

Evaluating Social and Cognitive Effects of Video Games using Electroencephalography

by

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### ***Abstract***

*Games User Research* (GUR) is an area of evaluative player research and human-computer interaction (HCI) that aims to improve games, focused on a player's understanding and on their experience when playing games. In this field, techniques are available to measure and understand user experience. These techniques each have their own strengths and weaknesses. To improve and extend GUR methodology, this thesis explores ways that electroencephalography (EEG) can be used as an evaluative measure as part of a mixed methodology. The thesis aims to improve the accuracy and richness of GUR results obtained using EEG. *Hemispheric Frontal Alpha Asymmetry* (HFAA) is reviewed in depth as a useful EEG technique to measure arousal in real time. HFAA, the EEG methodology proposed in this thesis is used in several experimental studies reported here to show new insights into the social and cognitive factors of gaming. The research presented in this thesis shows that player experience related to the social environment of a game does not necessarily arise from gameplay, but instead relies more on the expectations of a player than the current literature suggests. Additionally, the thesis introduces a new way to investigate player understanding and learning in games, using real-time data about the player's brain state. This is particularly useful for game designers creating introductory tutorial mechanisms for their games. The result of this research is useful for both researchers investigating the human brain immersed in the virtual world of a video game and game designers wanting to use real-time user feedback to build their games.

## ***Chapter 1: Introduction***

The Entertainment Software Association of Canada 2013 Report<sup>1</sup> states that there are 329 video game companies in Canada employing approximately 16,500 people and contributing \$2.3 billion to Canada's Gross Domestic Product (GDP). The report also states that 58% of Canadians are gamers. The gender distribution of gamers is almost even with 46% female and 54% male gamers (*2013 Essential Facts about the Canadian Video Game Industry*, 2013; Entertainment Software Association of Canada, 2012). The products and systems coming from the video game industry have an impact on many Canadians today.

Video games are applications, or more generally a computer *system*. Like all computer systems, video games rely on conveying information between the computer and *user* or the person using the system. Human computer interaction (HCI) focuses on this communication between the computer and the human user. A user has expectations of a system and the system has a set of functions it can perform, which together create the system's functionality. The overall system's functionality is described by the term *useful*. The system's built-in functionality can only meet those expectations if the system is usable. The term *usable* denotes that the system must be designed in a way that promotes its use by making the functionality accessible to the user. This may encompass having a system, which can be easily navigated, is clear, consistent and helps prevent errors, or any other specifications that contribute to the ease of use. Useful and usable are not interchangeable terms. A system can be useful yet not usable. In this sense, systems may be necessary for the job being completed but require the user to exert effort to access the functionality. On the contrary, a system can also be usable but not useful. In this case, the system would be easy to access and use but only have limited functionality.

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<sup>1</sup> Available online at: <http://theesa.ca/wp-content/uploads/2013/10/ESAC-Video-Games-Profile-2013-FINAL-2013-10-21-CIRC.pdf>

In productivity applications such as Microsoft Office<sup>2</sup> (Microsoft Cooperation, 2014) or Amazon.ca<sup>3</sup> (Amazon, 2008-2014), the main concern is helping the user complete an objective, quickly and easily; therefore, having both a useful and usable system is mandatory. However, it is also important to make interfaces, software and applications more enjoyable to use (Pagulayan & Keeker, 2003).

A user's impression of a system and satisfaction with this system is important in HCI, but these items become paramount when designing video games because games are focused on entertainment. For example, in HCI an interaction designer creates a system with an intended *product character*, which not only contains content and functionality but also an interaction and presentation style. This style – conveyed by the designer – is then perceived by the user and a core to their user experience. The user's perception is not guaranteed to match that of the designer. This theory is at the core of Hassenzahl's model of user experience (Hassenzahl, 2005).

Hassenzahl divides product features into two categories: *pragmatic* and *hedonic*, applying to functionality versus understanding the experience. The hedonic experience may be positive, such as excitement, passion, or interest or it can also be negative, eliciting frustration or anger. Hassenzahl extends on this idea by categorizing products by pragmatic and hedonic strength. Products can be *self*, strongly hedonic and weakly pragmatic or *act* products weakly hedonic and strongly pragmatic. Self-products are of importance to the user for more than just functionality. Self-products are part of the self-expression of the user and are independent of behavioural goals. For example, the function of a t-shirt is standard and a brand name t-shirt does not have an increased functionality. Regardless, the brand name t-shirt is valued more highly due to the appreciation of the label, which users may feel has added value to themselves. This added value may be as simple as an aesthetic

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<sup>2</sup> <http://office.microsoft.com/en-ca/>

<sup>3</sup> <http://www.amazon.ca/>

change or and increased confidence. The experience is also situation-dependent based on the user's goals (Hassenzahl, 2005). All in all, Hassenzahl's model shows the importance of good user experience in product design. If a product provides its user with a good experience and can be tied to one's self then it is profitable for the designer. Hassenzahl also advises that when designing the user's experience, the designer should consider the goals of the system being designed; these goals are tied to the functionality of the product. Therefore, the user experience, which is the communication of these ideals, is pivotal to product design and profitability. The product should be not only functional and usable, but also enjoyable to allow for the largest profit margin. These principles apply explicitly to video game development, because games are at their heart about conveying experiences in the best possible manner.

A large portion of HCI is dedicated to the study productivity applications, such as applications programs, web pages and forms. Heuristics and evaluation techniques in the field cater mainly to these interface types (Bødker, 2006). For example, Nielsen's heuristics provide guidelines for interface designers to help design and create more usable interfaces, which lead to an improved overall user experience (Nielsen & Molich, 1990; Nielsen, 1994a, 1994b, 1994c). Games are now also designed using HCI principles to help improve game design and create better user experiences. However, heuristics – mainly applied to classical interfaces – do not always lend themselves to creating a good user experience for games. For example, a largely accepted rule of thumb in HCI and a part of Nielsen's heuristics discusses the prevention of errors. This particular example does not necessarily apply the same way in games, where errors go hand in hand with learning, which is part of the fun – at least if you follow Raph Koster's theory of fun in games (Koster, 2005). Additionally, errors are positive because they pose a challenge and an opportunity for the players to improve themselves.

In games, usefulness is not the primary concern, more important is what the player is experiencing related to playing a game system. In other words, the functionality is not necessarily the focus of user research for games; instead the focus pertains to how enjoyable the game is. This sentiment was expressed succinctly in an article about user-centered design in games written by user researchers from Microsoft Game Studios: “For more than a decade at Microsoft, we have been applying, refining and inventing new [User Centered Design] techniques to improve not only the usability of our games, but, more importantly, the enjoyability” (Pagulayan & Keeker, 2003).

HCI for productivity applications focuses on usefulness, usability and user experience. HCI for games redefines these terms and focuses on the playability of a game and more on the player experience. Researchers studying HCI for games have begun to focus on user experience for games or player experience as part of *Games User Research* (GUR) to improve game design. GUR is a relatively new field but it has gained a considerable amount of attention from both academia and industry. For example, methods to improve GUR practice through academic studies have been proposed recently (Mirza-Babaei, Nacke, Gregory, Collins, & Fitzpatrick, 2013). Recently, in addition to having their own summit co-located with the annual Game Developers Conference, the GUR community has been more present at the CHI conference in a series of workshops (Mirza-Babaei, Zammitto, Niesenhaus, Sangin, & Nacke, 2013) and the HCI and games community is also establishing a new conference CHI PLAY in 2014<sup>4</sup>.

