Inner Disturbance: Towards Understanding the Design of Vertigo Games through a Novel Balancing Game

Richard Byrne
Exertion Games Lab
RMIT University
Melbourne, Australia
rich@exertiongameslab.org

Joe Marshall
School of Computer Science
University of Nottingham
Nottingham, UK
joe.marshall@nottingham.ac.uk

Florian 'Floyd' Mueller
Exertion Games Lab
RMIT University
Melbourne, Australia
floyd@exertiongameslab.org

ABSTRACT
The design space of vertigo games is under-explored, despite vertigo underlying many unique body based game experiences, such as rock climbing and dancing. In this paper we articulate the design and evaluation of a novel vertigo experience, Inner Disturbance, which uses Galvanic Vestibular Stimulation to affect the player's balance. Following study observations and a thematic analysis of Inner Disturbance (N=10), we present four themes and associated design sensitivities that can be used to aid designers of future digital vertigo games. With this work we aim to encourage others to experiment within this exciting new design space for digital games.

Author Keywords
Vertigo; play; games; galvanic vestibular stimulation; balance.

ACM Classification Keywords
H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

INTRODUCTION
Vertigo has been described by play theorist Caillois as one of the four main categories of games and play (Caillois, 1961). Whilst intuitively it may seem that games should avoid sensations of vertigo in their design, such sensations can be the basis for a wide variety of popular non-digital activities and sports such as rock-climbing, spinning in circles, skiing, and dancing. Caillois describes these activities as games which 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). Psychologists have considered that the main attraction in participating in these activities is "the pursuit of vertigo" (Alderman, 1974; Kenyon, 1968).

Vertigo is somewhat underexplored when it comes to digital game design, despite the body playing an increasingly integral part of many digital game experiences. Exertion games (Nijhar et al., 2012; Mueller et al., 2011), for example, increasingly emphasise the role of the body in their design, often focusing on sports such as climbing (Kajastila et al., 2016) to create exciting player experiences. We believe that vertigo can be a positive aspect of digital games, and that digital technology offers novel opportunities to facilitate unique and engaging vertigo play experiences not previously possible.

Little has been written concerning the design of digital games of vertigo; some designers consider it to be an unwanted effect of gameplay, similar to Virtual Reality (VR) simulator sickness (Sharples et al., 2008), but we believe that due to the focus on the body in digital games, now is a good time to explore vertigo in digital games.

We first discuss related work, before detailing the development of a novel single-player vertigo game called *Inner Disturbance*. We follow with a description of a user study with ten. Exploring player's experience with the game allows us to investigate our research question of: *"how do we design vertigo games?"* With this work we make the following contributions:

- A proof of concept design of a novel vertigo game system.
- Four themes derived from the analysis of the *Inner Disturbance* player experience and three design sensitivities for designers of digital vertigo games.

BACKGROUND
Little has been written about the vertigo of digital games, with some designers considering that Caillois' definition "falls outside the boundaries of games" and goes "beyond a description of games" (Salen et al., 2004). However, Bateman (2006) argues that vertigo can heighten the player's enjoyment within digital games and since then designers have developed games that could facilitate vertigo experiences. Hämäläinen et al. (2015), for example, collate several body-based games involving apparatus such as trampolines and gymnastics rings that could create a feeling of vertigo in players. Early VR experiments discovered that people were able to experience vertigo within the VR space (Meehan et al., 2002) and consequently, designers have also considered using VR to create entertaining vertigo experiences. For example, *Haptic Turk* (Cheng et al., 2014) requires a group of players to physically move another player whilst he/she "flies" through a VR world possibly facilitating sensations of vertigo. Similarly, designers have created immersive tightrope experiences where players are challenged to walk over simulated drops between two buildings (Inition, 2014; Sony Pictures Home Entertainment, 2016).

OzCHI '16, November 29 – December 2 2016, Launceston, TAS, Australia

http://dx.doi.org/xx.xxxx/xxxxxxx.xxxxxxx.

