposefully aim to make players feel uncomfortable and putting the mask on is part of the greater experience. In a similar way, designers could make attaching the GVS system (or another way of inducing sensory confusion) as part of the experience, rather than it being just a necessity to play.

Digital vertigo experiences require players to experience sensory confusion and designers could consider how they design the game based around the method of stimulation. For example, in *Inner Disturbance*, the calibration stage served as a gentle introduction of the sensation, putting players at ease, and as they played more rounds they became used to the sensation. I then observed that players seemed no longer anxious about the system, but were instead focusing on winning each round, actively battling the sensation, and experiencing it differently with closed eyes (theme 2). Designers are encouraged to create entertaining ways of incorporating the stimulation technology into the wider gameplay to create a more engaging experience.

5.5.3 Tactic 3: Work with or against player exceptions of vertigo

The participants freely offered analogies of real-life experiences that they were reminded of when playing the game, and often spoke about what they would like to play in the future (theme 4). For example, both tightrope walking and climbing were mentioned several times by different participants, whilst others reflected on how the game reminded them of their experience sailing and even dancing. Designers could challenge players' preconceived expectations of vertigo games based on popular experiences. Persuasive games for example, can be used to change players opinion of a subject matter, often challenging their preconceived notions of that subject to promote empathy (Kors, Ferri, van der Spek, Ketel, & Schouten, 2016). Designers of digital vertigo experiences could borrow ideas from such work for entertainment purposes: e.g. designers could create an experience which appears to players to be one thing, but actually does something different. For instance, players often talked of how they enjoyed the surprise of playing *Inner Disturbance* (theme 2), and designers could choose to make the element of surprise the main purpose of their vertigo experience.

Designers could, for example, suddenly change the physical environment by using projections (Kajastila, Holsti, & Hämäläinen, 2016), making a platform beneath a player become see through, or alter the virtual environment (Tennent et al., 2017) in order to surprise players and creating another level of sensory confusion to overcome/combat. Designers could use the player's expectations to their advantage, changing the experience on the fly if players are doing well or through lulling players into a false sense of security. Such techniques are often used in horror games for example, where a previously traversed room suddenly has an enemy appear in an area players had already thought safe. Such techniques would stop the experience from being predictable, and prevent players from becoming too used to the game. I suggest designers appreciate that players will have expectations of vertigo experiences, and to either a) build on these expectations or b) change the experience to create something more unexpected.

5.6 Developing the Framework

With the study and development of *Inner Disturbance* I was interested in exploring the sub-research question of:

> "What kind of experience is created when affecting a player's sense of balance with digital stimulation, such as GVS?"

The experience of playing *Inner Disturbance* suggested that at low levels of stimulation in the first few rounds (between 0 and 60% of the maximum), players found the experience to be a little boring. On the other hand higher levels of stimulation were more enjoyable and challenging. However, some players found that when they closed their eyes that the experience became quite difficult and too intense.

The type of experience players could have is dependant on the two extremes of boredom or causing nausea from extreme stimulation. This suggests that in digital vertigo experiences, digital stimulation systems like GVS are able to induce sensory confusion in players, and reduce their bodily control through confusing their sense of balance by affecting their vestibular system. Designers need to consider how close to the two extremes identified here they want to push the experience, asking do we make a boring or easy going experience, vs. do we try to make players feel nauseous?

5.6.1 Expanding the framework with the "Boredom" and "Nausea" risk areas

With what I learned in this case study I was able to add two new risk areas to the framework, as illustrated in figure 5.4. The lower left, where not much control has been surrendered and not much balance affected digitally I have defined as a "Boring" risk area.

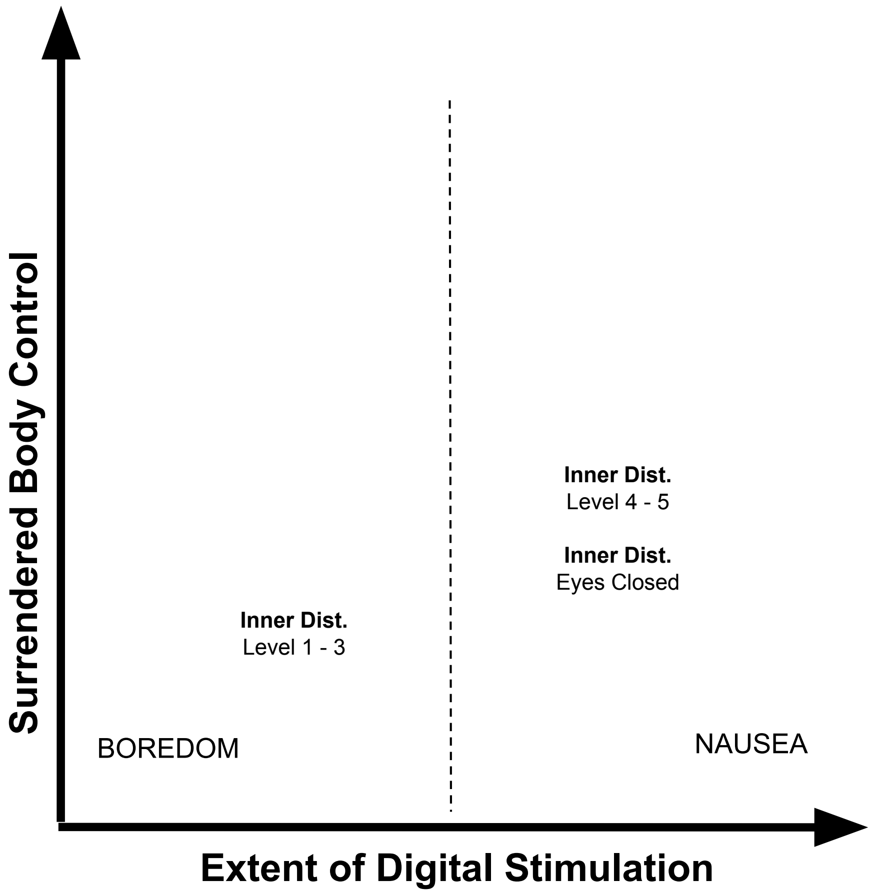

Fig. 5.4 The framework with inner disturbance plotted. Also two risk areas: Boredom and Nausea. Vertigo experiences in the boring space have a chance to become boring, e.g. if too little stimulation is applied, whereas nausea could occur if too much is applied when players are not prepared for it.

Some players commented in the early levels of the game where the stimulation was very low (20% - 60% of the maximum calibrated) that they did not feel that *Inner Disturbance* presented much of a challenge, and that is why levels 1-3 are placed within this area, as digital vertigo games that do not affect the players that much are at risk of creating increasingly boring user experiences.

The lower right risk area I have defined as "Nausea", and this is when the extent of the digital stimulation extremely affects players when they have not surrendered much bodily control. With *Inner Disturbance* players did not report being nauseous, but did allude to this possibly happing if they had kept their eyes shut for a long period. If I had designed the game to be played blindfolded as well as on one leg it may have run the risk of becoming more nauseous and move further to the lower right corner.

At higher levels of stimulation (between 80% and 100%) players who had not enjoyed or felt an effect at lower levels of stimulation, (i.e. found the lower levels “boring”) were usually affected by the higher stimulation and did experience sensory confusion at these levels. However, again at the higher levels shutting one’s eyes drastically increased how easily players were affected by the GVS systems, and again this could have lead to them becoming nauseous if the intensity had lasted too long.

5.7 Summary

In this case study, *Inner Disturbance* was presented to participants as a single player game, where the main objective of the game was not to lose one’s balance whilst playing and battling against the induced GVS sensation. The game was controlled from a computer that activated a pre-programmed GVS pattern, increasing in intensity through 20% intervals up to a maximum as the game rounds progressed. A qualitative analysis of a user study allowed me to derive four recurring themes that provided additional understanding regarding the design of digital vertigo experiences, and identified two potential user experience areas within the developing framework.

This work highlighted that players responded positively to the sensory confusion they experienced as a result of a GVS based digital vertigo experience. However, the repetitive nature of the pattern, and the lower stimulation levels seemed to be less enjoyable to players, suggesting a more advanced or interesting way of triggering the stimulation would be worth exploring.

In the next chapter I present *Balance Ninja*, which was designed with both the gameplay and game design feedback in mind. As such, *Balance Ninja* is a two-player balance game that still uses GVS as the main method of digitally inducing sensory confusion in players, but makes some important changes based on the results of the *Inner Disturbance* study. For example, the GVS system is no longer controlled by a computer oscillating a repeating pattern, but players control their opponent’s system through their own body movements.

Chapter 6

Case Study 3: *Balance Ninja*

6.1 Introduction

In this chapter I discuss my third case study: *Balance Ninja*. Building on the previous case studies, this two-player game used the movement of one player to affect the balance of a second player (and vice versa). This was different to *Inner Disturbance* where the GVS system that affected a player's sense of balance was controlled by a pre-programmed and repeating pattern stored on the Arduino. A study of *Balance Ninja* allowed me to extend my existing design themes and accompanying design tactics through the thematic analysis of participant interview data. The design of the game and the associated study is presented below.

With this case study I explore my primary research question by asking the sub-research question of: *"What is type of vertigo game that emerges when a player has to both experience sensory confusion and actively participate in the vertigo experience?"*

6.1.1 Related Publication: Best Paper Honourable Mention

Work in this section has also been peer reviewed and reported on in a full conference paper (10 pages) entitled: "Balance Ninja: Towards the Design of Digital Vertigo Games via Galvanic Vestibular Stimulation" (Byrne et al., 2016a), which was presented at The ACM SIGCHI Annual Symposium on Computer-Human Interaction in Play (CHI PLAY) 2016 in Austin, Texas, USA. This paper also won a Best Paper Honourable mention award at the conference (top 5% of papers, 29% acceptance rate).

The paper is available to view in the ACM digital library: `https://dl.acm.org/citation.cfm?id=2968080&CFID=832584700&CFTOKEN=46126740`, and a video presentation of the game is available to view at `http://www.richbyrne.co.uk/balance-ninja/`.

6.2 Balance Ninja

Balance Ninja is a balance game for two players. Both players stand on their own wooden board (which I call a balance board) resting on a shared wooden beam (see figure 6.1) and both players are attached to their own GVS system. Players also wear a pouch containing a tight-fitting Android mobile phone, and the accelerometer readings taken from the phone affect the opposing player's GVS system. For example, if player 1 leans to the left, the GVS of player 2 creates a pull to the right for player 2 (and vice versa). The more player 1 leans, the greater the level of stimulation applied to player 2. The maximum stimulation is applied when players are leaning around seven degrees from the vertical, which, although a noticeable lean, is not enough that a player would lose their balance without the extra stimulation being applied.

Fig. 6.1 *Balance Ninja*: Two players playing the game, labels indicate the balance boards players stood on, the two GVS prototypes and phone position.

The object of the game was to cause the opposing player to lose their balance and either step off their board, or touch their board to the floor (see figure 6.2). The game was not turn-based and players were free to "attack" at any time. A point was awarded to the winner of the round and the first player to reach five points would win the game. Music played in the background whilst the game was being played and stopped when the round was over. A voiceover would then play that indicated to the players that the round was over and that the winning player had been awarded a point. The points were displayed on a laptop that served as a scoreboard and was visible to both players and spectators throughout the duration of the game. Judging of when players stepped off the board (and who won the point) was handled by myself and I manually stopped the game and awarded the points accordingly.

Fig. 6.2 Player two (left) smiles as he wins the round when player one touches their balance board to the floor.

The balance board was used to help reduce a player's sense of bodily control by putting them off balance (much like the players standing on one leg in *Inner Disturbance* and the workshop in chapter 4). Through removing some control in this way a player's sense of balance is affected not only through GVS but also due to them needing to stand on uneven ground. Standing on non-firm ground has been shown to exaggerate the loss of balance in physiological studies (Shumway-Cook & Horak, 1986), and I used it here to help exaggerate the GVS effect since players are already slightly off balance (making them slightly more susceptible to the digital stimulation) as was observed in the prior case studies.

6.3 GVS System, Version 3

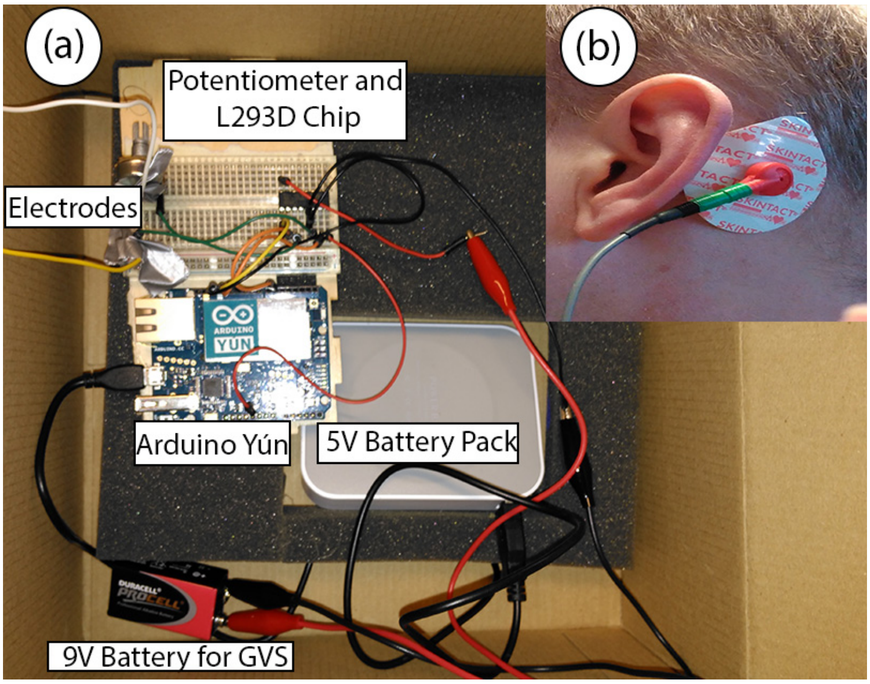

Fig. 6.3 (a) The GVS system used in the study. (b) GVS Electrode placement.

Based on the feedback of the *Inner Disturbance* Case Study (chapter 5), the GVS system was iterated a final time went. For this study I built two identical systems (one for each player) and refined the circuit. One of the two newer systems can be viewed in figure 6.3a. Instead of using four NPN transistors I switched to a simple L293D full bridge motor driver chip. This motor chip performs the same function as the four transistors, acting as an H-Bridge allowing the anode to alternate from left to right electrode as before. The circuit was again controlled with an Arduino Yún microcontroller, which performed the function of allowing communication between the computer and GVS system so that it could be started and stopped remotely. Again the system was designed such that the maximum current could not go over 2.5 mA.

For the calibration stage and to set the maximum level of stimulation, a 10K potentiometer was used to limit the current and allowed me to fine tune the effect felt by the players. The potentiometer acted as an extra safety feature since once set the current could not go over this amount.

The GVS circuit and the Arduino were powered via a 9V battery and a 5V battery pack power supply respectively. Longer cables were also used in this study based on feedback from the prior studies. Two low resistance insulated wires, (one for each electrode), of around two metres each completed the circuit and attached to the electrodes via typical snap-style electrode connectors (see figure 6.3b). This was again an extra safety feature since the snap-style connectors are easier to "pop" off the electrodes if the wires were still too short (i.e. someone has stumbled too far, or walked away without first removing the electrodes).

6.3.1 Safety Considerations

The system, as in the previous studies, was designed with safety of the participants in mind, and the maximum current of the GVS systems could once again not go above 2.5 mA. I chose this number since related work indicates good performance from 1 mA - 2.5 mA (Fitzpatrick et al., 1999; Nagaya et al., 2005), and it is far less than the recommended maximum of 5 mA (Curthoys & MacDougall, 2012).

Although the GVS circuit is relatively simple (essentially a small current of no more than 2.5 mA alternating via an H-bridge), I made sure that the system would be as safe as possible to use in the study. Also, due to the effect of GVS causing an individual to lose their balance, I took the following precautions when using the system:

- I designed the GVS system to be modular, and thus come apart under physical stress. If a participant were to stumble excessively (which did not happen during the study) I made sure that the cables easily detached from the breadboard, in addition to the "pop off" style electrode connectors described above.

- I made sure that no physical obstacles that could cause harm during play were near participants. This included the deliberate choice to not use soft mattresses or crash mats next to the game. As the balance boards are only a few inches from the ground, players recover very quickly by stepping onto solid ground. A soft surface, I reason, may have caused players to actually stumble and trip when recovering.

- The system was started and stopped remotely from my laptop (players could not activate it, but could detach themselves by removing the electrodes), and I made a stop button on the computer that would immediately end the game and any stimulation, should a participant feel uncomfortable or in the case of any excessive stumble.

- Two researchers were present during the study. Not only did this help with the setup and calibration stage, but also meant one researcher could always be near the participants to help them if they needed assistance.

- As with the prior case studies, the GVS systems were battery operated, and therefore electrically isolated from any mains power.

The above were assumed precautions and due to these precautions none of the study participants were injured or stumbled dangerously.