Games are fundamentally different from productivity applications. This means that games and productivity applications have different goals. Games are considered by many to have their primary purpose for enjoyment and fun versus applications that have task accomplishment as their purpose. Therefore, the design goals are different as well. In productivity applications, there is a need to

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<sup>4</sup> <http://chiplay.org/>

design programs to help the user finish their goals as quickly as possible, consistency is encouraged and the application is meant to be transparent. In contrast, games are designed to present a challenge. The focus is not on completion of the game but instead the journey. Game designers aim to make novel interactions and new experiences for the player; as a result, the games industry is competitive. This feeds back into the game design goals causing further deviations away from the design goals of productivity applications (Pagulayan & Keeker, 2003).

Enjoyment or fun can manifest itself in a variety of ways. For example, fun may stem from learning skills associated with gameplay or in contrast fun may originate from the interesting decisions or challenges presented (Pagulayan & Keeker, 2003). As a result, GUR seeks to improve the user experience. The direct goals of this research problem are wide. The game designer plays an integral role in deciding where the fun in the game will originate from and therefore game designers play an important role in setting up goals and points of interest in GUR.

User experience and player experience have the same underlying meaning but specify the application in focus and the target person. However, in some of the literature these words are used interchangeably. Unlike player experience, which explores the needs of the player during gameplay; playability is the study of games to improve the game system (L. E. Nacke, Drachen, & Kuikkaniemi, 2009).

GUR seeks to improve game design to improve the user experience in games (Bernhaupt, 2010; Isbister & Schaffer, 2008). Researchers in the field of GUR seek to understand games as they affect the player mentally, physically and socially. The intention is to find information and create theories or guidelines that modify the player experience by studying people playing games. In academia, GUR is done to understand all games as a whole. The GUR in academia has a wide scope and attempts to understand how – in general – games can be improved to affect the player's experience. GUR theories are intended to be generalized to a larger population. In other words, the

findings are meant to be applied to many games. Industry GUR is often performed for the benefit of the company or the specific game being tested.

GUR stemming from academia helps game designers understand how their design decisions affect the players. Game designers benefit from GUR, because the research conclusions can help them make informed design decisions that can lead to a better player experience. Game designers may consult the literature originating from the GUR community before creating a new game, in the early stages of game production. Information to help facilitate the design process is available at all points of production. The conclusions made by GUR help with planning the player experience of the product. Game designers can adapt strategies based on the literature to ensure the success of the game while it is in production. For example, by understanding the literature on learning in games, a game designer may choose to design the learning or tutorial level in a way that makes the information provided accessible to the player. By creating a good foundation, the player can better adapt to difficult levels presented later in the game – thereby reducing frustration and creating a better player experience (Wehbe et al., 2013).

Frameworks assist in the comprehension of the factors surrounding player experience. For example, one player experience framework (L. Nacke & Drachen, 2011) discusses player experience by examining abstraction and temporal layers. The layers of abstraction place the context at a highest level and the game system at the lowest level. The player at the middle level is influenced by both the game at the lowest level as well as by the context at the highest level. This framework also highlights the importance of the temporal progression. The player carries with them their past experiences and their in-game actions become consequences. All in all, player experience can be understood within this thesis as stemming from the player interacting with the environment.

GUR differs from User Interface (UI) design for games. UI Designers or HCI game designers have adapted principles and applied them to create and improve the interfaces for the game that

they are producing. This area is dedicated to the creation of games, differentiating UI design from GUR (Pagulayan & Steury, 2004).

The GUR community uses qualitative, quantitative, psychophysiological and mixed-measure methodologies to gather information about players. Qualitative measures gather rich information about the players; they help to paint a picture of the players' thoughts and feelings. Qualitative analysis may include interviews, observational methods, artifact analysis, and behavioural analysis. However, qualitative methodology can have some weaknesses. Qualitative measures rely on self-report data, which may be affected by subtle changes, such as relation to the researcher, opinions about the topic and concerns for privacy. Additionally, qualitative data is often collected at the end of the experience; retrospective data can be unreliable because participants may forget small details or feel the need to explain themselves. Additionally, qualitative measures seek to capture a wide range of information, operationalize terms and constructs, and uses subjective analysis criteria. In contrast, quantitative methodology includes gathering data about the player in games, such as collecting metrics, wins and losses, highly travelled areas player deaths. Additional approaches may include looking at players' reaction time or physiological measures. However, quantitative data does not always give insight into the thoughts and feelings of the player, but instead helps us objectively understand the player's performance. Psychophysiological measures collect the data related to a person's physiological state to understand the player in their current situation. For example, researchers may use EEG to understand when a player is cognitively overloaded. These techniques can help researchers understand player experience (possibly in real time) in an objective way. Psychophysiological measures are not without their disadvantages; the most prominent problem is the barrier to entry. To begin research using psychophysiological measures, a research lab requires equipment and researchers need to be trained to prepare, record and analyze physiological data, especially the more complex EEG data. However, once familiar with the measures, a researcher can

write scripts and collect objective, diverse and rich data. Mixed-measure methodology combines any of the methodologies explained above. By combining complimentary methodology, a user researcher can overcome the disadvantages of specific techniques and maximize the advantages gained from the different methodologies. The result can be to gain an understanding of the players of a game to improve the game as is often done in the industry; or to generalize the findings to player experience in games through theories. In his model, Hassenzahl 2005 suggests a specific measure of player experience: arousal. Hassenzahl ties his model to arousal stating that high arousal can be preferable, indicating excitement. A high arousal state may indicate excitement, when the player's goals are action based. In contrast, if the goal is relaxation, then low arousal is preferred; during relaxation high arousal is self-defeating and signifies frustration (Hassenzahl, 2005).

Information about the player's arousal level can be obtained through qualitative and quantitative measures. For example, a researcher might choose to interview a player to understand how the player felt. Additionally, a researcher may give the player a questionnaire to understand the player's experience. These questionnaires can be based on a scale of answers (e.g., a Likert scale). Psychophysiological measures can provide researchers with an objective measure of arousal that will provide insight into the player's experience. Arousal can be measured using skin conductance (SC), heart rate (HR), eye tracking, and electroencephalography (EEG) (Cacioppo, Tassinari, & Berntson, 2007). Each measure has its advantages and disadvantages. In this thesis, I discuss the use of the EEG technique Hemispheric Frontal Alpha Asymmetry (HFAA) to measure arousal, which is a method still in its infancy, and argue its advantages, explain its disadvantages and showcase its use as part of a research design to understand player experience.

## Research Question

This thesis explores the ways that EEG can be used to understand player experience in GUR; it focuses on Hemispheric Frontal Alpha Asymmetry (HFAA) (Coan & Allen, 2004) as a measure to understand the brain state of a player. I will describe this technique, summarize the results and recommend use. In addition, this thesis will discuss the use of EEG in GUR and how it can give insights to game development and design. This research focuses on EEG as an evaluative measure to improve player experience or the combination of the thoughts and feelings of the player during gameplay. This research is important, because it can improve player experience.