Game designers have also created rock climbing games set within VR worlds (Crytek, 2016; Dufour et al., 2014). These works could exploit a fear of heights – acrophobia – as one way of creating a vertigo experience, using feelings of vertigo as an uncomfortable interaction method (Benford et al., 2012). Vertigo is also induced through sensory confusion caused by moving players through the use of specialised machines such as rollercoasters and amusement park rides (Eidenberger et al., 2015; Marshall, Rowland, et al., 2011).

We previously explored how to design for digital vertigo games (Byrne et al., 2016) in a design workshop process. In this paper we describe we build on this prior work with a description of an initial body based game study, aiming to provide game designers with an understanding of how to design digital vertigo games.

Galvanic Vestibular Stimulation (GVS)
Our game, *Inner Disturbance,* uses GVS to facilitate vertigo sensations in our players. GVS is a safe and simple way of eliciting vestibular reflexes (Fitzpatrick et al., 2004), used commonly in physiology and psychology (Utz et al., 2010). Electrodes connected to the mastoid bones behind the ears deliver a current usually between 1 and 2.5mA. The resulting effect on players is that they feel a *pull* or *sway* in the direction of the positive electrode, and player's balance is affected in that direction.

GVS has been used for entertainment and training purposes, such as: allowing astronauts to experience post-flight effects during training (Moore et al., 2011), allowing one player to remotely control the walking direction of another (Maeda et al., 2005), enhancing the immersion within a VR game (Maeda, Ando & Sugimoto, 2005), and finally, affecting one's balance in time to the rhythm of music (Nagaya et al., 2006). We find GVS to be widely versatile. Not only can a GVS system be made from simple components, but the systems also afford fine range of control over the level of stimulation, and can be digitally controlled. This versatility lends GVS systems to being simple to connect with other sensing and game design elements.

INNER DISTURBANCE
In *Inner Disturbance* players are attached to a GVS system and asked to try and remain balanced on one leg for a total of five rounds. Each round lasts for 30 seconds, during which time a GVS stimulation is applied in a pre-programmed pattern. The stimulation is first applied to the left mastoid bone, then the right mastoid bone, and continues to oscillate back and forth for the remainder of the round. The maximum intensity of the applied stimulation is increased each round, making the game become progressively more difficult as the player advances, and the absolute maximum intensity is derived during a calibration stage (described further below).

When the game starts, music is played to signify that the stimulation is applied. We did not deliberately choose music that had a rhythm matching the oscillating GVS pattern, but simply to serve the duel purpose of 1) making the game more engaging and 2) to symbolise that the system was running and that the GVS system was active,

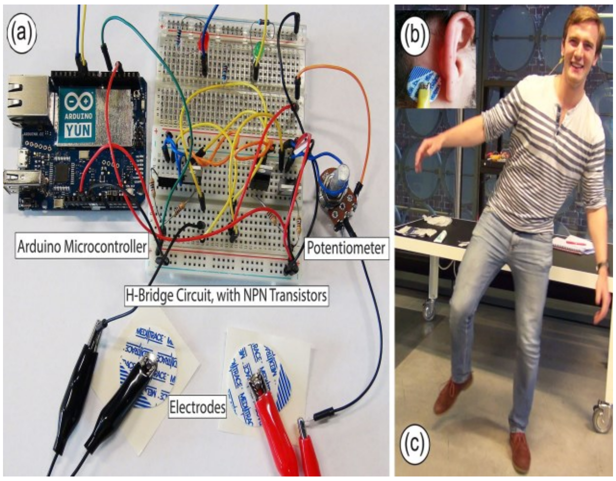

Figure 1. (a) GVS circuit used in the study; (b) electrode placement behind player's ears; (c) a player smiles as he feels his balance being affected.

as the sensation can be quite subtle at first. Players lost a round if they placed their raised foot back on the floor. Regardless of winning or losing, players were allowed a one-minute break before attempting the next round.