6.4 Study Procedure

Before playing *Balance Ninja*, players had to prepare by first attaching the phone pouches around their chests. The electrodes were then attached to the mastoid bones of each participant by either myself or the participants themselves, in which case I double-checked the connection and placement. Next, I calibrated the GVS systems for each participant.

To calibrate the system, participants were asked to stand on their balance board one at a time. Their GVS system was turned on and I slowly increased the current until the player lost their balance (by touching their board to the floor). I stopped increasing the current and this derived the maximum setting for that player. Calibrating the system was also a necessary safety precaution since it ensured that players would not experience stimulation higher than their comfort level. This process was then repeated for the second player.

Players were given a one minute practice round to familiarise themselves with balancing on the boards and the GVS sensation. After this practice round the game started properly. Each game session was started and stopped from my laptop, with music signalling both the start of each round and that the GVS systems were activated.

When a point was awarded (i.e. a player won a round) gameplay paused and the systems were deactivated between rounds. Following the game, participants were detached from the GVS system before they were asked to remove the phone pouches and electrodes. I then invited them to take part in a post-game interview.

6.4.1 Participants

I recruited 20 participants to play *Balance Ninja*, (17 Male, 3 Female), aged between 23 and 51 (M=29, SD=7.4). Participants were recruited via the university mailing list, word of mouth, and interest generated from watching the game being played.

6.4.2 Ethics Approval

Play sessions occurred in the open atrium of the computer science department of the University of Nottingham, UK, during the working day when first aid personnel were also available. Ethics approval was obtained from the University of Nottingham prior to the study, in addition to the approval already obtained from RMIT University (Reference Number: 0000019016-10/14). Each participant was thoroughly briefed and asked to provide informed consent prior to playing the game and taking part in the study.

6.4.3 Data Collection

Data was collected through the use of video and audio recordings of all gameplay sessions, pre- and post-game setup, and participant interviews. I used both video and audio due to the open nature of the study venue and wanted to ensure responses could later be transcribed correctly. Audio and video was taken with participants' consent and in total around two hours of video and audio were recorded.

After each play session, which lasted typically no more than five minutes, participants were interviewed in pairs using a semi-structured interview schedule (see table 6.1), which lasted an average of six minutes. Following the interview, participants were also invited to fill in a short 5-point Likert scale (1 = strongly disagree, 5 = strongly agree) questionnaire about the game to elicit a quantitative understanding of their experience. I chose these questions based on the comments of the earlier case studies and to also gather quantitative results on the experience of playing the game, which I realised during analysis of *Inner Disturbance* would be useful to record in order to support the qualitative findings.

How did you find it?
Did you find the game difficult?
Was it comfortable?
Would you describe what you experienced as vertigo?

Were you in control?
Was the sensation subtle?
Did it remind you of anything else?
What was the best bit, and what was the worst bit for you when playing?

Table 6.1 Main questions asked in the *Balance Ninja* interviews. Follow up questions to the above were asked based on participant responses and also contributed to the themes.

6.4.4 Data Analysis

Participant interviews were transcribed and the completed transcripts were exported to a spreadsheet for qualitative analysis. In order to garner meaning from the data I employed an inductive thematic analysis approach to the data (Braun & Clarke, 2006) as explained in my Methods chapter. In the transcriptions, each turn of speech was again considered to be a "Unit", and excluding interview questions there were a total of 206 Units to consider and of varying length (short answers and longer responses). In order to garner meaning from these Units, the same researchers (myself and my co-supervisor) designated our own codes and description of the codes to the Units independently. Following this process, a meeting was held where we refined the codes until a final agreement resulted in a total of 10 codes. These codes were then further examined and referenced with the transcripts to search for overarching themes, which were again reviewed by both of us in another meeting. This approach resulted in three overarching themes in total, which extend and contribute to the prior themes since they were in part informed by our prior knowledge of the previous studies.

6.5 Results

In this section I detail the responses to the participant questionnaire and also describe the three overarching themes which emerged from the analysis of the data. I have called the three recurring themes: Experiencing sensory confusion, Vertigo Gameplay Strategies, and finally, Technology to create a vertigo experience. These themes are discussed in detail below.

6.5.1 Questionnaire Responses

Likert responses can be viewed in figure 6.4. Participants generally found the game fun citing positive responses with a Median (M) of 4 and Standard Deviation (SD) of 0.7, with participants also agreeing that they would play the game again (M=4, SD=0.6). Participants had mostly neutral responses to the GVS sensation being uncomfortable (M=2.5, SD=1.2), however, participants mostly agreed that the GVS sensation was subtle (M=4, SD=1.0). The game received mostly neutral responses to participants being in control of their body and also feeling disorientated (M=3, SD=1.2), and finally participants mostly found the game difficult to play (M=4, SD=1.0).

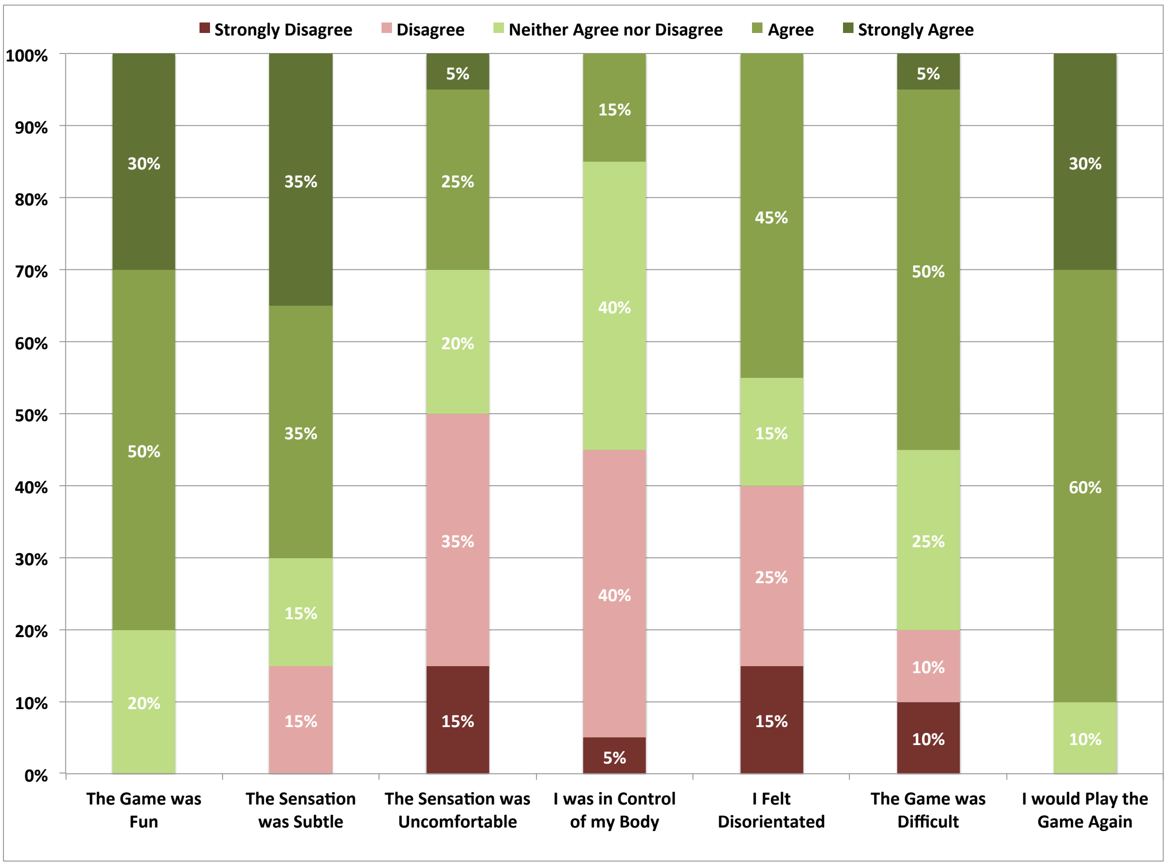

Fig. 6.4 Participant (N=20) responses to Balance Ninja Likert Questionnaire.

6.5.2 Theme 1: Experiencing Sensory Confusion

This theme describes 112 of the 206 Units and is divided into four categories: Feeling of GVS (88), After-Effects (9), and finally Enjoyment of experiencing sensory confusion (15).

I had expected to receive a high number of Units describing GVS as I did ask participants how it *felt* to play the game. However, I did also find that participants were eager to discuss their feelings from playing, and often required little prompting to describe their experience of the game and of using GVS.

Feeling of GVS

Participants explained how the GVS sensation was new: *"the feeling itself was really, like new to me, except for when I was drunk! and the best bits were just how weird it was, it was just, like, different"* [P3], whilst P14 said: *"I've never known [anything] like that before!"* [P14]. Participants did not appear to find the GVS sensation uncomfortable or unpleasant: *"I wouldn't say uncomfortable in a bad sense. If there was any discomfort it was in the playful sense, so all good"* [P16], *"it didn't hurt, it was very comfortable" [P11], "I think it wasn't any feeling of un-comfortableness"* [P10]. In fact, participants were often not aware that there was any stimulation being applied: *"I didn't feel anything [laugh] actually. I felt the sensation of not being balanced"* s[P8], finding any sense of the stimulation to be subtle in nature: *"mine felt subtle, I didn't know I was falling over until I fell over!"* [P6]. This finding is important, since I did not want to make an uncomfortable gameplay experience(Benford et al., 2012; Huggard et al., 2013). However, it is important to stress that there is obviously a difference between uncomfortable and *painful*, and no participants reported the game or the GVS as being painful. The main discomfort reported by the participants was interestingly not the GVS sensation or the gameplay but the process of removing the electrodes.

When asked if they had experienced vertigo whilst playing, participants generally agreed that they had: *"after a bit I could definitely feel it as a dizzy-ness, like a vertigo feeling that really made me sway"* [P1], *"I think it's a pretty good approximation [of vertigo]"* [P2]. *"Vertigo? Yeah it did feel relatively similar actually, the stronger sensations there definitely equate to that kind of feeling"* [P9]. Some participants were unsure if they experienced vertigo at first, asking if I actually meant acrophobia: *"vertigo is the fear of heights right?"* [P9]. However, in such instances I reiterated my vertigo experience definition (adapted from Caillois (Caillois, 1961)), which often led participants to agree that they did actually experience vertigo: *"um, I think under your definition for me I did achieve a degree of 'vertigo', yes. That's true, there was disorientation and a definite unusual state about it"* [P18].

After-effects of sensory confusion

Although participants did not report any pain or discomfort, some reported on interesting after-effects they experienced, saying that they felt: *"just a bit weird after, yeah"* [P12]. P5 said: *"I kind of, like, almost had to sit down just for a little bit to almost relax for a little bit, but I don't know if that's because we were trying to balance for ages and just standing on firm ground was not a balance thing"* [P3], and P5 added: *"I just felt slightly less control, I felt a little bit wobbly"* [P5].

Participants likened the effects to those felt post-exertion, such as: *"[it felt] like coming off a trampoline"* [P6], *"yeah, when you're not on the trampoline [anymore] you feel really weird"* [P3], which could have been due to the nature of using one's legs to keep the board balanced, resulting in muscle fatigue from doing so. To note is that although participants indicated that they experienced some post-game feelings, the feelings did not last very long: *"uh afterward you feel a bit of a hangover just for like 10 seconds maybe, 5 or 10 seconds"* [P12]. *"When I first stepped off I felt quite awkward, [and] not sure whether to move or stay still for a second, but that cleared quite quickly"* [P5]. By the end of the interviews none of the participants showed any sign that they were still experiencing adverse post-game effects, explaining that in the case that they had felt anything after the game, it had subsided quickly as they regained their sense of balance. Also to note is that a vertigo game, such as spinning around in circles, leaves the player feeling dizzy for a while afterwards, which is actually the desired result. For my players, playing *Balance Ninja* seems to have resulted in a similar experience, with the players feeling disorientated for a period after playing. This was quite important to me since it highlights that digital vertigo experiences can simulate the feelings of popular non-digital vertigo experiences.

Enjoyment of experiencing and extending sensory confusion

The feelings of vertigo also led to participants expressing how they had enjoyed playing the game *"the best thing was the two occasions I got where it was really clear that the game was actually affecting my sense of balance"* [P18], *"the best bit was when I did feel it, the kind of visceral feeling almost when you actually go: 'actually this thing has made me unbalanced' "* [P1]. Participants described the game as cool and fun: *"it was good I enjoyed it"* [P9], *"I think it is really cool"* [P17], *"yeah, it's a cool kind of game, definitely"* [P11], *"that was really good and fun"* [P14]. This was a really important finding as I purposefully designed the game to be difficult and physically challenging to play through affecting players' sense of balance, but I didn't want the game to be so difficult that it was no longer fun to play.

As well as participants enjoying the sense of their own balance being affected through GVS, participants also expressed that their sense of fun came from their ability to control other players: *"it was fun, as a game perspective trying to make the other person feel what I was feeling"* [P3], *"it was really funny. It kind of made me laugh, looking at [player] trying to balance and trying to throw me over at the same time, and me trying to do the same, it was kind of comical really"* [P2]. The post-game questionnaire responses support these findings, showing that participants positively agreed that the game was fun to play. This is in a way similar to other non-digital vertigo experiences, like when one person pushes another on a playground roundabout - it is fun for the player being pushed, but can be equally fun for the person doing the pushing.

A concern of mine when I decided to use GVS to affect player balance in a digital vertigo game was that players could have found the effect uncomfortable and off-putting. I was also concerned that this strange way of inducing sensory confusion coupled with the a more intensive amount of gameplay than I created for *Inner Disturbance* may have even induced nausea in the players, similar to when the players closed their eyes in *Inner Disturbance*. However, the study of *Balance Ninja* highlighted that participants enjoyed playing and did not report feeling nauseous, nor were they put off from playing and positively reported that they would play the game again (90% of the participants, with the remaining 10% neutral about replaying).

The participants found the experience engaging enough that they even thought longer term digital vertigo experiences would be enjoyable to play, and had ideas like a GVS controlled vertigo horror game: *"In a horror game, if you got that feeling at a crucial moment, that would make it a lot more fun, and, like, seem more real"* [P3]. Interestingly this supports the findings from case study 1, where the participants also suggested they would enjoy playing a horror themed digital vertigo experience. This finding suggests that designers need to consider that in addition to simply "fun" and "quick" experiences, they need to support digital vertigo experience that may last for a longer period of time, and would have to carefully consider how to induce sensory confusion over this longer period to keep the games engaging.

Balance Ninja also appeared to invoke other gameful states, such as competition, with participants commenting when asked to describe their favourite bit: *"winning was the best bit-"* [P2] *"-and losing was the worst!"* [P1]. *"The best bit was that I won! I don't win anything so I'm going to take this one and enjoy it"* [P14]. *"[The best bit was] winning! [Laughs]"* [P9]. These comments about wining and an eagerness to play *Balance Ninja* again suggests that participants did view *Balance Ninja* as a game, which further suggests that digital vertigo games could be adopted and appreciated by players and not seen just as novelty experiences. In *Balance Ninja*, participants played in pairs so generally played against their friends or colleagues, which may have also facilitated the sense of competition amongst the participants. Participants even suggested games that they would like to play with their opposing player in the future, for example that they: *"like[d] the idea there's cerebral gladiators out there [who] don't need sticks to knock people over"* [P13], which refers to a game where players traditionally hit each other with padded sticks to knock the other player off a podiums suspended high above crash mats. This is a great suggestion, and highlights how the digital offers a new opportunity for designers since the technology simulates a type of *magic* where sensory confusion can be extended to another player in an invisible way (e.g. they can feel what another person feels, or be controlled remotely by that player).

6.5.3 Theme 2: Vertigo Gameplay Strategies

This theme was present in 78 of the 206 Units and was divided into three categories: Game Strategies (21), Game Feedback and Difficulty (42) and Game Fairness (15).

Game strategies

Participants explored varying tactics to win the game, such as trying to stand still, *"there were definitely times where I felt the best strategy for me was to try and stand as still as possible"* [P9] and using their own breathing techniques to remain balanced, *"yeah I did Pilates, [laughs]"* [P13]. This particular tactic can be seen in figure 6.5, where player 2 loses a round, but employs breathing techniques to avoid losing in the next round. Interestingly, by concentrating on their breathing, the player was able to overcome the sensory confusion from the GVS system, whereas P9 concentrating on standing still achieved the same result. This suggests that concentrating could be one way of ignoring the stimulation, and designers will need to think of ways to distract the players so that their concentration is broken enough to be affected by the stimulation technology. Participants expressed how finding the right amount of movement was part of the fun of the experience: *"you're trying to knock over the opponent but at the same time you have to be a bit cautious - so it is [a] fun experience"* [P8], also explaining that the learning curve and finding the optimal strategy was important to the gameplay: *"figuring it [the game] out [...], once you've got a strategy off you go"* [P16]. For some players moving quickly was

Fig. 6.5 Player 2 (right) loses the first round, and concentrates on their breathing technique to remain balanced in the next round. (Note: the red lighting in this picture is due to the electric heaters in the venue where the game was played).

the best strategy in order to put the other player off balance as quickly as possible, *"little quick twitches were good"* [P5], to which P4 responded: *"Yeah that's how he got me!"* [P4]. This is different to concentrating on not being affected by the sensory confusion, as it is instead a tactic to inflict as much confusion on the opposing player in as short a period as possible.