EEG is the GUR method in focus for this thesis. Unlike other psychophysiological measures, EEG can be analyzed in different ways to yield different information about the same moment of gameplay. The same may be said about some other measures, such as cardiovascular data; however, EEG can provide more detailed information about the brain state of the player and ultimately allow us to make inferences about their experience playing the game or using the product. Unlike other measures, EEG can also be used to understand not only the physiological arousal of the player but also the cognitive factors as well. Using EEG, a researcher may find out more information about anything from how the player processes and understands sound to the cognitive load of the player.

EEG has been used in the literature before. However, often techniques used in the literature can be expanded upon to gain additional information and optimize use of EEG. EEG techniques presented in this thesis are not widely used. There are a wide variety of techniques available for use with EEG and this thesis will discuss their usefulness in the GUR field.

This thesis will first review the literature, and then guide the reader through experiments that were conducted throughout the course of my Master's studies, which used EEG to gain insight into the social and cognitive aspects of player experience. In Chapter Two, the basics of EEG research

will be discussed. The chapter will review different EEG techniques available, as well as the basics of the methodology for use with GUR. Applications in GUR will also be discussed. HFAA will also be reviewed in Chapter Two.

EEG is often used in conjunction with other methods and this thesis presents the ways that EEG can be used as part of a mixed-measures design to obtain player information during gameplay. In Chapter Three, HFAA is combined with other EEG techniques as well as questionnaires. In Chapter Four, HFAA is combined with questionnaires, interviews and game data in Chapter Four. Lastly, in Chapter Five, HFAA is combined with interviews to get both an understanding of players' brain states as well as their thoughts and feelings regarding the gameplay. Chapter Five develops the mixed methodology through the studies presented in this thesis to compliment measures in use.

The thesis presents EEG analysis as complementary to existing and widely used techniques in GUR to get a more in-depth understanding of the player. EEG gives the researcher more insight and understanding of the player's experience and allows us to understand information beyond that of self-reported measures. This thesis also contributes to the literature by using this mixed methodology to understand in-game social learning, as well as, how the social condition of the game affects the player experience.

## Chapter 2: Related Work

*The work in this section is based on significantly expanded previously published work:*

Wehbe, R. R. & Nacke, L. E. (2013). An Introduction to EEG Analysis Techniques and Brain Computer Interfaces for Games User Researchers. In Proc. of DIGRA '13.

*<http://www.digra.org/digital-library/publications/an-introduction-to-eeeg-analysis-techniques-and-brain-computer-interfaces-for-games-player-researchers/>*

Successful games (e.g., critical and commercial successes) are often described with adjectives such as *engaging*, *immersive* or *exciting* (Ermi and Mäyrä 2005; Ijsselsteijn and Kort 2007). Players might report “losing track of time” or “being completely focused” in the game (Brockmyer, J.H., Fox, C.M., Curtiss, K.A., McBroom, E., Burkhart, K.M., Pidruzny, 2009). Games that do not engage players or create optimal experiences are often considered failures (i.e., they do not achieve high sales and/or good reviews), costing businesses and video game players time and money. They also cause game developers frustration. Researchers have attempted to measure and to predict how to create good and engaging gameplay experiences, but currently there is no guarantee for the commercial and critical success of a video game.

Games User Research (GUR) uses mixed methods and theories from psychology and human-computer interaction to improve the player experience (Bernhaupt, 2010; Isbister & Schaffer, 2008). Simply stated, GUR takes play testing to a scientific level, where it is possible to maximize a game's chances to be considered a success (Mirza-Babaei et al. 2013).

**Qualitative Measures and Questionnaires.** GUR often uses post-gameplay methods, such as behavioural observation, player interviews, focus groups and questionnaires (L. E. Nacke, 2013). The Game Engagement Questionnaire (GEQ) (Brockmyer, J.H., Fox, C.M., Curtiss, K.A.,

McBroom, E., Burkhart, K.M., Pidruzny, 2009), for example, is used to help researchers better understand the overall player experience or the summation of the player's thoughts and feelings. However, this questionnaire is aimed at violent games. Other attempts at creating a questionnaire are still in progress. Recently, a more comprehensive questionnaire called Presence Involvement Flow Framework (PIFF) was created by examining measures of constructs previously studied in the literature (Takatalo, Kawai, Kaistinen, Nyman, & Häkkinen, 2011). However, questionnaires and other methods that are administered to players after gameplay are sometimes called into question because of their validity and reliability threats, meaning that researchers are asking players to *recall* feelings. This technique becomes complicated when seeking information on particular (e.g., perpetually occurring) gameplay events. In addition, stopping players during gameplay may interrupt their game flow and affect their feedback. Ideal game evaluation techniques provide real-time feedback to researchers during a game and can be timed to record important events.

The weaknesses of these methods include lengthy preparation of these measures, which are sensitive to bias. Additionally these measures are time-consuming to administer, they are subjective, and retrospective. Techniques like questionnaires and interviews rely on retrospective self-report data. Players may not remember – in detail – the thoughts and feelings that dominated their experience at the time. Self-report data can be unreliable and hard to collect, because humans are always in a social situation. Players may feel the need to phrase their answers according to what they perceive to be the experimenter's expectation. In addition, the player may also feel the need to agree with the interviewer. Preparation of the material for research using traditional methods, such as questionnaires or interviews are often hard to prepare and can be unreliable or invalid if the wording unintentionally conveys a direction or evokes an answer. These methods are at a disadvantage compared to real-time (often covert) measures of physiological player activity (Rosnow, Ralph, Rosenthal, 2008).

Despite their weakness, qualitative approaches are valuable because these measures provide researchers with a detailed understanding of the player experience. The barriers of entry to this methodology are low. Additionally, qualitative measures such as interviews or focus groups can reveal information about the experience that researchers were not aware of. In addition, qualitative measures such as interviews give researchers the opportunity to follow up on responses.

**Quantitative Methods.** Quantitative measures include but are not limited to, metrics, player data, and reaction time. Researchers have employed these measures to get an objective understanding of the player experience (Ducheneaut, Yee, Nickell, & Moore, 2005). For example, GURs at Ubisoft have used the count of player deaths and location of the death to map the areas of difficulty in a game. This allowed researchers to understand if intended areas are difficult. Additionally, unintended areas of high difficulty are flagged by researchers for further analysis (Chalfoun, 2013). Researchers use information about player actions to understand the player's emotional state. The paper explores the sequences of player actions that may indicate frustration (Canossa & Drachen, 2010). Quantitative measures also include physiological measures.

**Physiological Measures.** Physiological evaluation, such as recording skin conductance, electrocardiogram (ECG), eye tracking, electromyography (EMG) or EEG can be used for real-time evaluation (Cacioppo et al., 2007).

This chapter focuses on the use of EEG as a real-time evaluation tool for aspects of player experience during gameplay (M. J. Salminen, Kivikangas, Ravaja, & Kallinen, 2009) and as a tool for Brain-Computer Interface (BCI) applications (Krepki, Blankertz, Curio, & Müller, 2007; Nijholt, Erp, & Heylen, 2008). Although EEG has been traditionally used as a tool for medical applications, EEG has also been used for research. EEG methodology has been used to evaluate parts of player experience and to interact with computing systems, most often for players with interaction constraints.

EEG techniques have been predominantly used for the diagnosis of health-related issues and only recently made their way into mainstream applications and brain-computer interfaces for healthy neurotypical or typically developed individuals without physical or psychological symptoms affecting brain functioning. EEG can be used to assess emotional factors, cognition and mental errors in research. EEG is also used in GUR, but usually techniques used are simplistic and aimed at understanding concentration or relaxation of a player. However, EEG can be used to provide information that is more detailed and can be applied to GUR to better understand issues ranging from psychological arousal or player frustration to error comprehension. However, EEG is versatile and can also be used as a tool to better understand the effect of marketing (Krugman, 1971).