GVS Prototype
The GVS circuit (see figure 1a) is powered by a standard 9V battery and consists of an H-bridge built from four NPN transistors that switch positive current between electrodes. A 5K potentiometer allows for fine-tuning the effect felt by participants, which we explain further below. An Arduino Yún Microcontroller (powered by a separate 5V battery pack) digitally and wirelessly controls the GVS system. Two wires, each 2 meters long, complete the circuit, with one end attached to the GVS system and the other to the electrodes via easily detachable crocodile clips (see Figure 1b).

Safety Considerations
We designed our GVS prototype to be as safe as possible for our participants. Although the circuit is very simple, we 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. We chose this value since related work has shown good GVS performance between 1mA – 2.5mA (Fitzpatrick et al., 1999; Nagaya et al., 2005) and comfortable stimulation below 5mA (Curthoys et al., 2012).
- We ensured there was plenty of space either side of our participants to allow them to step sideways when losing their balance. When using our system participants do not fall forward or backwards since there is no stimulation in that direction.
- We did not use crash mats since we thought this could cause the participants to stumble. We observed in our own tests that simply placing the raised foot back on solid ground was enough to regain balance and overcome the effect.
- The game was started and stopped from the main researchers laptop, (although participants could disconnect from the system at anytime by detaching

the electrodes). The researcher also had a stop button that could immediately end the stimulation.

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

STUDY PROCEDURE

Due to players having different levels of skin impedance, it was necessary to first calibrate the GVS system for individual players (since a high stimulation for one player may be a weak stimulation for another). To calibrate we attached the electrodes to the mastoid bones of each participant (see figure 1b**)** with the GVS system turned off. Participants were then asked to stand on one leg and, gradually, the level of stimulation was increased by slowly turning the potentiometer until either the participant lost their balance, or they felt the GVS sensation. This level became the player's maximum level of stimulation that would be applied in round 5, in each of the other rounds (1-4) a percentage of this maximum was applied from 20% - 80% respectively.

The game started with round 1. During round 1 the stimulation increases from zero to 20% of the maximum stimulation over 5 seconds. Stimulation then switches to the right hand side, again increasing from zero to 20% of the maximum over 5 seconds, before repeating the pattern. The entire round lasts for 30 seconds, oscillating 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 1 minute break, participants moved onto round two (40% of maximum) and so on until round five (100%).

Other than raising one leg, we did not enforce any other rules about how to play the game. We 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.

We recruited 10 post-graduate participants (two female) through university mailing list and word of mouth. 7 were in the 25-35 age group, 3 were 40+. We checked that participants were comfortable standing on one leg for 30 seconds as a minimal level of balancing ability for safety.

Ethics Approval

We obtained ethics approval prior to running our study and precautions were taken to ensure safety to the participants as described earlier. Before taking part in the study each participant was thoroughly briefed and asked to provide informed consent. As the play and study sessions occurred during the day first aid personnel were also available.

Data Collection

Audio and video recordings for analysis were taken throughout the study with participants' consent. An hour and a half of audio was collected from interviews. Following each play session (typically no longer than 6 minutes), participants took part in a semi-structured interview about their experience of playing *Inner Disturbance*. Interviews lasted 10 minutes on average.

Data Analysis

To analyse the data we employed an inductive thematic analysis approach (Braun et al., 2006). Transcripts of the audio interviews were read and coded independently by two different researchers. Once each researcher 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. We described these themes briefly below:

Feelings of vertigo and engagement with the system (76 units), 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*". They also described brief after effects: "*a little hangover, because you lose the kind of fixed ground, then I was a little shaky"*. They also considered the best bit of the game was "*this invisible new sensation"* which also *"made me feel alive and good!*"

Players used a variety of **Challenge and play strategies (86 units)**: explaining that "*this challenge to stand on one leg also added a mastery,*" which lead to "*the desire to, <and motivation> to win";* Players used different strategies to achieve this: "Y*ou start using everything you can, flexing, breathing, fixing sight, are strategies if you want, so it gets easier*"; "*I challenged myself by closing my eyes and trying to balance … there were times when I was just shutting my eyes and letting it swing me around*"; "*I focused on dancing <to the game music> as it distracted me from focusing on the sensation."*

Participants often used a range of **stories and analogies (22 units)** to describe their experience, such as tightrope walking: *"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"*. A common theme was also feelings of drunkenness "*It reminded me of when you have too much to drink and you hit that point where your body is starting to compensate*"; *"With my eyes closed <it was> extremely difficult. I think worse than being drunk!*" Participants also suggested future applications such as: "*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*".