Players also found that they could use visual cues to regain control over their vestibular confusion, by focusing on a point in the environment: *"well [I] was looking at the ground, because that then made me regain my balance every time I looked at a new spot, so if I [did] it quickly enough I could maintain a balance"* [P3]. This is another method of ignoring the sensory confusion, and is also something designers could overcome by forcing the players to pay attention to something within the game, breaking their concentration and making them more susceptible to the induced sensory confusion.

Stimulation feedback to differentiate from balancing difficulty

Despite finding winning tactics, such as concentrating on their breathing patterns, participants did express difficulty in playing the game due to being required to balance on the balance boards, *"so I found balancing on the board quite hard anyway, but it's probably not my naturally good skill set"* [P18]. P6 said: *"if I just stood still I could see the other person swaying and go back and forth, as soon as I tried to do it as well then I just couldn't!"* [P6]. Some of the perceived difficulty could have been due to the game not providing much feedback to players that the other player's GVS system was activated: *"what's difficult is the fact that I did something in it that affected [the other player], but I* *couldn't obviously see that"* [P1]. P12 agreed: *"yeah sometimes I find it, I'm not sure I'm controlling the other player, am I really controlling him, or [is] he just losing [balance] by himself?"* [P12].

Although I did explain to participants that leaning their upper body would affect the opposing player's GVS system, it seemed more intuitive and a more natural body movement to move the actual balance board with their feet instead: *"also, I wasn't sure if it was tilting the board that got the effect. I knew, because you told me in the beginning, that the phone was the actual tilt sensor, but the natural feeling for me was that I should try tilting the board"* [P16].

Participants requested the inclusion of visual or audio feedback to confirm the system was working in future versions of the game: *"I would have liked some feedback, so I could see what part of my movement was having an effect. Apart from the effect on the other person I wasn't sure if it was actually working"* [P16]. With *Balance Ninja* I assumed that seeing the opposing player moving would be feedback enough but it appears that when the game was being played it was difficult for the players to differentiate between another player losing their balance because they were not good at balancing, or because the sensory confusion from the GVS system was affecting them.

Game fairness

Finally participants offered possible ways they'd have liked the game to be fairer for them when playing: *"often when the rounds started, you [player one] were already leaning!"* [P2]. The GVS systems were activated at the start of each round, so if one player was already leaning then the opposing player would receive a higher level of stimulation than the leaning player from the very start of the game until that player stopped leaning. Interestingly participants also offered ways of making the game harder to play, such as including sensors in the balance board itself: *"so you'd make it harder as you'd have to rock the board without touching the ground"* [P2]. This suggests that game fairness is subjective, i.e. there were participants who enjoyed the challenge and wanted more, whereas there were other participants who found it too difficult playing against players who had better control over their balance.

6.5.4 Theme 3: Technology to Create the Vertigo Experience

This theme relates to discussions concerning the digital and physical technology used to implement the game. 24 of the 206 Units were described by this theme, which were derived from one category code: Technology to create the vertigo experience (24).

Balance boards to encourage reduced bodily control

In *Balance Ninja* the balance boards were not attached to the beam but placed on top, which led to difficulty for some players in maintaining their balance: *"the balance board itself I thought, perhaps, was not very well designed"* [P17], *"I didn't like the wooden thing, it was too easy to fall off and it was too difficult to kind of, reset"* [P1], and suggested that the boards should have allowed players the ability to lean further: *"I should have been able to lean more before I fell off"* [P1]. I observed that at first participants seemed to prefer moving the board whilst keeping their body vertical, but quickly learned that they needed to lean their upper body and try not to move the boards to experience the game and the GVS effect properly. *Balance Ninja* was purposefully designed to encourage this upper body movement and lean, but did not anticipate that participants would find it difficult to grasp at first. Although, participants did offer that they quite liked the way the balance boards facilitated the balance aspect of the gameplay: *"I didn't mind it I thought it was good actually, I thought it was a good balance board for this"* [P2]. However, for multiplayer digital vertigo games perhaps consideration needs to be given towards supporting players of different balance abilities, and how the game environment can facilitate this support.

Equipment design

Finally, participants described the "worst" part of the game to be the removal of the electrodes, usually because of their hair getting stuck to the electrode adhesive: *"yeah the worst was trying to get rid of the [electrodes], [because of] my hair"* [P20], *"it was a bit sore, to be honest but that was partly because I got some hair caught"* [P15]. What I did find interesting with this study was that participants described only the electrodes as being uncomfortable to remove or the worst part of the game, suggesting that both *Balance Ninja* and the actual GVS sensations were not unpleasant to experience. Unfortunately GVS requires electrodes or some other conductive material to use, in much the same way as other electrical stimulation technologies (such as Electric Muscle Stimulation (EMS)) requires (Lopes et al., 2016), but thought could be given to how these are attached (such as not using glue but an elasticated headband, or retrofitted headphones).

6.6 Further tactics for Designing Digital Vertigo Experiences

Here I articulate five design tactics that I derived from my data analysis, informed by the recurring themes and participant feedback that I have previously described, and my craft knowledge from designing the game. These tactics are for designers of future digital vertigo games to guide the development and design of digital vertigo experiences like *Balance Ninja*.

6.6.1 Tactic 1: Design game environment to enforce the facilitation of sensory confusion

A popular technique the players used to remain balanced was to try and remain as still as possible and concentrate on not moving (theme 2). The balance boards were designed specifically to make it so players had to constantly balance. This could have been made more pronounced by actuating the surface on which the person is standing, so it occasionally shakes or wobbles, to require the players to respond. The breath controlled bucking bronco ride, by Marshall, Rowland, et al. (2011) employs a similar tactic, by deliberately jolting riders in an attempt to cause them to fall off once they reach the final difficulty level.

Some of the participants were able to win repeated rounds of the game by employing different tactics that helped them limit the GVS effects (theme 2). They uncovered these tactics during the course of playing the game, with one player, for example, focusing their vision so that they could concentrate on not losing their balance. With GVS, the effect is weakened when people focus hard on visual balance cues (Day, Severac Cauquil, Bartolomei, Pastor, & Lyon, 1997), so designers have the opportunity to employ this tactic by designing visual elements to distract the player, for example by using head mounted displays or blindfolds to remove any visual cues. They could also have things appear in the gameplay environment, such as projecting displays on the floor, creating an augmented environment (Kajastila & Hämäläinen, 2014) to distract the players or change the game in some way (e.g. they have to try and get the opposing player to fall into a particular area projected on the floor for bonus points).

In response to the findings of this study, I suggest designers of vertigo games would need to consider how to design the game environment (including the equipment used) to enforce the vertigo effects, and facilitate the induced sensory confusion to limit players in overcoming the induced effect.

6.6.2 Tactic 2: Use a narrative arc to prepare the players for the different vertigo sensations

In *Balance Ninja*, there were essentially three acts, or gameplay stages: setup, gameplay and post-game. Setup involved calibration before use, and post-game involved removing the electrodes and the possibility of feeling after-effects from the GVS stimulation (theme 1). To prepare players for these stages designers could lean on the work of trajectories (Benford & Giannachi, 2008) and videogame narrative to creatively explain why their players must wear a special stimulation system and also engage in a calibration process. Marshall et al. employed a heavily narrative driven arc to entice players to wear their modified gas mask (Marshall, Walker, et al., 2011), and digital vertigo designers could incorporate an equally compelling reason for players to have to wear systems like GVS.

For example, a "mind control" game could involve players trying to gain physical control over another player's movements. This could require the player to wear a futuristic helmet with the GVS inside which, in turn, would affect the other player. After playing, any confusion they feel could be explained as the after-effects of the mental exertion.

In a supernatural horror game, players could wear mobile GVS systems that activate when an imposing presence is near by, causing them to momentarily lose balance when trying to run away. Designers could also employ the use of trained actors to perform the setup stage, in a role appropriate for the particular digital vertigo game. For example, Yule, MacKay, and Reilly (2015) investigated the role of using docents in mixed-reality games, finding that the role of the docents improved the player experience. These docents were trained in the use of the system and acted as guides who also helped to explain why players were performing their particular tasks, all whilst remaining in character. As such, I recommend to designers to consider an appropriate narrative that will prepare players for the sensations to come and help them enjoy the experience.

6.6.3 Tactic 3: Design for the subtlety of the stimulation technology

GVS is a subtle and nuanced sensation that also suffers from an inherent latency of approximately 200mS (Fitzpatrick et al., 1999), and participants said that at times they were unsure if their movements were actually affecting the opposing player (theme 2). Due to the delay, and because the intensity of the stimulation applied to players was based on how much the controlling player was leaning, there was a delay in feeling an effect, which at times could have led to some of the players questioning whether the system was working. Providing simple visual or audio feedback of when the GVS system was activated and inducing a level of stimulation, could have helped to alleviate concerns that the system was not working.

However, in other game genres, such as horror games, the subtlety of the sensation and the ambiguity of how the system is affecting players could in fact become the core strength of the game design. Designers of vertigo games who want to create this type of experience could consider ambiguity as a design resource (W. W. Gaver, Beaver, & Benford, 2003) to decide the level of feedback that is most appropriate for their vertigo game. Additionally, seamful design (Chalmers, MacColl, & Bell, 2003) argues that sensor limitations can be a good resource for game design (Broll & Benford, 2005), and with my work I extend these ideas by suggesting that how the body reacts to different stimulation systems can also be integral to creating different types of engaging experience.

As such, I recommend designers consider if highlighting the subtlety of vertigo through additional feedback in their games is the appropriate choice for the type of digital vertigo game experience that they are attempting to create. Designers should decide if they want to design to support the subtlety of the stimulation technology (through appropriate feedback), or instead incorporate the subtlety more into the gameplay (and embrace the ambiguity to create more confusion).

6.6.4 Tactic 4: Support players of different abilities through altering the amount of removed bodily control, or the level of stimulation applied

Some participants discussed that they found standing on the balance board to be difficult, whereas others found doing so quite easy (theme 3). Those who found it straightforward often said during the interviews that they usually had quite a good understanding of their sense of balance due to sports or meditation activities they frequently pursued (such as taking Pilates classes). This meant that if players played against someone who was better than they were, that the game was perceived as unfair.

In multiplayer videogame design work, consideration has been given to allowing players of different abilities to participate in the same game by limiting the abilities of experienced players, whilst providing a greater advantage to weaker players (Cechanowicz, Gutwin, Bateman, Mandryk, & Stavness, 2014). Similarly, exertion games have adapted the effort required from individual players based on the players' level of fitness, giving an advantage to less fit players and applying a handicap to more experienced ones (Altimira, Mueller, Lee, Clarke, & Billinghurst, 2014; Mueller, Vetere, et al., 2012).

Altimira et al. (2016) explored adapting the gameplay for individual players in multiplayer exertion games in order to provide a similar level of challenge for both players by penalising the more experienced (or skilled) player, and providing a boost or game play assistance to the less experienced player. Such an approach has been considered in video games to help less experienced players have an enjoyable experience when playing more skilled players (Cechanowicz et al., 2014). In multiplayer digital vertigo experiences, designers can learn from these examples if desired to help in creating a similar challenge for both players, through the consideration of two factors: 1) the environment affecting bodily control, 2) the level of stimulation further inducing sensory confusion. For example, in *Balance Ninja* simply helping the weaker player to balance by making the board stationary (the environment) would not help if they were also affected strongly by the GVS stimulation. Conversely if players are good at balancing themselves, giving them a higher level of stimulation than the weaker player may also be unfair as they may be particularly sensitive to the stimulation applied.

In flow theory (Csikszentmihalyi, 1991) an optimal experience can be achieved through considering two factors: the level of challenge and the level of skill. Similarly, in digital vertigo experiences, designers need to consider: 1) how much bodily control is removed and 2) the level of stimulation applied to each player in order to ensure an engaging digital vertigo experience. I encourage designers to consider a player's abilities and take advantage of the fact that the stimulation technology is digital and can therefore be altered based on the players ability.

6.6.5 Tactic 5: Use vertigo interfaces unpredictably to avoid players becoming desensitised

Vertigo can be subject to desensitisation effects. These effects are different to simply learning or gaining competence in playing the game, but are more related to players becoming used to and expecting the stimulation. For example, repeated long-term exposure to GVS can cause familiarity and an ability to overcome the effects (Balter et al., 2004; Dilda, Morris, Yungher, MacDougall, & Moore, 2014), and this was supported in the study for *Inner Disturbance*. This means that if vertigo-inducing stimulation is overused, digital vertigo games may no longer be exciting to play.

To reduce chances of players becoming overly familiar with the sensation, designers should be mindful of using the vertigo interfaces too excessively. In *Balance Ninja* the intensity of the effect felt by one player was determined by the lean of the opposing player (up to their maximum setting). This added unpredictability to the effect, which prevented players from becoming familiarised with a set pattern, since the effect was related to the movement of the opposing player. Doing so seemed to address the issues that arose in the *Inner Disturbance* study, where the same pattern was applied over and over again. Using these interfaces sparingly helps to overcome the familiarity effect and reduce chances of desensitisation. For example, stimulation could be used to exaggerate or punctuate specific game moments, and not be continually applied or repeated. As such, I recommend designers use the vertigo interfaces unpredictably or at only key moments, to avoid players becoming desensitised and familiar with repeated play sessions.

6.7 Expanding the framework

Balance Ninja was favoured by the participants who all said they had an enjoyable experience of playing the game. The findings suggested that players found it enjoyable to be able to choose when to try to “attack” and surrender more bodily control and to experience sensory confusion.

The study allowed me to further refine my framework, and the additions can be seen in figure 6.6, along with a rough estimate of where *Balance Ninja* sits within the design space (although the game does move through this space at different stages, such as at the start and end of each round as stimulation builds and reduces). Adding the balance boards increased the level of surrendered bodily control in this game (represented by the “Y” axis of the framework) over that surrendered in *Inner Disturbance*. The “X” axis has now become “The extent of Facilitated Sensory Confusion”, and represents how much sensory confusion is induced due to the applied stimulation.

This study also highlighted a potential new risk area in the framework: “Physical Injury”, whereby players too rapidly surrendering bodily control could be at risk of injuring themselves. In *Balance Ninja* this was unlikely since the sensory confusion induced through the GVS systems and the low height of the balance boards allowed players to safely lose bodily control. Players were able to choose when to move and when to battle the sensory confusion they experienced. This is why I have placed this area in the upper left region, since it is reasonable to assume that players would only be at risk of injury if control is too quickly taken away, or too much is removed such that any stimulation applied may result in them stumbling dangerously.

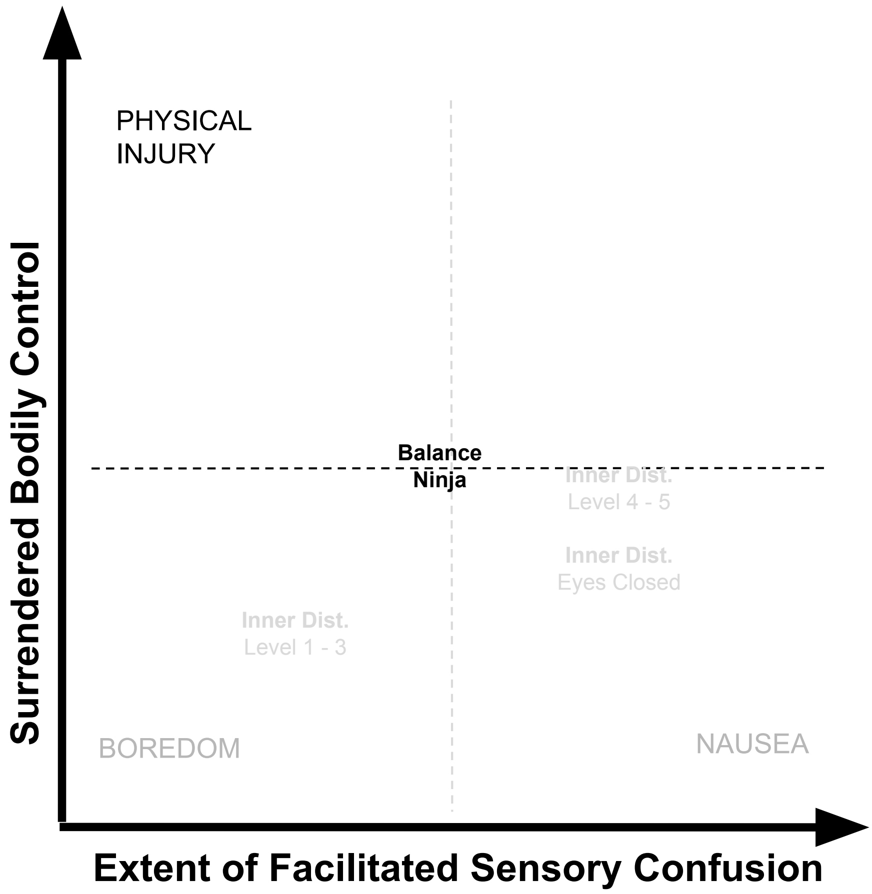

Fig. 6.6 The framework with Balance Ninja plotted and an additional risk area: Physical Injury. Experiences where a high degree of bodily control is removed would appear in this area. *Balance Ninja* did not directly move into this area, but participant discussions highlighted that it could have been a possibility.