A disadvantage of EEG is that has limited spatial resolution in comparison to functional Magnetic Resonance Imaging (fMRI) techniques. Researchers sometimes report EEG results as a function of the collection area (Cacioppo et al., 2007). EEG can also have problems with source localization. Although the electrodes record the signal from a particular scalp location, it is not guaranteed that the findings originate from the measured areas of the skull. Signals may originate from neighbouring areas of the brain and be recorded by other electrodes. This becomes more problematic when investigating signals originating from the lower brain, such as the basal ganglia (Teplan, 2002). However, in comparison to fMRI, EEG has great temporal resolution, which fMRI does not have. As a result, EEG can be used to study the effects of stimuli as a function of time. In addition, data can be looped back to a computing system in real time for BCI and human-computer interaction (HCI) applications. The loop created by the exchange on information is called the biocybernetic loop (Fairclough, 2009). This loop is best exemplified by neurofeedback, the process of showing and influencing ones brainwaves to increase awareness of one's psychophysiological being. Neurofeedback studies are discussed later in this thesis. HCI and BCI applications are also designed to be accessible for consumer and non-medical use. As a result, in this space EEG is better

in both cost effectiveness and accessibility (Buzsaki, 2009; Logothetis, 2008; Luck, 2005; Poldrack, 2006).

**Basics of EEG.** The cells comprising the brain are called neurons. Neurons release chemicals (excitatory) or are stopped from releasing chemicals (inhibitory) as a result of the passage of ions which change the overall electrical current of the axon or the body of the neuron between negative and positive. These chemicals are received by other neurons and allow the neurons a means of communication. This process of excitatory synaptic potentials is what is referred to when neurons are described as ‘firing’ or evoked potentials. The organization of neurons is important to the processing of the brain. Neurons are aligned in columns. As a result, neurons are clustered into both grey and white matter depending on the concentration of the axons, which are higher in white matter and the neurons found in greater quantity in white matter. The organization of the neurons allow for the formation of brain structures, which are comprised of groups of neurons that communicate consistently and maintain the same functionality.

The electrical currents arising from brain activity can be captured non-invasively (without damage or alteration of the body) using EEG. This method of collecting data allows researchers insight into the living brain without harming the participant. The waves are sine waves. Sine waves are repetitive waves, which vary in frequency and amplitude. Each wave has a period, which represents a full turn from one point (e.g., the peak) on the shape to the next point on the graph with the same voltage (the following peak). The period can be calculated by dividing one by the frequency of the wave. The period can also be referred to as the wavelength ( $\lambda$ ) (Buzsaki, 2009; Cacioppo et al., 2007; Luck, 2005).

**Data Collection.** EEG is recorded through a series of electrodes, which sit on the scalp of the participant. Electrodes should align to the 10-20 map of electrode placement, a reference map commonly used to align electrodes to scalp locations corresponding to lobes. The electrical activity

recorded by all electrodes (corresponding to neural activity) is often referenced against one or two reference points. Reference points may include, for example, the center of the scalp, nose, or mastoids processes (posterior-inferior projections of the temporal lobes) (Cacioppo et al., 2007). Alternative reference methods may include calculating the average as a global reference or using Driven Right Leg (DRL) and Common Mode sense (CM). The electrical activity of each electrode is subtracted from the reference point to obtain information about the brain of the participant by filtering out electrical activity that is not usable data. Once obtained the information can be analyzed using different techniques such as frequency analysis, hemispheric asymmetry, event-related potential (ERP), or connectivity. The choice of technique depends on the information needed as specified by the hypothesis of the research that someone plans to carry out (Cacioppo, Tassinari, Berntson 2007; Coan and Allen 2004; Coben and Hudspeth 2008; Luck 2005).

**Equipment.** There are many different companies producing EEG equipment for data collection that vary in reference points or number of electrodes as well as purchase price. One interesting fact is that in recent years, EEG devices have seen resurgence in the low-cost market, making EEG technology available to more people than ever before. Recordings may be done with a dense electrode array of 132 electrodes (Krepki et al., 2007), 62 electrode caps (Aftanas, Varlamov, Pavlov, Makhnev, & Reva, 2002), 19 electrodes caps (Kouijzer & Moor, 2009) or 16 electrodes as in the consumer-price EPOC Emotiv system seen in Figure 1.

**Figure 1: EPOC Emotiv**



The above picture shows a person wearing the EPOC Emotiv Headset

Ten electrode caps are also used (M. Salminen & Ravaja, 2008)) or even as few as one electrode and references (Schild, LaViola, & Masuch, 2012) as in the consumer-price Neurosky systems shown in Figure 2 and

Figure 3.

**Figure 2: Neurosky headset**



The above photo shows the Neurosky Mindwave headset, a one electrode EEG.

Introducing multiple electrodes can increase spatial resolution but increase the cost of the system and it may also increase complexity of the analysis, depending on the technique used. In contrast, certain evaluation techniques may not be possible with the available electrode arrangements. For example, hemispheric asymmetry techniques cannot be used with a single electrode system. However, in most cases, a high-density electrode system is not required for frontal frequency analysis. Researchers need to consider the best system to use based on the purpose of the study proposed and the targeted analysis technique, which will be discussed below (Buzsaki, 2009; Cacioppo et al., 2007; Coan & Allen, 2004; Luck, 2005; Thatcher, 2012).

**Figure 3: Neurosky Mindset**



The above photo shows the one electrode Neurosky Mindset.

**Preparation of EEG data.** EEG data can be analyzed in alternative ways to provide different information about the brain state. However, EEG is not a robust measure and can yield less than the expected amount of information if not collected properly leading to a low signal-to-noise ratio (e.g., more artefacts, noise). The significance of the findings can also be affected by improper treatment of the data during analysis. For example, the accuracy of a time stamp can affect where to search for a brain response (Cacioppo et al., 2007; Luck, 2005).

**Time Stamps.** EEG techniques explore the brain state following a change in the environment or in stimuli. Consequently, it is important to have an indication of event time or stimulus presentation to run an analysis. Averaging over time with no events or incorporating resting state into the average analysis can change the significance levels of the results. Time stamps are especially important for the *event-related potential* technique (ERP) analysis (explained in an upcoming section), because of the sensitivity of the components to a time within milliseconds post-stimulus or after the presentation of an event. For example, the N170 (a component of ERP analysis) is found in adults 170ms after the presentation of a face or face-like stimuli (Luck, 2005).

**Baseline.** It may be necessary to have a baseline for comparison depending on the design of the experiment. This may be collected as an eyes-open baseline or an eyes-closed baseline based on the experimental protocol being used. The processing of visual input might influence alpha and arousal activity levels and this should be taken into account when considering eyes-open or eyes-close as a baseline (Buzsaki, 2009; Cacioppo et al., 2007; Luck, 2005).