Finally, participants also reported **variations in level of control during the experience** (**45 units**), particularly in the harder levels: *"Maybe you can explore this game as a submission under physical forces*"; *"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"*; *"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.*"

DISCUSSION: DESIGN SENSITIVITIES FOR THE DESIGN OF DIGITAL VERTIGO GAMES

Here we articulate three design sensitivities (Jensen et al., 2014) that are informed from participant feedback and the recurring themes outlined above. These sensitivities are to assist designers of future digital vertigo games.

Design for the Loss of Bodily Control in order to Allow Autonomy or Purposefully Create Anticipation

In *Inner Disturbance*, the GVS system is pre-programmed and repeats each round, albeit at a higher level of stimulation. Participants have an opportunity to learn the stimulation pattern as a result of playing the game, in consequence becoming able to anticipate a) which side they will lean towards and b) when the lean will occur. There are no other cues that would indicate when the stimulation would be applied, and designers could alter this by either allowing the computer to randomly apply different stimulation patterns or alter how the stimulation is controlled. An alternative approach, for example, could be similar to the one applied in the work of Marshall et al. (Marshall, 2011). In this work a mechanical "Bucking Bronco" is controlled by a player's own breathing rate. Designers of digital vertigo games could also use a similar technique to control the stimulation in their games, allowing players to be fully aware of when the stimulation would be applied, and adjust their breathing rate accordingly. Each type of control has advantages and disadvantages; for example, completely removing a player's autonomy increases anticipation of when the stimulation will be applied, but could also increases the game's level of difficulty. On the other hand allowing a player to be in control of the game completely may make the game too easy. Designers should therefore experiment with how they want to facilitate players' loss of control.

Design for the Anticipation Created by the Stimulation Method

Several participants were initially apprehensive of playing *Inner Disturbance*, having never used any form of stimulation devices before. However, all participants enjoyed the game and suggested they would play it again, often being surprised with how they felt whilst playing. Designers can either choose to embrace this apprehension, allowing a level of suspense in playing the game, or gently ease players into the experience. Marshall et al. (Marshall et al., 2011) embrace the discomfort of their breath sensing system which is incorporated into a gas mask, for example, as a method of creating "fearsome" interactions. With games that require a form of stimulation, designers can 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. We 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. We encourage designers to consider the level of suspense they wish to place around the stimulation method.

Design Surprising Interactions to Challenge Players' Vertigo Expectations

Our participants freely offered analogies of real life experiences that they were reminded of when playing the game, or even offered suggestions for future vertigo game designs. 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, or even dancing. Designers could play with this notion of familiarity by creating vertigo games based on popular experiences. However, designers could challenge player expectations of these experiences by exploiting the *unknown*. Using extra stimulation or suddenly changing the environment could enhance the vertigo experience by surprising players. 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 that has not been there previously. Such techniques would stop the experience from being predictable, and prevent players from becoming used to the game. We suggest designers deliberately consider challenging players' vertigo expectations.

LIMITATIONS AND FUTURE WORK

In this work our vertigo game was controlled through one main method of stimulation (GVS). Future iterations of the work could aim to explore different methods of altering player perception and inducing sensory confusion, for example, through VR, or mechanically moving players. Building different games with different methods of integrating vertigo is of interest to us in future work, and we are currently exploring these approaches in order to articulate a digital vertigo game design space.