6.8 Summary

In this chapter I have described my third case study, *Balance Ninja*, which builds on the development and findings of the prior case studies. Through a study with 20 participants I identified three overarching design themes, and articulated these along with five accompanying design tactics for designers of digital vertigo experiences. These findings have supported the refinement of the framework.

In the next chapter I describe the development of my fourth and final case study: *AR Fighter*, which uses HMDs as the stimulation technology to induce sensory confusion in players to achieve a vertigo experience in players.

Chapter 7

Case Study 4: *AR Fighter*

7.1 Introduction

In this Chapter, I describe my fourth case study that centres on a digital vertigo experience called *AR Fighter*. In the previous case studies the player's visual senses were important in maintaining balance and employed as a tactic to avoid experiencing sensory confusion (e.g. focusing on a point in the distance to overcome the GVS effect). When the visual senses were affected, i.e. by closing their eyes, players noted that they were far more susceptible to the stimulation effect induced by the GVS systems. Therefore, in this study, I wanted to see what would happen if a game nearly identical to *Balance Ninja* would present a different experience when played with Head Mounted Displays (HMDs) instead of GVS systems. Sensory confusion has been reported in studies that use HMDs (Sharples et al., 2008), and is often the result of sensory discrepancies that can lead to players experiencing simulator sickness when their visual sense does not match their vestibular sense (McGill, Ng, & Brewster, 2017). A further benefit of using HMDs over the GVS systems in this digital vertigo experience was that it negated the need to attach cumbersome electrodes, which was one of the main negative aspects of using GVS as reported in the prior studies.

Studying *AR Fighter* and comparing the findings to the previous case studies allowed me to further refine my understanding of how to design digital vertigo experiences. As GVS was the only stimulation method investigated in the prior studies, investigating a different method of stimulation allowed me to ensure that the framework was not specific to GVS and more technology agnostic as I had investigated more than one method of digitally facilitating sensory confusion in players.

7.1.1 Research Objective

The study of *AR Fighter* therefore answers the sub-research question:

> *"How does using a different method of facilitating sensory confusion, such as an HMD, change or support what I have understood so far about designing digital vertigo play experiences?"*

7.2 AR Fighter

AR Fighter is a two-player HMD game where both players attempt to remain balanced on one leg. Players who place their raised foot back on the floor first lose the game round, and the winning player (who is still balancing) earns a point. The first player to earn a total of five points wins the game. Originally the intention was to use the *Balance Ninja* balance boards in this game, but I chose not to use them since the reduced field of view when playing made them difficult to see, and possibly dangerous to play with.

The HMDs consist of low-cost cases (about AUD$20) each housing a Google Nexus 5x mobile phone, with the phone initially displaying the feed from the phone's back camera. Whilst due to the camera placement on the phones, this view is slightly offset, it is sufficiently close to the user's normal view to enable them to balance easily. Being able to see the world around the players was important, since work has shown that being able to view the world outside of the HMDs can help to limit simulator sickness (McGill et al., 2017).

When players first wear the HMDs, or whenever the game is reset after a round, they see the direct view of the camera, so that the horizon in the view is at the same angle as the real horizon. However, during gameplay, as one player tilts their head, the display of the other player is rotated in that same direction. This means that the other player perceives visually that they are tilting from side to side, even if they are not. This mapping is symmetrical, so that player 1's head tilt controls the view of player 2 and vice versa.

AR Fighter players experience sensory confusion since their vestibular sense reports that they are orientated one way, whilst their visual sense reports something different. As with *Balance Ninja* players need to battle the confusion they experience in order to stay in the game, but they also have to try and move since their movements affect the confusion felt by the opposing player.

When one player eventually loses their balance and places their raised foot back to the floor the game round is over.

Fig. 7.1 Two players playing *AR Fighter*.

7.2.1 Gameplay

A game of AR Fighter consists of multiple rounds. Each round starts with a countdown from five to one, at which point the game music starts, and players must raise one leg and begin to balance. During the round, players' head movements are mapped to the opposing player's HMD as explained above. When a player places their foot on the floor the other player receives a point and the system enforces a rest period (where players can rest their legs and remove the HMDs) before the start of the next round.

I chose to include a rest period based on the findings of *Inner Disturbance* and *Balance Ninja*, which both suggest using rest periods in order to allow players to recover from the effects of vertigo and standing on one leg. Furthermore, I also wanted to prevent players becoming too disorientated as continual sensory confusion from wearing HMDs can result in a feeling of nausea (Sharples et al., 2008). Rest periods lasted typically 1 minute, and gameplay resumes once both players are ready. When a player scores a total of five points, they are declared the winner of the game.

7.2.2 Technical Implementation

The main game program was written in Unity 3D, and used a slightly modified version of the python server I wrote for *Balance Ninja*. The server ran on a laptop and communicated with the mobile phones over a WiFi connection. The tilt value of one phone was sent to the server, which forwarded the value to the opposing player's phone, setting the phone's tilt value, and vice versa. Foot touch detection was performed by a myself, and the game manually stopped when I witnessed a player placing their foot to the ground.

7.2.3 Safety Precautions

The HMDs were fitted to player's heads via easy-to-adjust straps, and the devices were cleaned (before new players took part) and checked to make sure that they were secure before playing. All players were instructed that they were permitted to remove the HMDs if they felt uncomfortable. Before players started I also made sure that there were no obstacles in the immediate area.

I received ethics approval from the university before conducting the study, where participants were invited to play the game in pairs. The game did not require a prolonged calibration stage, although fitting the headsets comfortably served as a way of easing players into the experience. Once the headsets were adjusted and each player was ready they were invited to stand in the play area (roped off for the safety of both the participants and spectators) and to face each other. Players removed the headsets when walking, so once they were ready they placed them over their eyes and were then asked to prepare to balance on one leg. A countdown from five to one signalled the start of the game.

I closely observed the players during the gameplay to 1) make sure that players did not stumble dangerously (helpers were also on hand in case players stumbled, although this did not happen during the study), and 2) to monitor when a player placed their foot back on the floor. When a player placed their raised foot back on the floor, I awarded a point to the winner and paused the game (which also paused the visuals on the HMDs) and invited the players to remove the HMDs as they rested after the round.

Although a sensor could have been implemented to detect when a raised foot was placed on the floor, for simplicity and reliability of observing the participants, I controlled this myself.

The process was repeated until a player reached five points. I chose five since it seemed a good amount in the prior case studies, and given the tiring nature of *AR Fighter*, I assumed this was a large enough number to get multiple rounds of gameplay (as all pairs shared winning rounds to some degree), but not too many that it would overly fatigue the participants. Once the game was over, participants were invited to take part in a semi-structured interview, where I asked each pair about their experience of playing *AR Fighter*.

7.2.4 Participants

21 players in total (8 female, 10 pairs) played *AR Fighter*. One player played against a previous participant as their opponent was no longer available (otherwise there would have been 22 participants total). The participants were aged between 19 and 42 (M=26, SD=5). Participants were recruited primarily via the university mailing list and word of mouth, although some volunteered after observing others playing the game.

7.2.5 Data Collection

As with my previous case studies, data was collected with participants consent through the use of audio and video recordings of each gameplay session and interviews. In total around one hour of audio and video was recorded from the interviews.

After each play session, which lasted typically no more than five minutes, participants were interviewed in pairs using a semi-structured interview schedule (see table 7.1). Following the interviews, participants were also invited to fill in a short 5-point Likert scale (1 = strongly disagree, 5 = strongly agree) questionnaire to elicit a quantitative understanding of their experience. I chose these questions based on the findings of the earlier case studies and to also gather quantitative results on the experience of playing the game.

How did you find it and what was it like to play?
Did you find the game difficult?
Did you feel disorientated or sick?
Would you describe what you experienced as vertigo?
Did you feel in control of yourself?
Did it remind you of anything else?
What was the best bit, and what was the worst bit for you when playing?

Table 7.1 Main questions asked in the *AR Fighter* interviews. Follow up questions to the above were asked based on participant responses and these responses also contributed to the themes.

7.2.6 Data Analysis

As with the previous studies, I employed Braun and Clarke's (2006) thematic analysis approach for the data analysis. Participant interviews were both audio and video recorded in order to assist me with this process. I consider each turn of speech as a "Unit" following this approach and for this study there were a total of 170 participant units to consider. Coding of these units was carried out by myself and my co-supervisor, first independently, and then together, where we derived a total of 8 codes that described the participant experience of playing *AR Fighter*. These codes we further grouped into three recurring themes that are described further in the following sections. As the same reviewers (myself and my co-supervisor) have carried out the same approach for all of the studies these themes are inherently informed by the prior studies.

I report on the themes as discovered from analysing the participant data from the interviews, but acknowledge that the themes are similar to those that appeared previously. As I am investigating how to design digital vertigo play experiences, this study mainly focused on how the experience differs when a different digital stimulation technology is used to induce sensory conflict in players - in this case HMDs instead of GVS. Therefore this study data in part presents similarities to the previous study findings, which is a worthy outcome, as it helps to validate the previously discussed themes. There were also additional findings that were HMD specific (as with the prior studies contributing only GVS specific findings), and these are also discussed in the following sections.

7.3 Results

In this section I first explain the responses to the participant questionnaire, and then describe in detail the three overarching themes that were derived from the data analysis of the participant interviews. The three themes are categorised as: Gameplay and Enjoyment, bodily control and recovery, and finally: vertigo feelings and effects.

7.3.1 Questionnaire Responses

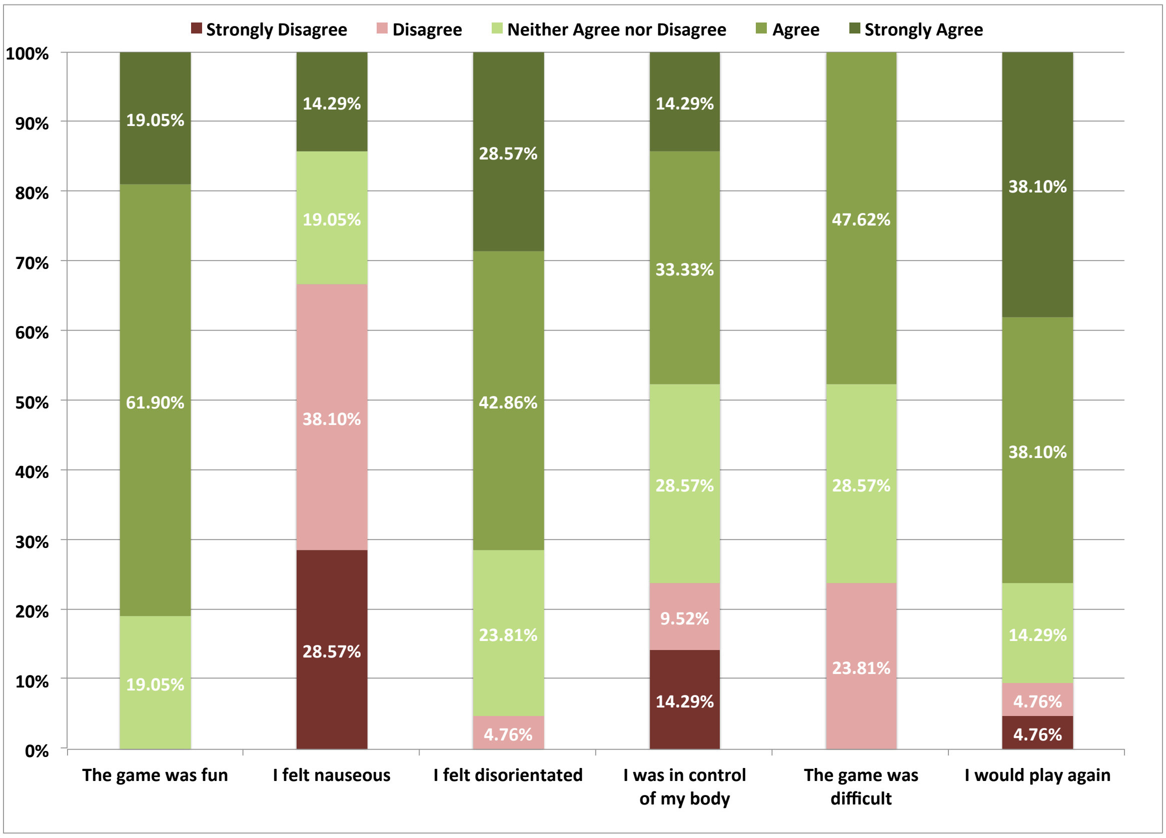

Fig. 7.2 Participant (N=21) responses to *AR Fighter* questionnaire.

Results to the 5-point Likert questionnaire are visible in figure 7.2. Participants agreed that the game was fun (Median (M)=4 and Standard Deviation (SD)=0.63). Asked to consider if they felt nauseous when playing, participants indicated that they generally did not (M=2, SD=1.32). When describing a feeling of disorientation and whether they felt in control of their body participants stated that they did feel disorientated (M=4, SD=0.86) yet they were in control of their body (M=3, SD=1.26). Participants were split on whether they found the game difficult (M=3, SD=0.83). They mostly agreed that they would play the game again (M=4, SD=1.10).

7.3.2 Theme 1: Gameplay and Enjoyment

This theme was derived from 120 of the 222 Units, and four code categories: Enjoyment, Difficulty and Game Design, Vertigo Analogies, and Gameplay Strategies.

Enjoyment

Participants found the game enjoyable (*"I really enjoyed [it]"*) [P12], and compared the activity to other enjoyable vertigo experiences: *"You go to enjoy those rides to experience the unpleasant, which I was able to experience here, so that was good, yeah!"* [P2]. They also expressed that even when losing they found *AR Fighter* fun to play: *"I laughed, I smiled, so I guess that's a thumbs up from me, even though I did lose"* [P16], and *"The experience was fun. So I would try it again, but I don't think I would win [laughs]"* [P2]. Players even had what they described as an adrenaline rush: *"It was exhilarating, there was a real adrenaline rush"* [P1]. They also described the game as being something new: *"Something really new, never done anything like it"* [P4], and *"I've never played this kind of game before"* [P10].

Participants suggested that the social aspect of the game contributed to their enjoyment, explaining the game was *"very fun, I liked it because I was not the only one playing, it was with a friend"* [P3], and the *"best bit was the team - not team, but playing with someone"* [P3]. This social aspect added an element of competitiveness for some players: *"It was fun, but, I guess it helped that [other player] and I have a little bit of a rivalry sometimes"* [P12], to which their opponent responded: *"Yeah! So I have totally walked away ashamed!"* [P11].

Difficulty and Game Design

Players found the game difficult to play, *"Yeah, it was hard"* [P15], and although challenging also found the game to be fun: *"It was a challenge, it was fun"* [P15]. Some players used the challenge to their advantage: *"I just had to wait for [the other player] to lose, right? Because I wasn't able to do anything that would challenge them - I never got to that point. I had to just hang on and wait for them"* [P14]. This suggests that some players had a more difficult time battling the sensory confusion, and relied on the other player making a mistake, rather than actively trying to induce further sensory confusion in the opposing player. Others found the game hard, but still enjoyed playing: *"the game was a lot harder than I expected, but it was a good experience - it was really fun trying to make my balance work when I was being thrown off so much"* [P18].

The difficulty of playing may have also been a result of players not being able to keep track of their orientation, or losing their bearings when playing due to the narrow field of view of the HMDS: *"Most of the time, it was not player 2 that I was seeing, but something else that I was seeing, even though I think I was looking straight, you have to tell me if I was looking straight or not!"* [P1].

The game was setup in the same way for all players, and although some found it difficult, some players appeared to rely on their own previous balance experience to help them in playing, for instance two players found the gameplay quite easy, explaining that *"because we Longboard"* [P4], they had gained a very good grasp of battling the environment and their sense of balance. Another player also found a way to overcome their disorientation, explaining that they: *"found it easier balancing by disregarding the opponent, [since I am] both a dancer and someone who regularly does yoga, balance is something I am very used to"* [P17].

All players appeared to enjoy playing the game, with many suggesting that they would play again (76%), and zero players stating outright that they did not find the game fun. This could have been because although players had different balancing abilities, the game was interpreted as being very accessible and simple to understand: *"[it was] easy to play, just put [the HMD] on and play it. So that was quite nice"* [P14]. One player commented on how the game: *"was easy, because it didn't have many rules. Just look and try to keep yourself balanced and try to knock the other player [over]"* [P6]. Another player expressed that they: *"love[d] the simplicity of it all, like something at a party, you can pull it out and yea - just the one-up-man-ship is just great. The way you can play it anytime of day, anywhere. Very easy!"* [P17]. These were important remarks for me, as I wanted this game to be more accessible, quick to experience, and less invasive than my previous case studies which relied on GVS to create the sensory confusion in the players.