**Artefact Removal.** Researchers attempt to collect clean data to minimize the amount of artefacts or noisy data collected. Some precautions that are common include minimizing muscle movement and head turning; keeping light settings consistent, ensuring electrode contact with the skull of the participant, running the experiment in a separate room free of distractions. Other precautions can include attempting to reduce bridging (the return of identical recordings between electrodes) by keeping moisture between electrodes, which conducts electrical signals, to a minimum. Researchers often measure the head of the participant using landmarks like nasion (the dip between the eyebrows) and the inion (on the back of the skull) to ensure strict adherence to the 10-20 system for electrode placement. Pilot studies should be run to check if the data collected is usable before running a full experiment (Luck, 2005). However, —despite best efforts—noise and artefacts may still be recorded.

Artefact removal involves omitting messy data that is not the result of brain signals. Artefacts can be caused by blinks, lateral eye movements, muscle activity and movement. Artefact removal also includes reduction of noise caused by electrical currents near the experimental set up from the data. Artefact removal may be necessary to ensure the internal validity and reproducibility of the study. For example, artefacts can cause artificial results (Luck, 2005).

A common method of removing artefacts is visual inspection. This involves the researcher searching the data for peaks, messy sections, rectangular patterns associated with lateral eye movements or other patterns associated with artefacts (Aftanas et al., 2002; Ibric, Dragomirescu, & Hudspeth, 2009; L. E. Nacke, Stellmach, & Lindley, 2010; M. Salminen & Ravaja, 2008; Ulloa & Pineda, 2007). Visual inspection produces clean data. However, there is the threat of compromised inter-rater reliability, because this method is subjective. In addition, researchers may accidentally remove real data. Visual inspection lacks efficiency; it also requires time and effort from the experimenter. Some researchers combine visual artefact removal techniques with statistical analysis of the peak to ensure that only outliers and not valuable data is being removed from the EEG recordings (Kouijzer and Moor 2009). This alleviates concerns of visual inspection; but is still time-consuming and can also be affected by individual differences between researchers when identifying components for statistical analysis.

Other researchers use electroculography (EOG) channels near the eyes to identify artefacts (Aftanas et al., 2002; Krepki et al., 2007; Wilson & Russell, 2007). This makes artefacts arising from eye movements more salient. It reduces the chances of removing significant data, because data that has peaks that are not reflected in the EOG channels are not removed.

Researchers may also employ programs to artefact the data. In their 2012 study, Malik et al. used the *Neuroguide* software (Malik, Pauzi, & Khairuddin, 2012) for artefact removal. Researchers

may also wish to employ a combination of the above techniques depending on their tolerance for artefacts (Aftanas et al., 2002).

In contrast, researchers may also choose not to artefact or remove messy data before analysis. This process can be time-consuming, so that some researchers do not artefact (Hwang et al., 2011). Researchers studying BCI and HCI application may also choose not to artefact, because it does not suit the final application of their results (Nijholt et al., 2008).

The decision regarding which approach to artefacts will be used depends on both the researcher and the sensitivity of the data to artefacts. Therefore, decisions to artefact or not must be made on a case-by-case basis. Researchers should be able to justify the concluding decision.

**Filtering.** Filtering can result in cleaner data, salvage previously unusable data and positively affect the significance of the finding. However, filtering can also distort the data and must be considered carefully before use (Luck, 2005).

Notch filters are often utilized because electrical equipment near the experimental setup can cause 60 Hz interference, which can introduce artefacts to the data. As a result, researchers may choose to notch filter at 50 to 60 Hertz (Cacioppo et al., 2007; Luck, 2005). Band Pass Filters limit the upper and lower ranges of the frequency ranges being used in the study. Researchers should also ensure that the sampling rate is at least twice as high as the highest frequency (Cacioppo et al., 2007; Luck, 2005).

Component analysis such as Principal Component Analysis (PCA) and Independent Component Analysis (ICA) are powerful techniques for identifying components to be removed, such as artefacts caused by muscle movements or electrical noise. It allows the artefact removal process to be more automatic but can distort the data (Cacioppo et al., 2007; Luck, 2005; Thatcher, 2012).

**Analysis Techniques.** EEG utilizes many techniques to analyze data. Choosing the right analysis technique depends on one's hypothesis or research question. One can have time-domain and frequency-domain, depending on the chosen methodology and research question. Analyses that depend on power of a frequency band or decomposition of the EEG signal include frequency analysis, neurofeedback, hemispheric asymmetry and synchrony techniques. ERP techniques are used to understand the brain changes after an event or stimulus presentation. Lastly, synchrony and power change are of interest during connectivity studies or studies that further explore the connections within the brain. The analysis will dictate the specifications of the equipment and setup. It will also affect the study design and statistical analysis. The chosen analysis must reflect the research question. This chapter will now review different analysis techniques and how they may be used to explore different hypotheses.

**Frequency Analysis.** Questions involving the brain state of the player may employ frequency analysis. In frequency analysis, the EEG data is divided by frequency bands determined by separating the signal into its component waves. A common approach to this analysis would be to use a Fast Fourier Transform (FFT). Information obtained by this analysis depends on the area of collection. For example, for scalp collection, the alpha band consisting of 8-13 Hertz frequency, and can be an indication of a drowsy or relaxed state (Cacioppo et al., 2007; M. Salminen & Ravaja, 2008; Ulloa & Pineda, 2007).

The delta band is defined from 1-4Hz. The theta band is from 4-12Hz and can be associated with sleepiness. The alpha band is 8-13Hz and is often associated with a relaxed state (Cacioppo et al., 2007). The beta band is from 13-30Hz and can represent concentration. Lastly, the gamma band is from 30-50Hz (Nacke, 2013). Fluctuations in the definitions of each band exist. Researchers look to the literature to set criteria (Cacioppo et al., 2007; L. E. Nacke, 2013).

This method has previously been used to study sleep, where the differences in sleep level are associated with different frequency bands. In a study by Landolt et al. (1995), frequency bands were used to assess the effect of caffeine in the depth of sleep of the participant. The study revealed that caffeine reduces the prevalence of the low-frequency delta activity (Landolt, Dijk, Gaus, & Borbély, 1995).

This methodology was employed by Salminen and Ravaja in 2008 to study the effects of violence on players playing a first person shooter. The events recorded for the analysis (as stimuli) involved shooting and injuring other players. The results showed that in response to violent events there is an increase in oscillatory theta activity (M. Salminen & Ravaja, 2008). The study was limited to only one game, so conclusions drawn were not referenced against a control condition of non-violence. Future continuations of this study may want ensure the results are reproducible against a more rigorous control criterion.

Pre-calculated frequency measures for entertainment and relaxation are available for Neurosky MindWave and MindBand headsets. Although built-in and usable, Neurosky has not released the calculations of the two black-box variables and, therefore, these formulas are not advisable or available to use for academic purposes.

In a paper by Schild et al. (2012) on player experience, these formulas were used and compared to questionnaire data after playing a game. The resulting data from the EEG contrasted the results of the questionnaire. This is likely due to the use of the non-released black-box formulas in the analysis (Schild et al., 2012).

Additionally, a study by Crowley et al. used the measures of relaxation and attention from the *Neurosky* headset. The researchers were particularly interested in the brain state of the participant during mistakes (Crowley, Sliney, Pitt, & Murphy, 2010). Another approach to the same problem

could involve using Error Related Negativity (ERN) (Holroyd & Coles, 2002) discussed later on in this chapter. However, use of this methodology would require a change of equipment.