CONCLUSION

With this work we have introduced a novel vertigo game, based on GVS called *Inner Disturbance*, which allowed players to challenge their own sense of balance. We derived four recurring themes from a thematic analysis of a study with 10 participants, and in turn articulated three design sensitivities for designers of digital vertigo games. With this work we suggest possible ways forward, and challenge designers to explore vertigo in their own game designs in order to create engaging and novel user experiences that embrace feeling of vertigo.

ACKNOWLEDGMENTS

We would like to thank our participants. We also thank our reviewers for their useful and helpful feedback. Joe Marshall thanks the Leverhulme Trust (ECF/2012-677), and Florian 'Floyd' Mueller the Australian Research Council (DP110101304&LP130100743).

REFERENCES

Alderman, R.B., 1974. *Psychological Behavior in Sport*, Saunders.

Bateman, C., 2006. The Joy of Ilinx. *Only a Game*. Available at:

http://onlyagame.typepad.com/only_a_game/2006/05/the_joy_of_ilin.html [Accessed December 30, 2015].

Benford, S., Greenhalgh, C., Giannachi, G., Walker, B., Marshall, J. & Rodden, T., 2012. Uncomfortable interactions. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, pp.2005–2014.

Braun, V. & Clarke, V., 2006. Using thematic analysis in psychology. *Qualitative research in psychology*, 3(2), pp.77–101.

Byrne, R., Marshall, J. & Mueller, F. “Floyd,” 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*. Eindhoven, Netherlands: ACM, pp. 296–303. Available at: http://10.1145/2839462.2839465.

Caillois, R., 1961. *Man, play, and games*, University of Illinois Press.

Cheng, L.-P., Lühne, P., Lopes, P., Sterz, C. & Baudisch, P., 2014. Haptic Turk: A Motion Platform Based on People. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. Toronto, Ontario, Canada: ACM, pp. 3463–3472.

Crytek, 2016. The Climb. Available at: http://www.theclimbgame.com/.

Curthoys, I.S. & MacDougall, H.G., 2012. What galvanic vestibular stimulation actually activates. *Frontiers in neurology*, 3.

Dufour, T., Pellarrey, V., Chagnon, P., Majdoubi, A., Torregrossa, T., Nachbaur, V., Li, C., Ibarra Cortes, R., Clermont, J. & Dumas, F., 2014. ASCENT: A First Person Mountain Climbing Game on the Oculus Rift. *Proceedings of the First ACM SIGCHI Annual Symposium on Computer-human Interaction in Play*, pp.335–338.

Eidenberger, H. & Mossel, A., 2015. Indoor Skydiving in Immersive Virtual Reality with Embedded Storytelling. *Proceedings of the 21st ACM Symposium on Virtual Reality Software and Technology*, pp.9–12.

Fitzpatrick, R.C. & Day, B.L., 2004. Probing the human vestibular system with galvanic stimulation. *Journal of Applied Physiology*, 96(6), pp.2301–2316.

Fitzpatrick, R.C., Wardman, D.L. & Taylor, J.L., 1999. Effects of galvanic vestibular stimulation during human walking. *The Journal of Physiology*, 517(3), pp.931–939.

Hämäläinen, P., Marshall, J., Kajastila, R., Byrne, R. & Mueller, F., 2015. Utilizing Gravity in Movement-Based Games and Play. In *Proceedings of the 2015 Annual Symposium on Computer-Human Interaction in Play*. London, United Kingdom: ACM, pp. 67–77.

Inition, 2014. Future of 3D #5: Oculus Rift Vertigo Experience. Available at: http://www.inition.co.uk/case_study/future-3d-5-oculus-rift-virtual-reality-experience/ [Accessed April 1, 2016].

Jensen, M.M., Rasmussen, M.K. & Grønb\aek, K., 2014. Design sensitivities for interactive sport-training games. *Proceedings of the 2014 conference on Designing interactive systems*, pp.685–694.

Kajastila, R., Holsti, L. & Hämäläinen, P., 2016. The Augmented Climbing Wall: High-Exertion Proximity Interaction on a Wall-Sized Interactive Surface. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*. CHI ’16. New York, NY, USA: ACM, pp. 758–769. Available at: http://doi.acm.org/10.1145/2858036.2858450.