Vertigo Analogies

When trying to describe the experience of playing *AR Fighter*, players often relied on analogies of similar experiences in relation to how they felt when playing, such as comparing the game to fast theme park rides: *"A little bit like a mini rollercoaster but not like the turn ones, just the really fast ones"* [P3]. Similarly, one player compared *AR Fighter* to a disorientating tunnel ride: *"there was a tunnel with a bridge through the middle of it, and you have to walk through the tunnel and the whole tunnel spins, so the visuals, everything you see is rotating around, and everyone on the bridge just can't help but fall. It's just absurd to watch that. So I found this similar to that as well"* [P4]. This type of ride aims to confuse players' senses in order to result in them falling over, and for players to compare *AR Fighter* to this ride experience seems to suggest that the HMDs did help to induce sensory confusion in players in a similar way to the ride. Further, players reported the game as fun, so the sensory conflict created a pleasurable and enjoyable experience, and could therefore be said to have been a digital vertigo play experience.

Players also articulated how the experience reminded them of childhood games such as "hopscotch" due to players jumping around on one leg. Another player was reminded of games they used to make up as a child to challenge their sense of balance: *"As a kid you'd make games up on the spot and sometimes when you are walking on the street, you would find a line or a path that you would try and stick to, and you would try to balance yourself and make sure that you're staying on that path. Whether it is like some concrete edge or something like that, it kind of reminded me of that even though it wasn't walking or anything. It felt like the same or similar type of experience of trying to balance myself"* [P13].

Another participant recalled an experiment they had seen in a TV documentary: *"I saw this silly experiment that they do on a documentary where they have three walls and some pattern on the wall and they stand on this block and they have to hold this platter with a glass of water. Then they move the walls, but they don't tell them that they are going to move the walls and when they, as soon as they move the walls then they drop it. Even though they haven't moved"* [P12]. Playing *AR Fighter* reminded this player of something they had once seen where sensory confusion was caused in people standing still, simply be manipulating their visual perception through rotating the walls of the room. Such an illusion is the basis of several popular rides, most notably the "Haunted Swing" illusion (Wood, 1895) (described earlier in chapter 2.4.1), and the VR equivalent created Tennent et al. (2017). These analogies and comparisons to existing systems help to confirm that *AR Fighter* was able to illicit feelings of vertigo in its players.

Strategies to overcome sensory confusion

Players were inventive in attempting to score points and win the game, employing different bodily strategies to overcome the sensory confusion facilitated by the game. For example, one player commented that: *"I was trying to mess [the other player] up, so I just shook my head, [laugh]"* [P8]. The player chose not to move the rest of their body, but just their head, so that the opposing player would become disorientated through their own movements and the visual sensory confusion induced by the player's rapid head movements.

This appeared to be a popular strategy, with players trying to ignore the visual stimulation: *"For me, I more focused on my body, rather than on the visual"* [P10]. Another player went so far as to overcome the sensory confusion by closing their eyes: *"You know what, I felt like, I don't know, if you say it was cheating, but I could stabilise only when I closed my eyes. But when I was looking forward I could not balance myself"* [P5] Closing one's eyes appears to be a strategy employed to allow players to re-orientate themselves and regain an aspect of bodily control to strategically beat the opposing player: *"I was stressing so much like 'no! I am losing all the points!' so I closed my eyes and then I could stabilise myself"* [P5]. Although for some players closing their eyes was not entirely easy: *"I noticed the challenge of people being able to close their eyes, I noticed in one round it was still a little difficult, you still have to balance and what not, but yea there is that 'cheat' against your opponent"* [P17].

7.3.3 Theme 2: Bodily Control

Below I describe the findings concerning bodily control in *AR Fighter* as derived from one code category: Control and Recovery (43 Units).

Players described how they lost and recovered bodily control during the gameplay: *"I was in control because I could do some action to recover from whatever disturbance was brought to my visual system. So I think yea, I'd say yes. Although it was difficult to recover from that disturbance."* [P4] Players appeared to find keeping their own sense of bodily control whilst trying to affect the other player's to be challenging: *"Yes and no. It's only when I start doing the 'attack move' and then I don't know where I am now (laugh) once you lose the person, you're just like 'where is he?'"* [P3]. Losing sight of the opponent sometimes resulted in the player losing the round: *"I was trying to find you [player 1] and that's when I lost my balance, tilting my head and I lose control of my leg (laugh)"* [P2].

Players expressed different levels of feeling in control: *"I would say 60% in control, but 40% sometimes"* [P8]. They explained that they were able to remain in control until they attempted to move: *"It's like a fifty-fifty thing when I was trying to concentrate very hard, trying not to make the view move fast, I think I was in control. But once I moved just the slightest bit, it was all haywire"* [P1].

For other players, the feeling of control was not very strong: *"I was not feeling in control at all. I was like a free bird, you know? 'I have to fly!' I was feeling, like, I'm high or something, you know?"* [P5].

Players were surprised at how easily they lost bodily control when playing, particularly when they were proficient and experienced with balancing techniques: *"Having spent years of pretty much my entire life doing martial arts which is all about spatial awareness and body balance, being able to have that taken away from me so easily, that is what I enjoyed"* [P12]. *"It was cool. It was interesting, I didn't think it would be that hard to control my body"* [P7]. Another player, when asked if they had felt in control of their body responded: *"definitely not! That was the biggest conflict of the game - just when you think you have control, just when you think you've got [the other player] on their last leg, all of a sudden you realise your whole body is starting to tilt and you can just feel yourself falling"* [P17]

Despite losing control, some players suggested that they were not sure whether the other player was also losing control, or if it was just themselves: *"so you know you may sit there and strategically hold steady and let them attack and once they sort of settle down - like you could have a double bar graph, one that says how much they are affecting yours, and how much theirs is actually unstable. How much they are swaying, because then you can look at it, because if they are really attacking you - and steady - bad time to attack. You need to cop [bear the brunt of] the attack, sort of thing. Then attack back when they are unsteady and quickly 'shake the head, shake the head, shake the head!' Or 'lean, lean, lean!'"* [P12].

Rest and Recovery

Players seemed to appreciate that the HMDs could be removed during the rest periods, or if they felt uncomfortable when playing, suggesting that knowing they were able to stop playing and maintain an aspect of control over their actions meant a greater level of enjoyment for that player: *"Well, the thing is, I know at any point I can do this [lifts*

HMD off] and the disorientation is going to stop, I re-orientate. When I think about the unpleasantness of nausea connected to vertigo it is more because, well, some of the scuba divers I dive with get vertigo and they just hate it because when you are underwater, and everything's spinning, it's just a nightmare and you know it can't stop. The other thing is you can't just bail [escape] because you are thirty meters underwater and you'd just kill yourself; so here at least we always know that at any point we can escape, so there's sort of an escape from the vertigo element. But that is sort of what makes it fun" [P12].

In some vertigo experiences, such as being strapped in a roller coaster, players can not remove themselves until the ride stops, but as another player also said: *"knowing that as soon as you take the headset off, 'everything is fine', - it makes perfect sense"* [P18]. Vertigo games require players to make *"calculated risks of limited duration"* in order to play (Caillois, 1961; Stevens, 2007), and *AR Fighter* appears to have supported players in calculating these risks by having a very simple and quick method of removing oneself from the gameplay and accompanying sensory confusion.

The game was also described as being quite physical to play: *"it's a physical activity kind of game so it's very enjoyable, in that way. You are tired at the end, not really exhausted but yea certainly trying to get your breath back"* [P17]. Despite the physical nature of the gameplay, the rest periods appeared to allow players to recover from the physical strain, and even appeared to help in reducing players from feeling nauseous: *"I think if I played longer I may have started to feel a bit sick"* [P15], and many players even stated that they did not feel nauseous at all at the end of the game, despite being disorientated when playing.

7.3.4 Theme 3: Vertigo feelings and effects

The final theme contains two categories, detailing 59 of the 222 Units: Vertigo and Disorientation, and Nausea and Vision.

Vertigo and Disorientation

One player found playing *AR Fighter* made them question what they knew about their own bodies: *"I've become very reliant on my balance, you know, especially doing a lot of sports where spatial awareness doesn't matter, where you always have a sort of knowledge of where you are. To then have that, completely taken away - it's almost to my detriment that I rely on that sense so much now. [The other player] would tilt the head and I would feel like going, my body, I just - cognitively I know it is an aspect of [the other player] chang-*

ing my perspective but the internal mechanics of my brain are already wired to go 'Whoa, oh, you're falling!' So that is why there was sort of, a lot of skipping" [P11] The skipping referred to here was a result of the player hopping around when playing, instead of staying completely still on one leg, in their attempt to remain in control of their balance.

Other players did find the experience disorientating: *"it was of course disorientating, the screen was shaking around quite a lot"* [P15], *"dizzy and disorientated but I didn't feel nauseous"* [P16]. One player described that *"if [the gameplay] would be slower then [...] I'd have played it again and again for a long period of time"* [P1], which supports the findings of the prior case studies that experiencing shorter moments of could be more enjoyable and noticeable than continually experiencing the sensation.

Nausea and Vision

Only a small portion of the players reported feeling nauseas (14.29%). This was quite a small amount considering how some HMD simulator rides can easily result in motion sickness if too much disorientation is experienced (Hettinger & Riccio, 1992; Sharples et al., 2008). Although these findings are similar to the after effects of theme park rides (some riders feel more nauseous than others), a possible reason that only a small amount of players felt any nausea in *AR Fighter* could be due to the control they maintained over their body movements. P13 explains: *"I think that potentially some of the reason that I didn't feel nauseous was that the movement of the screen was not being changed against my own will. Like I was influencing the movement. Even though [the other player] had some impact on it as well, because I was also moving along I didn't feel that sense of nausea. Whereas in the past, with Oculus Rift games, when you are not moving but the Oculus Rift is moving against your own will, that gives you like a disconnect between what is happening on the screen and what is happening to your body, or what is not happening to your body"* [P13].

Interestingly, one player described being able to detect when their opponent was losing control because of how it affected their own vision: *"What I was seeing in my vision was lots of tilting, so as I said before your opponent controls your visualisation of what you see or what sort of angle you are seeing - so I just see the disorientation from the opponents view, or perspective, and yeah its just a bit wobbly because he had a weaker sense of stability at the time"* [P20]. Another player noted how their body moved in reaction to their vision being distorted: *"It was good, it was definitely a new and strange experience. The minute I put the headset on, it was already a strange feeling. My vision was already altered, but when the music kicked in, the rest of my body went with my vision so my body* *went all over the place and I was having trouble standing on one leg"* [P21].

7.4 Further Tactics for the design of Digital Vertigo Experiences

Below I present tactics for the design of digital vertigo experiences as derived from the analysis of *AR Fighter*. Playing HMD games can cause disorientation, and I have shown with *AR Fighter* that this facilitated sensory confusion can actually be quite fun to experience. In this section I describe four design tactics derived from the study of *AR Fighter*, aimed at designers of future vertigo play experiences, or designers interested in introducing vertigo into existing HMD based games.

7.4.1 Tactic 1: Dynamically adjust sensory confusion based on a player's surrendered bodily control

Players of vertigo experiences will have different bodily capabilities, and some will lose control faster than others at different levels of facilitated sensory confusion. Theme 1 and theme 3 highlighted that at times players could rely on their own experience of balance activities to help them overcome the disorientation, or at other times found it surprising at how easily their bodily control was lost, despite being proficient at balancing activities. For players less experienced with balancing, however, the game was found to be often difficult, especially when paired with an experienced player. This is not a surprising finding, but in the same way that not all rollercoasters are suited to all riders, designers of digital vertigo experiences, which require confusing two or more senses, need to consider whether the game should appeal to all players, or a specific type of player, (e.g. for "extreme" or "novice" players).

Digital vertigo experiences benefit from being able to finely administer stimulation to one or more senses to facilitate sensory confusion, but could be further extended to also sense the bodily control surrendered by players as a result of the facilitated sensory confusion administered. For example, if players appeared to be getting too quickly out of control, the system could detect this and reduce how much disorientation was being administered to the player. Similarly, if the players were not responding very well to the facilitated confusion, the systems could automatically increase the extent of the stimulation.

Designers should also be aware that external factors could contribute to the facilitated sensory confusion in unwanted ways, which may negatively affect the experience. In theme 2, for instance, I described how players found it difficult to “find” their opponent after they had turned around too much in the real world and were no longer facing one another. This was an unexpected outcome of the gameplay. Furthermore, players noted how easy it was to lose control (theme 1) from the visual confusion alone, and coupled with losing the position and direction the other player was in relation to themselves at times caused certain players to become *too* disorientated.

I therefore recommend designers try to detect how much bodily control is being surrendered in their digital vertigo experiences, and allow the system to dynamically alter the facilitated sensory confusion based on if this is too much or too little at the present game play time. If too little, designers are encouraged to design the system to increase the facilitated sensory confusion, and likewise reduce it when players appear to be too greatly out of control in order to ensure players have the “optimal” experience. That is to say, to keep players in what I consider to be a “sweet-spot” - where players are neither too disorientated (and at risk of nausea), or too under-stimulated and at risk of a boring gameplay experience. Dynamically altering the facilitated sensory confusion by detecting the surrendered bodily control, (e.g. by using sensors like the Microsoft Kinect to detect too much body sway), will allow players to remain in this “sweet-spot” of gameplay, and will also help to limit unwanted sensory confusion from diminishing the experience as the system will react when players get too out of bodily control.

7.4.2 Tactic 2: Allow players to recover from repeated, or extreme periods, of facilitated sensory confusion, by regaining bodily control

Players of *AR Fighter* noted in theme 1 that the game was physically demanding, and that the rest periods allowed them to avoid becoming nauseous from prolonged gameplay or from experiencing too much disorientation, such as described in theme 2. I see rest periods as a valid method of prolonging the vertigo experience, as vertigo moments in games, Caillois states, should only last for limited periods of time (Caillois, 1961). Therefore, by extension, vertigo experiences should also limit the duration of facilitated sensory confusion if designers want players to enjoy their experience.

Other vertigo experiences can also be prolonged with frequent breaks, such as in rock climbing, where climbers often rest to recover from muscle fatigue, or to plan their next moves. More intense vertigo experiences, however, need to be limited in duration to avoid overly stimulating players or removing too much bodily control too quickly. For example, in the activity of Zorbing, the amount of time spent in the inflatable ball is extremely limited. Riders are able to climb back to the top of the hill and have another go, but the hill they are pushed down allows the ball to only travel for a short distance. The rider inside experiences intense sensory confusion due to an overloaded vestibular sense that then conflicts with the other non-overloaded senses, as they continually roll over and over. If this were to last a long time, riders would be at risk of nausea or physical discomfort.

In HCI literature, Benford et al. have suggested the use of trajectories (2011; 2008) as one method of controlling the user experience through the rising and falling actions of Freytag's narrative (Freytag, 1863). Similarly, HMD vertigo experiences could follow similar trajectories, starting with a limited amount of sensory confusion, rising to a climactic moment of high sensory confusion, before tailing off and allowing the players to recover bodily control. Depending on the desired outcome of the experience, designers can choose to have a single intense experience, following a single Freytag trajectory (such as Zorbing), or several smaller ones to create many vertigo moments (as with *AR Fighter*).

I recommend that designers of vertigo experiences take advantage of introducing rest periods into their games (as was also found in *Inner Disturbance* and *Balance Ninja*), as enforcing rest periods is one easy to implement way of ensuring players regain enough bodily control to make them susceptible to experiencing sensory confusion in an engaging way.

7.4.3 Tactic 3: Discourage players from regaining bodily control through ignoring facilitated sensory confusion

My results described above suggest that HMD-based vertigo experiences can be very accessible to players (theme 2), as they allow players to place the HMD on their heads and immediately start playing. There is a limited setup required compared to other vertigo experiences that require custom-made hardware (Marshall, Rowland, et al., 2011). Even *Inner Disturbance* and *Balance Ninja* required custom-made hardware in the form of GVS. The lower barrier to entry required to play *AR Fighter* appears to be something of a strength, there are also possible weaknesses that designers need to be aware of when designing HMD based vertigo experiences.

As described in theme 2, one of the strategies employed by players to overcome an induced sensory confusion was to shut their eyes. Manipulating players' sense of vision, however, is obviously the primary way in which HMD digital vertigo experiences would be able to induce sensory confusion in players. However, it appears that closing one's eyes allows enough of a break from the induced sensory confusion in order to overcome the effects, essentially breaking the game in a way that I had not anticipated in the design. This appears to be specific to visual methods of creating vertigo; for example on rollercoaster rides, it is usually impossible to opt out of the vertigo sensations in this way until the ride comes to an end. Similarly, in my previous case studies (*Inner Disturbance* & *Balance Ninja*), the GVS directly affected the player's sense of balance, and could not be ignored by closing one's eyes as this practice exaggerated the effect. The only way a player could overcome the stimulation is if the GVS is turned off or players stand still (which ends up stopping the games).

In related work, Marshall et al. (Marshall, Rowland, et al., 2011) witnessed a similar occurrence when they observed riders trying to beat their Bucking Bronco ride, which was controlled by the riders' own breathing patterns, by actually holding their breath. This work parallels mine since with the Bucking Bronco game, players would eventually have to breathe, and after holding their breath they would most likely breath heavily which would cause the ride to spin quicker. In *AR Fighter*, players who closed their eyes may have temporarily overcome the facilitated sensory confusion, but if they did not win shortly after doing so, opening their eyes may reveal that they are in a completely different position, having rotated around their axis through any balancing movements (such as hopping), and this confusion could also lead to the player becoming even more disorientated.