Using EEG data and frequency-based analysis to manipulate and interact with physical prototypes is an application of *BCIs*. *Brainball* is a game played by two players on a table, which employs a physical ball. The object of the game is to keep the ball away from your end of the table. If the ball rolls towards your opponent, you are declared the winner. To meet the objective it is necessary to relax. Thinking about winning or about game strategies will only benefit your opponent. The game uses EEG input to determine the player's relaxation level using frequency analysis. For ensuring the winner is in a relaxed, meditative or peaceful state, the theta, alpha and beta levels of the players are compared against each other. This application is a demonstration of the ways EEG can be used to manipulate physical objects (Hjelm, 2003). However, the authors do not explain the creation of the table and no particular research objectives were set for this design.

In the previously cited works, the overall frequency of the brain was analyzed. However, depending on the research question, researchers may choose to analyze signals from only few areas of the scalp by limiting the electrodes. For example, theta frequencies average from the entire area of the scalp can signify sleepiness or drowsiness, while theta occurring over the midline area can represent concentration (Cacioppo et al., 2007).

The *mu* rhythm is collected in the alpha frequency range of 8-12 Hertz over the motor cortex. To isolate this brain pattern, data from electrodes overlapping or near the motor cortex (i.e., horizontally between the ears) is used. The mu rhythm fires when observing an action performed using the hand or mouth and is suppressed when the participant performs that action (McFarland, Miner, Vaughan, Wolpaw 2000; Nyström, Ljunghammar, Rosander, Hofsten 2011; Ulloa, Pineda 2007).

In a similar study, McFarland et al. (2000) studied the mu rhythm. The researchers used topography as part of their analysis (McFarland et al., 2000). Topographies allow for visualization of the decomposition of the signal into component frequencies overlaid on a depiction of the skull. The topographies allow for visual identification and removal of artefacts, and it also allows for the visual identification of information (Cacioppo et al., 2007).

Together with research colleagues, I have also used mu rhythms to study learning in video games. We showed that learning depends on the order of watching a game played first versus playing the game before watching the video. The results also indicated that the order of play also affected arousal (Wehbe et al., 2013). This study will be described in detail in Chapter Five.

**Neurofeedback.** Presenting the brain state of the participant to the participant in a compressive way will allow them to alter their brain state according to the feedback provided. This premise is the foundation of neurofeedback. Often studies employ a visualization to inform players of their brain state (Gevensleben et al., 2009), but one may also use a physical representation (Hjelm, 2003). Often neurofeedback techniques measure meditation or relaxation using frequency analysis (Cahn & Polich, 2006). *Brainball* is an example (discussed above already) of neurofeedback, because it informs the participant of their current brain state (relaxation) and allows the participant to act on that information (Hjelm, 2003). Individuals can also learn and benefit from neurofeedback. Research has shown that this technique can alter an individual's brain in measurable way (Ibric et al., 2009). Neurofeedback is currently trending in industry released products for health and wellness. Neurofeedback is advertised as an effective technique to increase relaxation and reduce stress. Industry applications of EEG will be further discussed in the upcoming section *EEG for Everyone*.

Neurofeedback has also been used widely for clinical purposes. Neurofeedback has been used to help children with Attention Deficit Hyperactivity Disorder (ADHD) or Attention Deficit Disorder (ADD) (Gevensleben et al., 2009; Lubar, Swartwood, Swartwood, & O'Donnell, 1995;

Masterpasqua & Healey, 2003) as well as children with Autism Spectrum Disorder (ASD) (Kouijzer & Moor, 2009).

**Hemispheric Frontal Alpha Asymmetry.** Hemispheric Frontal Alpha Asymmetry involves frequency analysis. This technique involves analyzing the hemispheric activity of the opposing lobes of the brain. This may include comparing statistical power of the frequency analysis of a wave in the right hemisphere versus the left (Cacioppo et al., 2007). Further statistical tests can be used to analyze the data by lobe, to look for significant differences in activation between lobes. The full protocol was outlined by: (Coan & Allen, 2004).

This technique has been applied to player experience and gaming. Salminen et al. (2009) studied Super Monkey Ball 2 and examined its game events (e.g., falling off the track) to determine their effects on the player. The researchers propose that games that are more arousing are more engaging. Therefore, this technique can provide a measure of player experience. This methodology is useful, because the player does not have to be disrupted to get feedback (M. J. Salminen et al., 2009). Hemispheric Frontal Alpha Asymmetry can also be used as a measure of negative emotions, such as stress or aggression. Researchers have examined the use of hemispheric frontal alpha asymmetry during task completion of impersonal stimuli versus interpersonal or socially induced stressful conditions. The study concluded that this technique can be used as an indication of these negative emotions during both events (Verona, Sadeh, & Curtin, 2009). Studies employing this technique should employ a second measure, such as a questionnaire, to interpret the data accurately (Wehbe et al., 2013).

**Event Related Potential Technique (ERP).** Questions that involve cognitive understanding may be answered using the event-related potential technique. Researchers employing this methodology study different components or patterns that appear post-stimulus or after an event. This technique uses time markers to identify the point of the stimulus is presentation.

Researchers often record hundreds of milliseconds both pre and post stimulus. One then searches for the expected component within the time range. For instance, the P300 component is a pattern that occurs at 300 ms after a visual stimulus. When looking for this component pattern, one would record an overlapping time section and expect the peak to occur at 300 ms after presentation of the visual stimulus (Luck, 2005).

Data pre and post stimulus onset is examined by summing the brain waves collected from each electrode for each stimulus event. Random fluctuations will be resolved through this process leaving only systematic differences. Patterns of activation previously established in the literature seek to make inferences about the cognitive state of the participant. The appearance of the component can also depend on the population being studied. For instance, the N170 component appears 170ms after presentation of a face or face-like stimuli, but in children it appears around 250ms after stimuli (Luck, 2005).

Stimuli or events are not always concrete. ERP analysis can be used to study more abstract concepts, such as creativity and insight (Dietrich & Kanso, 2010; Dietrich, 2004a, 2004b). In addition, components can also include patterns that occur indirectly or as a result of cognition following task or stimuli. For example, Error Related Negativity (ERN) is a negatively occurring peak that ensues after an error is made. ERN is robust and does not discriminate between tasks and increases with the severity of the error (Holroyd and Coles 2002).

P300 and N200 components were studied as participants responded to visual stimuli. The end application was a photo browser. For this reason, the independent variable was the highlighting of the photos to attract player attention. Dependent measures included performance and ERP analysis of the P300 and N200 components (Tangermann et al., 2011).

Another BCI application was used for computer security and authentication. The researchers purpose that EEG can be used to authenticate players. The researchers believe that EEG will be a

more secure method of authentication because passwords can employ the use of the implicit memory system (Martinovic, Davies, & Frank, 2012). Implicit memory, or more specifically procedural memory, is a component of memory that is not immediately accessible, but manifests during task completion (Galotti, 2008). The researchers had participants complete a two-hour training playing a game,—Guitar Hero—which requires players to press buttons in sequence to earn points. The researchers show that the P300 component can be used for multiple individuals as an authentication strategy. The authentication can be completed by playing the game, despite the fact that players were unable to recite the password or even portions of the password (Martinovic et al., 2012). However, in the article, researchers do not address the problem of memory decay and do not test how often the player will need to complete training or authenticate to continuously keep the password stored implicitly.

ERP analysis also has been used as an evaluation technique. In a study by Li et al. in 2008, fatigue during stereoscopic 3D was quantitatively measured using ERP analysis (Li, Seo, Kham, & Lee, 2008).