Kenyon, G.S., 1968. A conceptual model for characterizing physical activity. *Research Quarterly. American Association for Health, Physical Education and Recreation*, 39(1), pp.96–105.

Maeda, T., Ando, H., Amemiya, T., Nagaya, N., Sugimoto, M. & Inami, M., 2005. Shaking the World: Galvanic Vestibular Stimulation As a Novel Sensation Interface. *ACM SIGGRAPH 2005 Emerging Technologies*.

Maeda, T., Ando, H. & Sugimoto, M., 2005. Virtual acceleration with galvanic vestibular stimulation in a virtual reality environment. *Virtual Reality, 2005. Proceedings. VR 2005. IEEE*, pp.289–290.

Marshall, J., Rowland, D., Rennick Egglestone, S., Benford, S., Walker, B. & McAuley, D., 2011. Breath control of amusement rides. *Proceedings of the SIGCHI conference on Human Factors in computing systems*, pp.73–82.

Marshall, J., Walker, B., Benford, S., Tomlinson, G., Rennick Egglestone, S., Reeves, S., Brundell, P., Tennent, P., Cranwell, J., Harter, P. & Longhurst, J., 2011. The Gas Mask: A Probe for Exploring Fearsome Interactions. In *CHI ’11 Extended Abstracts on Human Factors in Computing Systems*. Vancouver, BC, Canada: ACM, pp. 127–136.

Meehan, M., Insko, B., Whitton, M. & Brooks Jr, F.P., 2002. Physiological measures of presence in stressful virtual environments. *ACM Transactions on Graphics (TOG)*, 21(3), pp.645–652.

Moore, S.T., Dilda, V. & MacDougall, H.G., 2011. Galvanic vestibular stimulation as an analogue of spatial disorientation after spaceflight. *Aviation, space, and environmental medicine*, 82(5), pp.535–542.

Mueller, F., Edge, D., Vetere, F., Gibbs, M.R., Agamanolis, S., Bongers, B. & Sheridan, J.G., 2011. Designing Sports: A Framework for Exertion Games. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, pp.2651–

2660. Available at: http://10.1145/1978942.1979330.

Nagaya, N., Sugimoto, M., Nii, H., Kitazaki, M. & Inami, M., 2005. Visual Perception Modulated by Galvanic Vestibular Stimulation. *Proceedings of the 2005 International Conference on Augmented Tele-existence*, pp.78–84. Available at: http://10.1145/1152399.1152415.

Nagaya, N., Yoshidzumi, M., Sugimoto, M., Nii, H., Maeda, T., Kitazaki, M. & Inami, M., 2006. Gravity jockey: a novel music experience with galvanic vestibular stimulation. *Proceedings of the 2006 ACM SIGCHI international conference on Advances in computer entertainment technology*, p.41.

Nijhar, J., Bianchi-Berthouze, N. & Boguslawski, G., 2012. Does Movement Recognition Precision Affect the Player Experience in Exertion Games? *Intelligent Technologies for Interactive Entertainment*, 78, pp.73–82.

Salen, K. & Zimmerman, E., 2004. *Rules of play: Game design fundamentals*, MIT press.

Sharples, S., Cobb, S., Moody, A. & Wilson, J.R., 2008. Virtual reality induced symptoms and effects (VRISE): Comparison of head mounted display (HMD), desktop and projection display systems. *Displays*, 29(2), pp.58–69.

Sony Pictures Home Entertainment, 2016. The Walk VR. Available at: https://www.wearvr.com/apps/the-walk-vr [Accessed June 30, 2016].

Utz, K.S., Dimova, V., Oppenländer, K. & Kerkhoff, G., 2010. Electrified minds: Transcranial direct current stimulation (tDCS) and Galvanic Vestibular Stimulation (GVS) as methods of non-invasive brain stimulation in neuropsychology--A review of current data and future implications. *Neuropsychologia*, 48(10), pp.2789–2810.