A solution to players holding their breath on the Bucking Bronco ride was to make subsequent levels more difficult for that player as a direct result of them attempting to "cheat" the game (Tennent et al., 2011). This creates an interesting challenge for designers of HMD-based vertigo experiences and poses the question: should we penalise players and discourage them from closing their eyes? Designers of HMD based vertigo experiences could choose, similarly to Tennent et al., to penalise players who close their eyes (by detecting this through sensors embedded in the HMDs). In most HMD games designers should be aware that players who close their eyes may reduce the effect of the vertigo experience, but designers could choose to penalise them in other ways (for example not being able to aim in-game weapons or see approaching enemies).

7.4.4 Tactic 4: Ease players into experiencing sensory confusion and surrendering bodily control

HMDs can greatly affect a player's field of view, and not being able to see a full field of view could create a certain amount of anticipation concerning tripping, falling, or injuring oneself when playing. This is an obvious shortcoming of using HMDs, and is something that is also referenced by leading HMD manufacturers. The guidelines for the HTC Vive, for example, explicitly state that players need to remove any obstacles or hazards before playing (Vive.com, 2017). In addition to making the gameplay area inviting and obviously free of any obstacles, I envision several additional ways in which designers can ease players into surrendering bodily control, and hence be open to experiencing the facilitated sensory confusion.

The power of HMDs is that they allow players to become absorbed into another world, or have the world around them appear to be changed. Game designers allude to the "Magic Circle" (Salen & Zimmerman, 2004, 95-96) as a way of referring to the physical space and its challenges vs. the conceptual space for players to play in (i.e. the real, physical world game area, vs. what players observe through the HMDs). The challenge for HMD-based digital vertigo experiences is how to allow players to asses the risk (as required per Caillois' vertigo description (Caillois, 1961)) in playing a body-based game whilst wearing an HMD, and thus be open to experiencing the sensory confusion and surrendering bodily control.

One possible method is simply to allow players to observe the game being played – either through a live demonstration or introduction video that would outline the gameplay rules and mechanics, with an emphasis on how safe the environment is to play in, and how safe players feel when playing. Finnegan et al. (2014) took this approach with their blindfold exertion game, allowing and encouraging others to watch them play as one blindfolded player tried to catch three other players within an obstacle free game play area. The blindfolded player was able to track the other players based on intermittent audio cues. Watching the gameplay encouraged others to take part, allowing them to easily access the risk of playing.

Another way of easing players in has been previously described in *Inner Disturbance* and *Balance Ninja* where I suggested the use of the calibration stage of the GVS device to help ease players into experiencing the game. Once players had succumbed to the effect of the induced sensory confusion for the first time they enjoyed playing both *Inner Disturbance* and *Balance Ninja*, and any apprehensiveness was reduced through this easing-in stage. Related work also suggests that slowly introducing players to an altered environment through an HMD can improve their experience and ability to measure distance within the environment (Steinicke et al., 2009; Valkov & Flagge, 2017).

As described, *AR Fighter* did not really need a calibration stage (beyond affixing the headsets securely), but I observed players becoming more comfortable with the experience, (with players even hopping around the game area (theme 2) or skipping (theme 3)), as they became more open to the facilitated sensory confusion and reducing their own bodily control as the game went on, and especially after they had played one round.

Therefore, in addition to obviously creating a low-risk gameplay area, I encourage designers to create a calibration stage or gameplay tutorial that acts in the capacity of easing players into surrendering bodily control. Players need to accept that they will experience sensory confusion and that they need to surrender bodily control for this to be effective. Tutorials in vertigo experiences are essential in helping the players to *open up* and doing so allows them to fully embrace the digital vertigo experience.

7.5 Expanding the Framework

As with the previous chapters, this study helped me to validate and refine my framework from a new perspective. In this game players wore HMDs instead of the GVS systems of the three prior studies. This was important for me to explore as I wanted to see if the same sort of experience was possible through changing the digital stimulation method.

Interestingly, the themes unearthed in the data analysis seem to support those already uncovered, although I was able to derive a few specific scenarios for HMD type vertigo experiences. These findings helped me to add a final "danger area" to the framework - the upper right corner of "Sensory Overload". In some of the reported feedback, for example, players explained how they were unable to find their opponent again, and that this led them to become even more disorientated. Other players reported that the quick nature of the gameplay also disorientated them so much that they did not feel like they could play for too long.

This highlighted the upper right area since at high levels of stimulation, and a lot of surrendered control, it is possible that player's senses may become too overloaded when they experience intense sensory confusion. This is, of course, part of some existing vertigo experiences (such as zorbing), but is also something to consider in digital vertigo experiences since designers can control how much stimulation is applied and reduce it accordingly to the type of experience they have aimed to create. Essentially designers

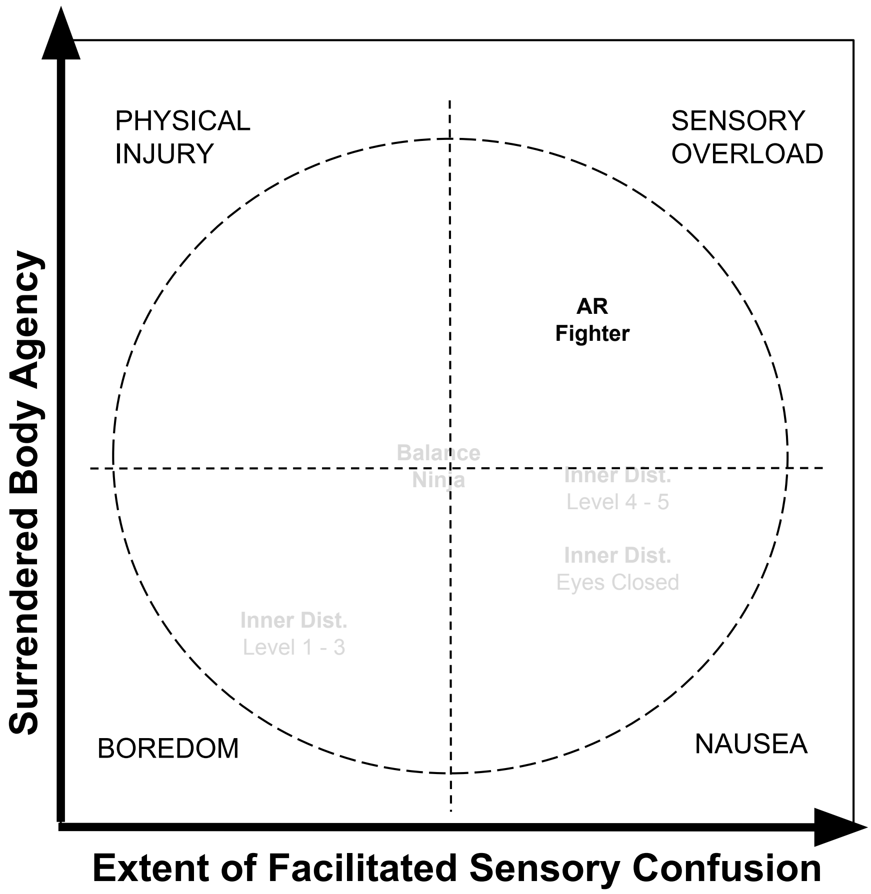

Fig. 7.3 The framework with *AR Fighter* plotted. Also an additional danger area: Sensory Overload. Experiences where a high degree of bodily control is removed, and a high amount of facilitated sensory confusion is induced would move into this area.

should avoid *accidentally* creating experiences that they did not intend, otherwise the players may respond negatively since the contract they make with the game (assessing the risk) will be broken. For instance, if players think they'll experience something akin to the easy-going "Tea Cup" theme park ride (where tea cup shaped chairs spin slowly around an area), but experience something more like zorbing, they will very likely not enjoy the experience or desire to replay any future ones.

At this stage it was also possible to add a suggested space to the framework, to suggest to designers where digital vertigo experiences should fall to create an enjoyable experience for players, and thus not lead to players being at risk of: boredom, nausea, physical injury, and sensory overload. This space is of course a suggestion, and is represented by the white circle encapsulating the games I created. The "danger areas" are represented by the area outside of this circle.

In figure 7.3 I have placed *AR Fighter* in the upper right quadrant. Compared to the GVS games there was a high level of sensory confusion due to the unlimited and fast rotation of the visuals. Additionally players surrendered a high level of body agency through standing on one leg and playing with a limited field of view.

As I have investigated more than one method of facilitating sensory confusion (GVS and HMDs) in players, I also renamed the bottom (X) axis to “Extent of Facilitated Sensory Confusion”. The Y axis has also been renamed to “Surrendered Body Agency” to represent that it is not just control players surrender in these games, but a sense of agency (Gallagher, 2000; Tsakiris, Schütz-Bosbach, & Gallagher, 2007), since the stimulation systems are only partly responsible for reducing their sense of control.

I describe the full framework in the next chapter, where I elaborate further on the stages of creating the framework.

7.6 Summary

In this Chapter I have described my fourth and final Case Study, *AR Fighter*. This system builds on the findings of the prior case studies, and through a thematic analysis of a study with 21 participants I identified three overarching design themes, which serve to validate those already uncovered, and extend the framework through the consideration of an additional stimulation technology. Further, I articulated these themes along with four design tactics for designers of digital vertigo play experiences.

In the next Chapter I bring together all of my case study findings in order to present the Digital Vertigo Experience Design Framework.

Chapter 8

The Digital Vertigo Experience Framework

8.1 Introduction: Creating a Digital Vertigo Experience

In Chapter 1 and 2, I introduced the definition of vertigo games and current understandings of vertigo games from related work.

To refresh, Caillois defines vertigo games as:

> *"consist[ing] of an attempt to momentarily destroy the stability of perception and inflict a kind of voluptuous panic upon an otherwise lucid mind"* (Caillois, 1961).

My investigation set out to extend this definition with regards to the digital realm, and to this end I now present my Digital Vertigo Experience Framework.

This theoretical framework is an abstract understanding of the findings I have obtained through designing and building my case studies through my investigation.

In the following sections I will discuss the framework's derivation in full by discussing its component parts: the framework axis, four user experience areas, and the recommended design space and risks areas to avoid.

To support designers and guide them in the creation of their own digital vertigo experiences I also present a summary of the design tactics as derived from my case studies, describing them using the language of the framework.

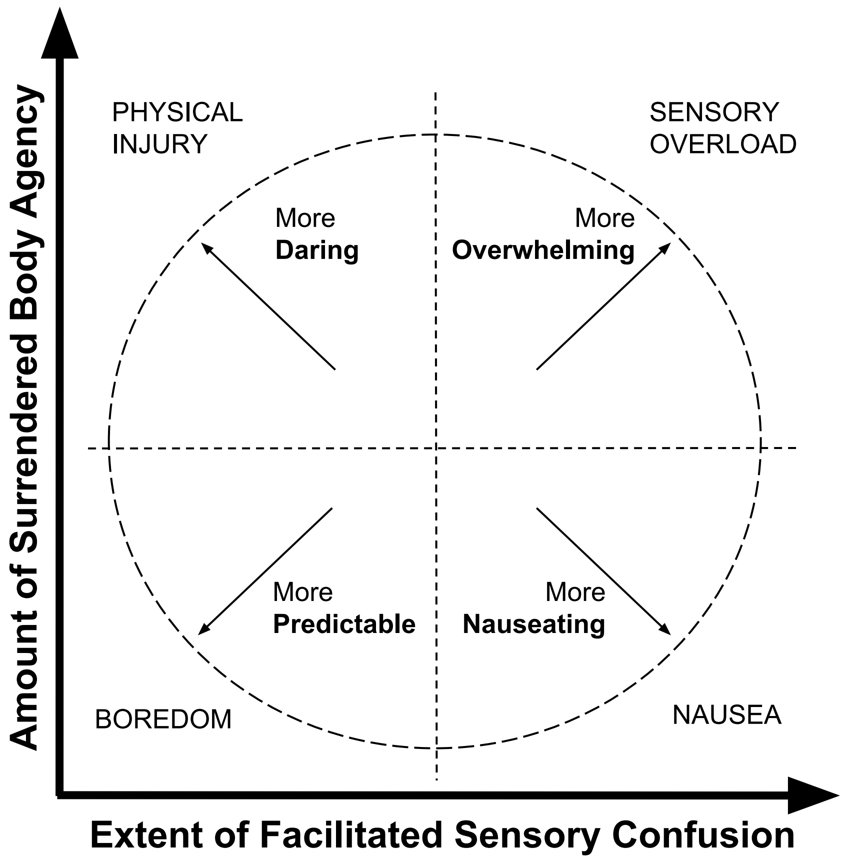

Fig. 8.1 The Digital Vertigo Experience Framework.

8.2 The Framework Axes

Core to the framework, are the two primary axes: amount of surrendered body agency, and extent of facilitated sensory confusion. In this section I describe each axis, and how they were derived. Supporting this, I include participant quotes from the prior case studies.

8.2.1 Amount of Surrendered Body Agency

Body agency is defined as the feeling that "I am in control of generating or causing an action" (Gallagher, 2000; Tsakiris et al., 2007) and in digital vertigo experiences relates to the bodily agency players have over their own actions when playing. As I discovered in my investigation, players are required to surrender some amount of body agency to experience the games. Caillois describes this as surrendering to a "momentary shock, which destroys reality" (Caillois, 1961). If players are not willing to reduce body agency then the ability to experience vertigo will be diminished.

Designing to remove one's sense of body agency has been explored in similar work and my work has highlighted that players can enjoy the experience of surrendering body agency, which is a finding also supported in the work of uncomfortable interactions (Benford et al., 2012), where control is surrendered to another person. In Marshal et al.'s breath controlled amusement ride work (2011), riders surrender agency to a digital system that monitors their breathing patterns and spins the ride they are sat on based on that breathing pattern. The players obviously have to breathe which creates a strange sensory experience as breathing does not usually make you also spin around.

Players of my digital vertigo experiences suggested that surrendering body agency, through standing on one leg or standing on the balance board in the case of *Balance Ninja*, allowed them to be more open to experiencing the sensory confusion induced through the digital technology: *"I think I was expecting to experience a loss of control. So I was opening up"* [P2, *Inner Disturbance*]. This feeling was, for some, quite powerful: *"<player 2> essentially threw me off and I stumbled - that was kind of powerful"* [P18, *Balance Ninja*].

Another player expressed that for them the *"best experience is, <when> you're trying to knock over the opponent but at the same time you have to be a bit cautious - it is a fun experience"* [P8, *Balance Ninja*]. This was also apparent in *AR Fighter*: *"so you are trying to mess up your buddy but you are trying to keep yourself in control, yeah that was fun!"* [P7, *AR Fighter*].

In addition to being "fun", it also appears that allowing players to experience a loss of bodily agency, and allowing them to regain it led to them questioning and appreciating their understanding of their own senses: *"I tried to feel my balancing senses somehow differently, and <use> different senses to experience, or to, compensate for the <game>, and this is very interesting"* [P2, *Inner Disturbance*].

Therefore, encouraging players to be open to surrendering body agency is one of the core challenges for designers to consider when creating their digital vertigo experiences, since if players are not able to surrender much agency, then the type of experience that designers create is limited.

With digital vertigo experiences, designers can ease players into surrendering bodily agency to encourage players to be open to the sensations they will experience when they trust the system.

Incorporating the surrendering of bodily agency into the design

It is possible to view this initial surrendering of body agency as a form of contract that the player makes with the game, where they agree that they are open to having their body agency reduced further. This is similar to riders stepping into the cart on a rollercoaster, whereby they are opening themselves up to the experience to come. When riding rollercoasters, riders do not have the opportunity to regain full body agency until the very end of the experience.

I designed each of my digital vertigo experiences to encourage players to surrender at least a small amount of body agency from the start. In two of the games players stand on one leg, surrendering some agency in the process. In *Balance Ninja* I facilitated the surrendering of body agency through having the players stand on a balance board, which for players who were not very good at remaining balanced for long periods, created an extra challenge (e.g.: *"I found balancing on the board quite hard anyway, but it's probably not my naturally good skill set"* [P18, *Balance Ninja*]. This action in itself leads to a surrendering of body agency as the players find it more difficult to remain standing still.

In digital vertigo play experiences designers also need to consider how to introduce players to the digital technology that will control the extent of facilitated sensory confusion (explained below). To this end I encourage designers to implement practice rounds into their games, which serve the dual purpose of 1) encouraging players to surrender body agency and be more open to the sensory confusion to come and 2) could act as a calibration stage for digital technology that requires it. Players were often apprehensive of the GVS systems, for instance, and in the case studies that made use of GVS, the calibration stage served the purpose of gently introducing players to the sensation and guiding them towards surrendering body agency. Often, after the players had experienced the GVS sensation for the first time and were affected by it, players were excited to surrender further body agency to the technology and the experience at hand.

In *AR Fighter* there was no need for an in-depth calibration stage, but the process of adjusting the headsets to make them fit securely and comfortably went someway to serving this purpose.