**Berlin Brain Computer Interface.** Krepki et al. (2007) introduced the Berlin Brain Computer Interface (BBCI) as a protocol for use of EEG for BCI applications using a combination of ERP analysis and neurofeedback techniques. Participants in this study attempt to use EEG in a game-like format as a possible control mechanism. Researchers suggest that further development and use of this system may contribute to future applications for special populations, such as a brain-controlled wheel chair (Krepki et al., 2007). BBCI has been applied by Lalor et al. (2005), who used ERP of visual stimuli for immersive game control (Lalor et al., 2005).

**Coherence, Synchronization and Connectivity.** Analysis techniques can also look closely at the time and frequency domains to understand the firing output mathematically. As explained

above, EEG is output in the form of a sine wave and is characterized by the features associated with amplitude frequency. Each rotation can be analyzed as a period or wavelength.

*Phase Analyses.* Phases can be checked for, resetting, shifting and locking. Phase locking and shifting occurs when the EEG rhythms are synchronous and then desynchronize (Thatcher, 2012). This is usually done by choosing a point at the same point in the sine wave cycle and investigating the period. Phase resetting (Thatcher, 2012) occurs when two waves reset or begin their period at the same time, despite their previous position in the cycle. Phase differences are further discussed by Nunez et al. (P L Nunez et al., 1994, 1999; P. Nunez, 1974; Paul L Nunez et al., 1997).

As discussed previously, EEG can be analyzed in the time and frequency domains. The study of whether two evoked potentials or two neurons are firing synchronously is a study of covariance. If the same measure was normalized, then it will be the correlation function co-efficient. In the frequency domain, when two neurons fire consistently over time, they are firing in a steady state. We can explore synchrony and de-synchrony of steady states as cross-spectral density. If normalized, then we are studying the coherence. These concepts are explained by Nunez (1999).

**Event Related.** Event-Related Synchronization (ERS) and Event-Related Desynchronization (ERD) are techniques that can be used to provide more information about the participant's brain state in association with a time event. Different methods of quantification have been used. for example, the separated alpha bands and theta band were examined for a study assessing emotional arousal (Aftanas et al., 2002). For an in-depth review, refer to Pfurtscheller and Lopes da Silva's 1999 article. Durka et al. (2004) discusses this method and can be valuable reference to researchers looking to employ this technique. The researchers also provide some guidelines at the conclusion of the paper (Durka, Zygierevicz, Klekowicz, Ginter, & Blinowska, 2004; Pfurtscheller & Lopes da Silva, 1999).

**Connectivity.** When two or more regions of the brain fire synchronously, they are said to be functionally connected despite the absence of physical connection (Delorme et al., 2011; Nolte et al., 2004; Thai, Longe, & Rippon, 2009). Unlike other EEG techniques, a functional connectivity technique is not exclusive to EEG. Other techniques such as functional Magnetic Resonance Imaging (fMRI) (Koshino et al., 2008) and Diffusion Tensor Imaging (DTI) (Sundaram et al., 2008) also employ functional connectivity. The brain is able to change in response to stimuli and connectivity techniques can be used to show real time changes in the brain state in response to stimuli (Hwang et al., 2011). Connectivity has been applied as an evaluative measure of player experience. Malik et al. (2012) examined brain states during gameplay on large screens. Researchers studied data in frequency bands. The paper states: *“We used three EEG measures: absolute power, coherence and phase lag to analyse [...] data”*. They report significant findings in absolute power in the occipital, parietal, frontal and motor regions (Malik et al., 2012). However, this study does not vary the screen size as an independent variable. Instead, the task completed by the participants was done on a large screen with no comparable screen condition. Future studies manipulating screen size would be a natural follow up and should understand player experience from a HCI perspective as the interface changes.

**Disadvantages of EEG.** As outlined above, EEG can provide researchers and developers with a unique view of the brain state of a participant. The above sections also hint at possible disadvantages, which will be reviewed in detail in this section.

Compared to fMRI, EEG has poor spatial resolution. This may lead to source problems or the inability to pinpoint the exact location the signal is arising from. However, compared to fMRI, EEG offers better temporal resolution or the ability to better understand what time the event occurred in relation to a stimuli (Cacioppo et al., 2007; Luck, 2005).

One of the disadvantages that can be most prohibitive to researchers is the robustness of the signal. EEG continues to be vulnerable to artefacts or noisy data. However, other physiological techniques have similar problems. Researchers must take precautions to ensure that the data collected are clean or the study may not yield usable results (Cacioppo et al., 2007; Luck, 2005).

Like all physiological techniques, EEG suffers from the one-to-many, many-to-one inference problem. In other words, because of the complexity of the human body there can be many origins of each signal or a single signal may be the product of many physiological processes (Fairclough, 2009).

### **EEG for Everyone**

EEG is no longer just for research purposes. EEG can be used as an input for games and for playfully designed toys and accessories. Neurofeedback games were briefly discussed earlier as one example. However, to expand on the topic, more companies have been created in recent years with the intent of releasing EEG-based games and technology. One notable company who has created a series of headsets is Neurosky<sup>5</sup>. The products also feature an accompanying web store with games designed for use with the EEG headset, which outputs the basics FFT values alpha, beta, theta, delta in real time. In competition with this headset is the EPOC Emotiv<sup>6</sup>, which features a 16 electrode setup that extends the basic functionality of the Neurosky's models. It adds the ability to incorporate facial expressions and head tracking in real time. In competition with both systems is the newly realised Muse by Interaxon<sup>7</sup>. Unlike the previous systems, the headset features seven electrodes that cover select locations on the areas across the player's forehead.

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<sup>5</sup> Neurosky.com

<sup>6</sup> Emotiv.com

<sup>7</sup> <http://www.interaxon.ca/muse/>

Games created span topics including health, mental well being, learning, concentration and serious games to help special populations. For example, in the Neurosky store there are games such as Math Trainer<sup>8</sup> (Neurosky, 2013). Math trainer is designed to help users understand problem areas while solving math problems to help players improve.

EEG has also been used for playful design and interactions. The Necomimi<sup>9</sup> head set from Neurosky translates the basic functionality of EEG into simple ear-wiggling patterns. Other interesting projects include NeuroKnitting<sup>10</sup>, which used EEG as an input for a knitting pattern to make customizable scarves. This project is just one of the many integration points between science and art. EEG has also been used to provide directional controls for a helicopter (Powell, 2013). This type of application leads into more serious uses of EEG, such as synthetic limbs, which are beyond the scope of this thesis.

### **Future Ideas**

Combinations of different frequency analysis techniques may allow for more dynamic gameplay. Techniques, such as ERP, are not commonly used in neurogaming (the use of EEG as game input). Using ERP as input for a game can allow researchers to create more complex puzzles and more engaging gameplay. In addition, during neurogaming, researchers can also examine player experience and use information to enhance gameplay based on their level of cognitive understanding. Other techniques such as connectivity may also allow researchers to investigate cooperation in gaming and assess the use of different areas of the brain during gaming to create a more challenging experience without cognitively overloading the player (Haroz & Whitney, 2012; Wilson & Russell, 2007).