8.2.2 Extent of Facilitated Sensory Confusion

The extent of facilitated sensory confusion refers to the quantity of sensory confusion being induced in players as a result of the digital stimulation (in my games this was through the GVS and HMD systems). The higher the level of stimulation, the higher the sensory confusion being induced in players. When this is combined with reduced body agency, different types of vertigo experience may emerge.

The ability to control the extent of this facilitated sensory confusion is extremely important to ensure an enjoyable user experience. Digital vertigo experiences afford this opportunity extremely well since the digital technology allows for fine grained control over the experience through the use of stimulation technology to confuse the senses, or to sense how disorientated a player has become (if they have become unsteady, for example through the use of body tracking cameras).

In *Inner Disturbance*, the GVS stimulation oscillates from the left to the right, and through slowly increasing the GVS intensity players start to lean in the direction of stimulation. Therefore, players are no longer directly responsible for this bodily action, and experience a reduction in body agency. After a short time the stimulation switches sides. However, I also made sure that the intensity could not go too high, and thus, did not aim to induce an intense level of sensory confusion, in order to keep the game fun and enjoyable. This also facilitated the ability to allow players to regain a sense of body agency (and not be immediately pulled over by the stimulation). Essentially the sensation is strong enough to be affect players, but weak enough that people can fight it in an engaging way. In *Balance Ninja* and *AR Fighter*, the ability to regain agency and combat the sensory confusion led to some play rounds lasting longer as players became familiar with combating the sensory confusion. For instance in *AR Fighter*, some players chose to close their eyes in order to regain some bodily agency, whereas in *Balance Ninja* players tried to focus on something in the distance in order to distract from the GVS sensation.

The extent of facilitated sensory confusion is the second key factor (in addition to surrendered body agency) to consider when designing digital vertigo experiences, and key to the enjoyment of these experiences. As one player remarked, for example: *"being able to have my sense of spatial awareness and balance taken away from me so easily is what I enjoyed"* [P12, *AR Fighter*], suggesting how the ability to digitally induce sensory confusion led to an enjoyable loss of bodily agency.

8.3 Four Digital Vertigo User Experiences

I now revisit the framework to discuss four specific user experiences and associated risks related to the design of digital vertigo experiences. Each quadrant considers one type of user experience afforded by different amounts of facilitated sensory confusion vs. surrendered bodily agency within each of the four areas. I also discuss the risk that designers

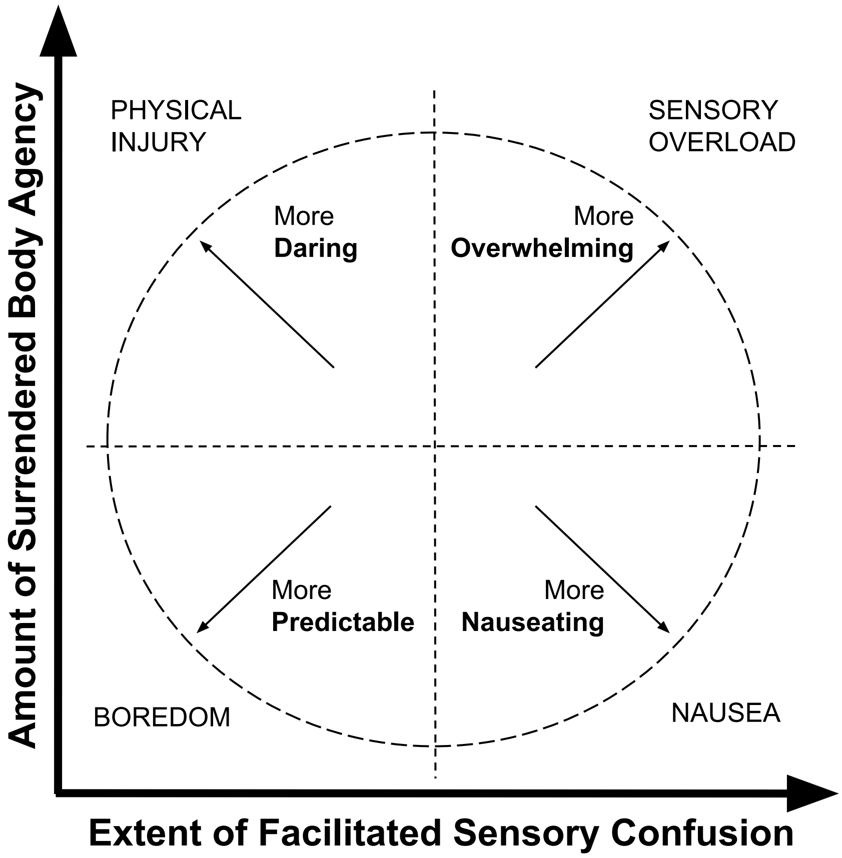

Fig. 8.2 The framework user experience spaces, and the recommended space for designers to remain within (dotted line), and the four possible risks to users if designers go outside of this space.

may face when designing within each user experience area.

Related HCI work, such as the Interaction in Motion Framework (Marshall, Dancu, & Mueller, 2016), and the Spectator Experience Framework (Reeves et al., 2005), have shown that extending the framework language in this way can be a useful method of denoting different types of user experience or design principles afforded to designers. I borrow from these works, and apply their understanding in extending the Digital Vertigo Experience Framework by considering the four areas and different type of experience that designers could create for players, based on the extent of sensory confusion and the extent of bodily agency the user is required to surrender.

Figure 8.2 illustrates these areas plotted onto the existing framework. The areas are: more daring, more comfortable, more overwhelming and more confusing. I explain each user experience area further below.

Further, for a true vertigo play experience, the combination of the surrendered body agency and the facilitated sensory confusion needs to result in a *voluptuous* experience, as per Caillois original definition (Caillois, 1961).

In vertigo play experiences designers need to balance the extent of facilitated sensory confusion with the reduction in player's body agency such that the experience is pleasurable and not too uncomfortable. For example, removing too much body agency could lead to players injuring themselves, or creating overwhelming sensory confusion could lead to players feeling nauseous. As discussed, it has been suggested that nausea can be reduced in VR games by allowing the player to maintain a level of agency over their movements within the game world (Sharples et al., 2008). This suggests that for digital vertigo experiences that as the amount of sensory confusion increases, and the longer it lasts, the greater amount of body agency should be returned to the player to avoid an unpleasant experience.

For example, in the popular activity of Zorbing, people experience intense sensory confusion for a momentary period of time whilst rolling down the hill. To recover, they exit the ball and rest until they regain their sense of body agency. This is similar to the vertigo activity of spinning in circles until you fall over - in order not to become sick the activity needs to be of limited duration, with a prescribed rest period to return body agency when sensory confusion becomes too great.

I see parallels between this voluptuous vertigo experience and flow theory (Csikszentmihalyi, 1991), in that there is an optimal space to keep players in to ensure they experience flow, or in my case, vertigo. With my work, I suggest that digital technology affords the opportunity to optimise the voluptuous vertigo experience to keep players in the optimal area of each user experience area. This can be achieved by either immediately altering the amount of facilitated sensory confusion, the amount of surrendered body agency, or both.

Designers need to carefully consider the trade-off between reducing a player's body agency and increasing sensory confusion, to avoid causing nausea. Additionally designers may also inadvertently create a "boring" vertigo experience through being overly cautious and also reducing sensory confusion. Games within the "predictable" area do have their place, but vertigo experiences require some risk to play (Caillois, 1961), and if there is no risk then the designer may not actually create a true digital vertigo experience.

Figure 8.2 illustrates the four "risk areas" (outside of the dotted circle), and the recommended voluptuous space (inside of the circle). I recommend designers avoid allowing players to venture too far into these risk areas, and encourage designers to detect if players approach these areas and to immediately alter the facilitated sensory confusion or alter agency to the player to move them out of these areas as soon as possible in order to keep them at an optimum experience level.

8.3.1 A question of time

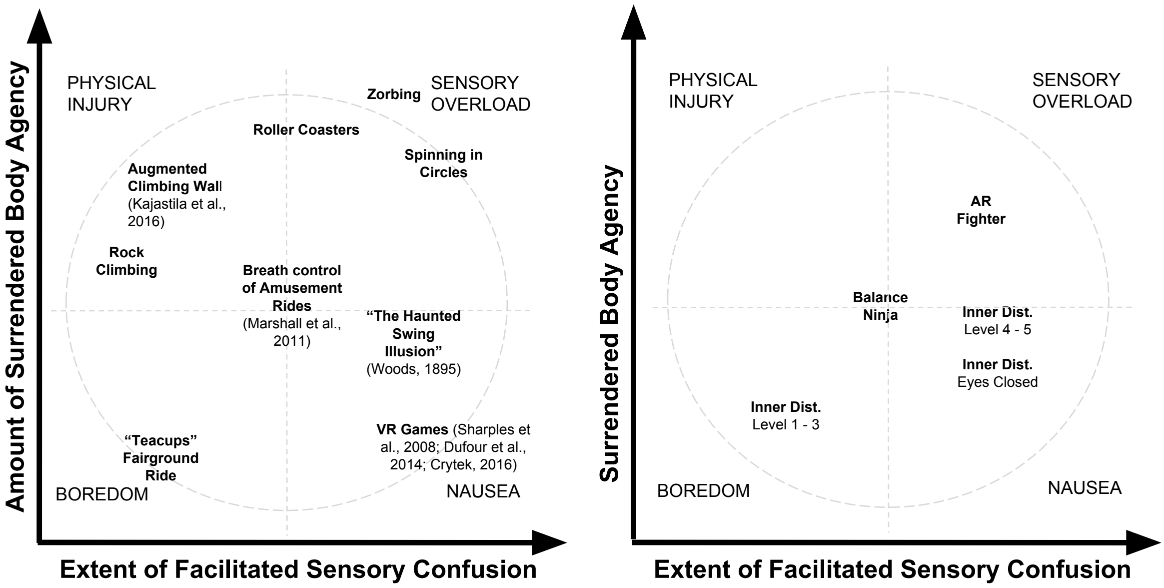

Fig. 8.3 An example of where within the design space relevant related work (left) and my vertigo experiences (right) would appear within the Digital Vertigo Experience Framework.

Not represented in the framework is the parameter of "time". Generally speaking, existing vertigo experiences can last for a long time (e.g. rock climbing) or can be extremely short (e.g. zorbing). Usually the difference with whether an experience should be lengthy or short is due to how great the extent of facilitated sensory confusion is, along with how much bodily agency has been surrendered.

For example, the related work plotted in figure 8.3 move within the design space over time, so are generally plotted where their intended outcome is likely to be. For instance Zorbing is designed to create intense sensory confusion and remove as much agency as possible, so appears in the top right of the graph.

With regards to the extent of facilitated sensory confusion, designers can choose to build this "extent" over time, as with Benford et al.'s trajectory examples (2008), or deliver a large amount of confusion (e.g. a high pull to the right from a GVS system) immediately. Further, digital vertigo experiences could move around this space throughout the duration of gameplay, allowing players to experience many different types of digital vertigo games, e.g. some may be short, some long and gradual, some full of moments of intense confusion and surrendered agency and then periods of little stimulation. I encourage designers to choose an area they wish their experience to mainly be in, and consider only moving into or through other areas as a matter of necessity (e.g. when introducing players to the game in the "predictable" area), or as infrequently as possible to avoid overwhelming the player.

In the next sections I describe each area in more detail.

8.3.2 More Daring, but Possibly a Risk of Physical Injury

Digital vertigo experiences in this area consist of those experiences that do not facilitate a large quantity of sensory confusion, but do require a large amount of body agency to be surrendered. For example, rock climbing for instance would fit within this area.

Designers can cater to players who want to experience what it is like to surrender a large extent of bodily agency.

In this area, players have surrendered a high degree of body agency. As such, they are at risk of losing bodily control and could fall or stumble in gravity based vertigo games, or crash in speed-based vertigo experiences. The end result is that players are at risk of physically injuring themselves. For the daring vertigo experience player the attraction to experiences within the "more daring" user experience area will be in part due to the reduced agency afforded by experiences within this space. To ensure an engaging experience, designers should detect when players are becoming dangerously out of bodily control and are at risk of injury, and can immediately return some agency to the player if the player requests it (some players may choose to take greater risks and not want the game to tell them when to stop playing). However, in the case that a player does have an accident then all stimulation should be immediately stopped. Further, designers would need to make clear the risk of playing digital vertigo experiences within this danger area.

8.3.3 More Predictable, but Possibly a Risk of Boredom

This area is for the novice or more apprehensive player. Designers could choose to start all of their experiences within this space to help ease players into the experience. By being able to predict what may happen within this areas players would become more open to surrendering body agency and perhaps experiencing greater sensory confusion. Therefore, designers could start and end games within this space, or program their games to return to this space if they notice players are getting too out of control or appear to be becoming distressed when playing.

The risk of designing within this area is that designers could end up creating a boring user experience (and are at risk of not creating a digital vertigo experience at all). If designers are too cautious in the designs then the players may not have the opportunity to enjoy the experience as they will either not be able to reduce agency, or very little facilitated sensory confusion.

8.3.4 More Overwhelming, but Possibly a Risk of Sensory Overload

Digital vertigo experiences in this area run the risk of being very intense for players. If a large extent of bodily agency is surrendered and a large extent of sensory confusion is facilitated in players at the same time then players could experience sensory overload, both physically and mentally. This is akin to when you spin around for too long on the spot and then try to walk in a straight line - your bodily senses are telling you that you are going one way but this is confused with your bodily actions of going another way.

Whereas this can be an extremely intriguing experience, it is one that designers should be careful of keeping their players experiencing for too long. For example, many people enjoy drinking alcohol to get to a state of intoxication, but if they drink too much their senses become overloaded. With digital vertigo experiences, designers can choose if they want to overwhelm their players, or try to detect when players get too close to this space, and reduce the facilitated sensory confusion to also allow them to regain more bodily agency. This could be fun for players who enjoy intense sensory confusion and want to repeatedly experience it.

This risk in this area is that it can lead to the most intense of all the digital vertigo experiences, since players could experience intense sensory confusion resulting in sensory overload. Staying too long in this area without helping the player transition back towards the "voluptuous" area could result in the player feeling extremely unwell and unable to carry on playing.

8.3.5 More Nauseating, but Possibly a risk of Nausea

Within this area players will be generally aware of their body agency, but start becoming confused due to the increasing sensory confusion. Most VR and HMD games sit within this space where player's proprioceptive and vestibular senses report that they are sitting at their desk and moving their head, but the game starts to trick their visual senses (such as the display going in the opposite direction to their head movement).

The risk in this area however is that of nausea as a result of experiencing intense sensory confusion. This is often what occurs when players experience motion-sickness when playing some VR games, since players know that they are not physically moving (i.e. they have body agency), but their visual senses conflict with this information (Sharples et al., 2008). Again, this is an undesirable area to remain in for too long since if players become nauseous they will obviously not want to continue playing for prolonged periods and may give up playing altogether.

8.4 Digital Opportunities in Vertigo Play Experiences

Designers can embrace the opportunities afforded to them in digital vertigo play experiences that are otherwise not available in non-digital vertigo experiences. I provide three example opportunities based on my experiences of developing the case studies. I describe them below as simple examples of opportunities designers could consider alongside using the Digital Vertigo Experience Framework in the creation of their own digital vertigo experiences.

8.4.1 Digital Opportunity 1: Make the sensory confusion public

The sensation of vertigo is a personal one that is felt internally. Although in extreme cases, this disorientation is visible externally through swaying when walking, or discolouration if severely nauseous, in vertigo experiences the sensation is usually private. If the GVS system of *Inner Disturbance* was bundled inside of a hat, for example, then spectators would not know why the player was not able to balance with ease. Reeves et al. (2005) would refer to this as a secretive experience. Alternatively designers could choose to create what Reeves et al. consider an expressive experience, through displaying the sensory confusion to others. For example, when building my early prototypes I programmed a LED to illuminate when the GVS stimulation was activated. I could easily have extended this functionality to a larger display, allowing the sensory confusion to be witnessed by the spectators who watched my participants playing *Balance Ninja*, or shown what each player was seeing in *AR Fighter* on a big screen outside of the play area. Designers could even combine GVS and HMDs to allow spectators wearing HMDs to observe an augmented reality view to the GVS stimulation being applied to the players in real time. These are opportunities that are only available in digital vertigo experiences, and designers can be imaginative in designing how they display the sensory confusion to spectators or even the current players.

8.4.2 Digital Opportunity 2: Create an automated sensory confusion feedback loop

Digital technology is able to not only induce levels of sensory confusion, but also at sensing and detecting body movement as a result of this confusion. In theme parks, ride operators observe the riders and have control over whether to speed up or slow down the ride based on how the riders are enjoying it. Technology has even been utilised to examine creating personalised ride experiences (Rennick-Egglestone et al., 2011). Digital vertigo experiences can also take advantage of the opportunities afforded by digital vertigo experiences.

For example, HMDs can affect an individual's sense of balance, causing them to sway, and this amount of sway can be monitored through technology such as a Kinect sensor. Designers could either choose to automatically reduce or increase the level of stimulation based on what the Kinect observes, creating a sensory confusion feedback loop. For example, if *AR Fighter* was setup in this way players could battle a mirror version of themselves - e.g. their sideways movement would be detected by the sensor which would in turn alter the visuals based on this information. If this was also combined with another stimulation technology like GVS, then designers could create games that combine both *AR Fighter* and *Inner Disturbance* gameplay mechanics.

Similarly, designers could choose to reduce the stimulation if the technology detects that the player is starting to loose too much body agency, and automatically detect the loosing condition of the player placing their raised foot back to the floor. Recent work has examined automatically calibrating digital stimulation systems (Knibbe, Strohmeier, Boring, & Hornbæk, 2017) and designers could extend these works to not only automatically calibrate digital vertigo experiences, but to adjust them based on a user's performance. Through inducing sensory confusion digitally in digital vertigo play experiences designers are afforded the opportunity to design varied play experiences into the same game.

8.4.3 Digital Opportunity 3: Share the sensory confusion across players

Using digital technology to control the sensory confusion affords digital vertigo experience designers the opportunity to explore novel vertigo game experiences where sensory confusion is shared across players, as I did in *Balance Ninja*. This is something I believe is only achievable with digital technology and could be expanded to create digital vertigo play experiences that involve more than two-players, such as a three-player game where the sensed movements of two players affect the movements and confuse the senses of the third player. Sensing and stimulating across players can be further explored, allowing players to re-experience previous game attempts, or even the attempts of another player through the stimulation technology replaying recorded sessions. This is similar to popular racing games who produce a “ghost" image of a previous race attempt to encourage players to beat their previous best time, or that of a friend. The experience does not even have to be localised and could be shared over a distance, as HCI work has shown this is possible with sporting activities (Mueller et al., 2003; Mueller, Stevens, Thorogood, O’Brien, & Wulf, 2007; Mueller, Vetere, Gibbs, Agamanolis, & Sheridan, 2010), and the CSCW matrix supports that networking is good at scaling to large numbers over both distance and time (Johansen, 1988). Therefore, players could even challenge their friends or others to a game of *Balance Ninja* or another digital vertigo experience even though they are not in the same geographical location.

8.5 Tactics for designing Digital Vertigo Experiences

Throughout this thesis I have presented four different case studies, each of which have examined the design of different types of digital vertigo experience. Each study uncovered recurring design themes and associated design tactics for the design of digital vertigo experiences based on the studies that preceded them. Below, and in table 8.1, I provide a summary of the tactics presented in this work grouped by their common principles. I provide these here as an overview of the common tactics designers can use when designing digital vertigo experiences, and encourage designers to read the more in-depth presentation of the tactics as specific to each of the case studies in the preceding chapters.

Group Name	**Inner Disturbance**	**Balance Ninja**	**AR Fighter**
Engaging vertigo	Alter a player's sense of bodily control to keep the experience from being too challenging or too boring through the level of stimulation applied	Design game environment to enforce the facilitation of sensory confusion	Discourage players from regaining bodily control through ignoring facilitated sensory confusion
Narrative acts	Incorporate the use of an unfamiliar interface to create sensory confusion into the gameplay	Use a narrative arc to prepare the players for the different vertigo sensations	Ease players into experiencing sensory confusion and surrendering bodily control
Limiting familiarity	Work with or against player exceptions of vertigo	Use vertigo interfaces unpredictably to avoid players becoming desensitised	Dynamically adjust sensory confusion based on a player's surrendered bodily control
Player ability		Support players of different abilities through altering the amount of removed bodily control, or the level of stimulation applied	Allow players to recover from repeated, or extreme periods, of facilitated sensory confusion, by regaining bodily control
Subtlety of stimulation		Design for the subtlety of the stimulation technology	

Table 8.1 A summary of the tactics from each of the digital vertigo experiences presented in case study 2-4.

8.5.1 Engaging Vertigo

Tactics grouped under this heading relate to creating an engaging digital vertigo experience. Players commented in the case studies how at times they were able to over-come the sensations they were experiencing and even cheat the game. These tactics provide examples that designers can use to help avoid that from happening in their own experiences. For instance in visual-based digital vertigo experiences (e.g. HMDs) designers can track whether players eyes are open or closed and penalise players if they close their eyes. Alternatively in GVS experiences designers need to design an aspect of the game to distract the player so they can not employ, for example, the strategy of concentrating on a point on the floor (reported in *Balance Ninja*).

8.5.2 Narrative Acts

Each of the vertigo experiences presented in my case studies followed a three stage process: 1) a calibration stage where the HMDs were fitted or the GVS systems attached and calibrated for each player, 2) the gameplay, and 3) removal of the systems and after-effects. These tactics provide designers with ideas of how to incorporate each of these stages such that it supports an engaging digital vertigo experience. For example, leaning on the work of Benford et al. (2012) who describe Freytag's narrative pyramid structure (Freytag, 1863) as a way of promoting an engaging gameplay experience, I encourage designers to see stage 1) as the rising action, 2) as the climax of the experience and 3) as the falling action.

Designers can use the calibration stage as a way of easing players into the experience, allowing them to gain trust in the stimulation system such that they are prepared to surrender bodily agency in the next stage of gameplay. Tutorials or easy "predictable" levels can also fit within this stage. Game designers could consider the after-effects stage as a way of creating a desired after effect (e.g. fatigue in players (Mueller, Toprak, et al., 2012a)), and design their digital vertigo experience to result in players feeling a certain way (e.g. did they feel as thought they had a "daring" or "overwhelming" experience?).

Moving through this narrative structure also provides designers with a method of understanding when to apply digital stimulation, and hence facilitate sensory confusion in players, and also when to remove or return bodily agency to players. Therefore designers of digital vertigo experiences can lean on these narrative stages as a way to structure their experiences.

8.5.3 Limiting Familiarity

An issue observed in *Inner Disturbance* was that players quickly became used to the repetitive nature of the stimulation being applied. The predictability of this pattern can be advantageous in early game rounds or tutorial stages but through prolonged gameplay sessions could lead to a “boring” experience. Designers could choose to start games in the predictable area in order to encourage players to open up to the experience to come, allowing them to understand how the sensory confusion will be administered and in turn encouraging them to surrender greater body agency. Similarly familiarity could be used to help players re-orientate themselves after a period of intense sensory confusion (e.g. after an experience situated in the “overwhelming” area). However, designers should try to facilitate sensory confusion at key points of the gameplay, or less predictably such that players do not get used to the experience through repeated play sessions. For example, in *Balance Ninja* and *AR Fighter* the predictability of the stimulation is limited as the sensory confusion is based entirely on the movements of an opposing player.

8.5.4 Player Ability

These two tactics detail how to support players of different physical abilities. As digital vertigo experiences affect the vestibular system a player’s adeptness at balancing is a factor in the experience they may have. Designers can choose to purposefully create a difficult experience if they desire, but should allow players the ability to assess the risk in playing, such that they do not injure themselves with playing.

When playing against an opponent, designers could choose to *balance* the game (Altimira, Billinghurst, & Mueller, 2013) such that the more experienced player is penalised in some way, and the less experienced player supported in order to allow the players to play with each other in an engaging way.

8.5.5 Subtlety of Stimulation

Designers are free to experiment with different types of digital technology to facilitate sensory confusion in players of their own digital vertigo experiences. In my experiences I used HMDs and GVS systems to achieve this. GVS was slightly problematic for some players of *Balance Ninja* who were unsure of if the system was affecting their opposing player. This was also referenced in *AR Fighter* that due to the disorientating nature and limited field of view it was sometimes difficult to locate the other player or see if they were affecting them.

Designers need to consider how to display feedback to the players (or spectators) what is happening with the systems. Some examples of achieving this are described earlier in section 8.4.1, and in the prior case studies. On the other hand, designers may wish to embrace the ambiguity afforded by sensory confusion systems like GVS so that players are surprised by what happens in the games. In these cases, consideration would also need to be given as to how to ease players into the experience such that they are open to surrendering body agency and do not fight the induced sensory confusion when they start to experience it.

8.6 Summary

In this chapter I presented my Digital Vertigo Experience Framework. The framework is the result of all four case studies described throughout this thesis. Through the knowledge gained from the iterative development of three different digital vertigo experiences, and the design workshop, I identified the core parts of the framework. Namely, for digital vertigo experiences, the relationship between the extent of facilitated sensory confusion vs. the amount of surrendered bodily agency of players is paramount to the different types of user experience that designers could create.

I have identified four types of user experience in total: more daring, more overwhelming, more comfortable, and more confusing. I have also highlighted that designers are free to move within these different user experiences and not stick just to one area. In fact, it is highly likely that through the duration of gameplay players will move, from one area to the next (such as from more comfortable at the start to one of the other areas as sensory confusion or surrendered body agency increases).

The framework also indicates four different risks that designers need to consider when developing digital vertigo experiences, and I have suggested designers to avoid designing games within these areas by keeping within a "voluptuous space". These four risk areas: risk of nausea, sensory overload, physical injury, and boredom occur at the extremes of each experience area and I suggest designers reduce facilitated sensory confusion or return body agency if the system detects players are in these risk areas for too long. The exception to this is "risk of boredom" which may occur if the game is too safe as a result of limited surrendering of bodily agency, and little facilitated sensory confusion. In this case I have suggested designers stay in this space only during tutorial stages or at the start and end of gameplay to ease players into the experience, or return them enough agency that their senses are not too overwhelmed after a long play session.

Finally I revisited the design tactics which are described in-depth throughout the case studies, providing a summary here to serve as a quick reference for designers.

In the next chapter I bring the thesis to a close, and describe ideas for future work.

Chapter 9

Conclusion

With this work I set out to answer the research question:

> *How do we design digital vertigo experiences?*

I have answered this question through the exploration of four case studies and the presentation of three digital vertigo experiences: *Inner Disturbance*, *Balance Ninja*, and *AR Fighter*. The associated studies allowed me to construct the Digital Vertigo Experience Framework, which designers can use to help guide their own design of digital vertigo experiences.

9.1 Research Objectives

In the introduction I presented four research objectives that would support my answering of my research question. Here I describe how I addressed these objectives:

9.1.1 Understand the role of vertigo in games, and its relationship to bodily interaction in HCI and play

I examined the relevant literature detailing current understandings of vertigo within the fields of HCI and bodily-play. I identified that vertigo was under-explored in the digital realm and that vertigo had even been considered to go beyond the boundaries of digital game design (Salen & Zimmerman, 2004, p.289), and I found that this was possibly due to the disorientating outcome of playing such games.

Interestingly, however, I found that there was already a body of work exploring digital games and play that had vertigo elements, such as digital rock climbing games. I also discovered work in the HCI realm that embraced uncomfortable interactions (Benford et al., 2012) and thrilling experiences (Marshall, Rowland, et al., 2011; Marshall, Walker, et al., 2011). Despite the work supporting the allure of vertigo in digital game design (Bateman, 2006) I identified that an understanding of how to design digital vertigo games was missing. This led me to also investigate possible ways of creating vertigo experiences digitally. I found interesting work related to electrical stimulation of the vestibular system in the form of Galvanic Vestibular Stimulation. I also identified that Head Mounted Displays offered a unique way of affecting a player's visual senses. Both of these senses, I had discovered, were key to place into conflict in order to achieve vertigo sensations.

Through gaining an understanding of the related work, and relevant technologies I was able to develop my research method and begin designing my case studies to answer my core research question.

9.1.2 Explore the design space of digital vertigo games

I achieved this objective through the exploration of four case studies: one initial design workshop and three novel digital vertigo experiences. Each stage allowed me to iterate on the previous and allowed me to create my Digital Vertigo Experience Framework.

Case study 1 helped me to identify that GVS did affect a player's vestibular system in an intriguing way, and this led me to use it in case study 2. Case study 2 presented the game *Inner Disturbance* - a single player digital vertigo game where a player battles against their own sense of balance, and also the repetitive stimulation from a GVS system. A user study with 10 participants contributed to the development of the framework by suggesting two possible risk areas for digital vertigo experiences: boring and nausea. Boring games could be the result of little stimulation and little loss of bodily control. Nausea could result from the player maintaining bodily control, but experiencing a high level of sensory confusion that they cannot make sense of.

The findings of case study 1 and 2 allowed me to develop *Balance Ninja*. In this two-player game each player controlled the other's GVS system through their own body movements. The game built on the findings of the prior studies, such as the players easily getting used to the repetitive stimulation of *Inner Disturbance*, and finding it too easy to stay balanced. *Balance Ninja* required players to stand on balance boards which immediately reduced a player's sense of bodily control over their balance, and the sensory confusion was unpredictable due to the other player's movements.

Finally I created *AR Fighter*. This two-player game used HMDs instead of GVS as the method of inducing sensory confusion in players. I used a HMD as I wanted to explore what would happen to the framework if a different stimulation technology was used.

9.1.3 Create a theoretical design framework concerning digital vertigo experiences

Through the investigation of my case studies I developed the Digital Vertigo Experience Framework. This framework is the first of its kind and articulates how to design digital vertigo experiences. The framework, along with the design tactics presented in this thesis, is designed to be used by designers of HCI and body-based games in order to design digital vertigo experiences.

9.2 Contributions

With my work I make the following contributions:

1. This research contributes to design knowledge by providing details on the implementation of, and insights gained from, the design and evaluation of three digital vertigo play experiences. The case studies and game prototypes demonstrate how digital games can be created and designed with vertigo in mind.

2. This research contributes to design knowledge through the provision of a conceptual understanding of the role vertigo can provide in body-based games and related HCI experiences.

3. The research presents the Digital Vertigo Experience Framework. It is the first theoretical conceptualisation of how to design vertigo experiences from a digital perspective, and along with practical examples and design tactics guides designers in developing their own novel digital vertigo play experiences. The framework was derived through the findings of the four case studies. Each case study consists of recurring design themes, as uncovered from the qualitative analysis of the user experience of playing the games. These insights and quotes provided a high level understanding of the experience of playing each of the digital vertigo experiences. These themes informed the design tactics, also present in each case study, which serve as practical examples for designers to develop digital vertigo experiences and facilitate the desired user experience as explained in the themes.

9.3 Limitations

Each game designed in case study 2-4 were only studied once, and participants only played each game once. This could mean that repeated plays would affect some of the results such as players already knowing what to expect on a second play-through. In future work I am planning to encourage players to use the games more than once. For instance, how would the framework look when players play the same game 20 times, as supposed to once? Would the stimulation need to be continually altered, or do players want the same experience?

Each system was only studied with a small number of players. Additionally it is possible that some of the players were not interested in vertigo type experiences in the first place, and therefore in future work I would like to recruit players who identify as "thrill seekers", such as those people who enjoy theme park rides, and also players who do not identify as such in order to compare the difference in the experience of playing the games.

During each play session the players were aware that researchers were watching and recording the sessions. This may have affected how they interacted with the experiences. It would be interesting to distribute the experiences and allow the players to play them in their own setting or outside of a lab environment (Mottelson & Hornbæk, 2017), to see how the findings or reported experience of playing the games would differ.

9.4 Future Work

Due to the scope of this thesis my studies were focused in order to help answer my core research question. The exploration of this work did present me with ideas for future work, and I discuss here some potential topics for future investigations.

9.4.1 Combine different stimulation methods

In this work I explored GVS and HMDs as the main ways of facilitating sensory confusion in players. However, I never combined them to see what an experience would be like for a player wearing both a HMD and a GVS system. My work identified that to overcome the GVS sensation players could focus their vision on a point in the distance, and that closing their eyes when wearing a HMD allowed them to take a break from the visually induced sensory confusion. It would be very interesting to combine both stimulation methods such that closing one's eyes when wearing a HMD and GVS system would result in the

GVS sensation becoming too extreme, or trying to focus on a point in the distance would be interrupted by some on screen event. Additionally it would be of interest to explore and identify other digital technologies that could be used to facilitate sensory confusion in players.

9.4.2 Identify different ways of inducing sensory confusion

GVS and HMDs are only two ways of inducing sensory confusion in players, and as future work I would plan to look at other existing ways of creating non-digital vertigo games, and seeing how I could adapt them to the digital realm.

9.4.3 Validate the Digital Vertigo Experience Framework

I presented my Digital Vertigo Experience Framework as the core outcome of this thesis, and therefore the next logical step would be to validate the framework. I plan to validate the framework's utility in practice through a design workshop, where designers of body-based games will be presented with the framework and tasked with creating a digital vertigo experience. The outcome of the workshop could be used to validate the framework.

9.5 Final Remarks

Vertigo games are fun to play. They challenge the body in ways that allow the player to experience feelings and sensations that are uncanny and exciting. As children we often enjoy the discovery of these exciting experiences, and as adults we look to thrilling and evermore exotic methods to achieve the same feelings, such as going to theme parks. Yet with digital technology, we have the opportunity to create exciting and thrilling digital vertigo experiences at home, without the need for expensive ride infrastructure.

As someone who enjoys the pursuit of vertigo, understanding how to translate the design of such experiences to the digital realm was the biggest challenge of this work. However, with the design tactics and Digital Vertigo Experience Framework I expand our understanding of designing digital vertigo experiences, and in doing so help to expand the range of exciting body-based games we play.

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