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<sup>8</sup> <http://store.neurosky.com/products/math-trainer>

<sup>9</sup> [www.necomimi.com/](http://www.necomimi.com/)

<sup>10</sup> <http://www.knitic.com/neuro/>

## **Conclusion**

EEG is versatile and can be used as an evaluative measure of player experience or contribute to Brain Computer Interface (BCI) applications. Overall, researchers must prepare an experimental protocol to reduce artefacts and maximize data quality. Techniques, such as frequency analysis, hemispheric asymmetric, synchronization, event-related potential technique and connectivity can provide different information. Applications of these different techniques can also be applied to BCI applications and HCI. In conclusion, despite the sensitivity of the methodology, electroencephalography (EEG) can provide researchers with insight into the participant's brain state and cognitive functioning.

## Chapter 3: EEG-based Assessment of Video and In-game Learning

### Introduction

This chapter presents the first study of this thesis. In this chapter, HFAA is paired with an alternate frequency analysis technique to understand not only the physiological arousal of the player but also to better comprehend learning in game.

Players always learn in games. Players use real world information to solve puzzles, gain new information about the game world, as well as learn from tutorials and embedded instructions in games. However, players also learn from other people. Often players can share information, take turns playing the same game or verbally coach each other through levels. If in-game social conditions are dependent on subjective perception, then we should be able to use a computer substitute to understand in-game social learning and ultimately, player experience.

In the following chapter, HFAA is combined with other EEG techniques. Here, HFAA and mu rhythms are used to explore the player's reactions to tutorials. Mu rhythms are rhythms in the brain that are activated by imitation learning. Mu rhythms were used to understand learning based on ordering in a study presented as a works-in-progress in the following publication:

Wehbe, RR, DL Kappen, and David Rojas. 2013. "EEG-Based Assessment of Video and in-Game Learning." CHI'13 Extended .... doi:10.1145/2468356.2468474.

<http://dl.acm.org/citation.cfm?id=2468474>.

This experiment used mu rhythms to determine the best approach to learning. In particular, my colleagues and I sought to answer whether watching someone play was more effective after first playing yourself or by watching someone play first and then start playing yourself.

## Related Work

Learning in video games is essential for creating good gameplay. Raph Koster even argued that the fun of gaming comes from learning how to play (Koster, 2005). This is sometimes facilitated by tutorials (Andersen et al., 2012). However, video game players often socialize by taking turns in playing a game and improve their skills by viewing each other playing. It is currently unclear whether learning to play the game individually is effective without this social interaction. In comparison, it may also be possible that learning is most effective in the period after watching someone play. For example, some people might remember gameplay moments with an older brother or sister that involved learning by taking turns playing a game. Here, effective learning is likely facilitated by mirror neuron activity. The firing of mirror neurons facilitates imitation learning, where we learn by observing and redoing the actions of others. This is commonly associated with activity of the Mu rhythm (Ulloa & Pineda, 2007).

For game designers, it is important to know whether playing a game is more arousing, and therefore, likely more engaging (M. J. Salminen et al., 2009). We wondered whether games are more engaging when you learn to play by yourself or when you watch somebody play the game first. Some games, such as New Super Mario Brothers Wii, are using artificial intelligence (AI) to have players watch gameplay actions when a sequence of the game becomes too hard for an individual player. Knowing when to watch gameplay, first and when to engage in gameplay yourself would be beneficial to players. Developers could then use these AI techniques to make gameplay more engaging. They could also teach players without interrupting flow and engaging gameplay moments.

Observational learning is the ability to acquire new knowledge by observing the behavior of others. Learning through observation and imitation is a strategy that can lead to natural acquisition of behavior (Bandura & Jeffrey, 1973) and planned acquisition of skills (Brody, Lahey, & Combs,

1978). For example, this strategy has influenced language skill learning and acquisition of skills at playing musical instruments.

A common learning approach in humans is to observe and then mimic the actions of that person until an understanding of the subject is grasped (Rizzolatti, Fadiga, Gallese, & Fogassi, 1996). This is facilitated by the Mirror Neuron System (Rizzolatti & Craighero, 2004) comprising of mirror neurons, which are multimodal association neurons (Keysers & Gazzola, 2009) in the brain, and are commonly linked to the activity of the Mu waves, known as Mu rhythm (Rizzolatti, Fogassi, & Gallese, 2001). The Mu rhythm is found over the motor cortex between 8-12Hz (Rizzolatti et al., 2001). Mu suppression occurs when observing an action performed using hands or mouth (e.g., reaching) (Ulloa & Pineda, 2007). Research indicates a strong correlation exists between the perception of an action and action possibilities (Ulloa & Pineda, 2007). Based on this theory, our objective was to compare Mu waves of a player observing a game video and then playing the game and a player playing the game without any reference to the game videos.

The key component of learning is the process of observing the actions of others, understanding their actions and imitating their actions. The process of imitation learning is learning accomplished by observing and redoing the actions of others. In a few simple games, some of the rules of the game can be identified through the process of learning by discovery. In others, repetition of certain tasks over time sets to engrave the rules into ones memory. Game literacy necessitates the accumulation of basic gameplay skills affording the playability of new games based on past experience. Very few players tend to read manuals prior to gameplay. However, the trend towards complexity necessitates the need for in game tutorials or procedures for learning to play while playing. Frustration may also arise from tutorials that are not useful or not completely understood. Frustration can be related to arousal (Verona et al., 2009). However, arousal during gameplay may result in more engagement (M. J. Salminen et al., 2009). Arousal can be measured

using EEG by measuring the difference between two lobes of the brain as frontal hemispheric asymmetry (Coan & Allen, 2004).

For investigating learning and arousal, we turned to a real time physiological evaluation technique, called electroencephalography (EEG). In particular, we measured HFAA as an indicator of arousal and Mu rhythm as an indicator of learning effectiveness. We also explored playing time as an indicator of performance. We hypothesize:

**H0:** Mu rhythm will not be affected by seeing the game played before or trying the game first then seeing someone play. Performance will also not be affected by seeing the video or trying to play first.

**H1:** Mu rhythm will be suppressed when the person observes someone playing and be pronounced when playing.

**H2:** Performance will improve if the participant plays the game before watching the video.

**H3:** Players will show more arousal during gameplay and lower arousal when watching the video.

## **Methodology**

The study employed a between participants design. Participants were divided into two groups. One group watched a video of a player playing a game before attempting to play and vice versa. There were five trials of each condition presented. Videos and levels were randomized. Participants were given approximately 2 seconds between videos and games. The study was conducted in a controlled environment in the Game Science Lab at University of Ontario Institute of Technology under the supervision of the UOIT Ethics Board.

**Participants and Procedure.** Participants were informed about the general procedure and they signed consent forms. No compensation was provided. A demographic questionnaire included questions revolving around gameplay experience, time spent per week playing video games, as well as basic information such as age and gender. Participants ranged in age from 20 to 29. All

participants had some experience playing video games. Most participants had no experience playing the stimulus game. Participants were excluded due to gender, color blindness, history of mental illness or experimenter error. Upon completion of the study, participants were thanked for their time and were debriefed.

**Game.** For the study, the game needed to have a goal in order to evoke mu rhythms caused by seeing an action and then performing the same action. The player had to be able to imagine themselves completing the tasks necessary to proceed. The participants were given simple instructions. No tutorial, practice trials or hints were given. The game chosen was Flow (Big Duck Games LLC, 2012) for iPad, a puzzle game. The game involves connecting nodes without overlapping paths. All nodes must be connected and the game board must be filled to complete the level. Puzzles involve spatial ability, for which gender differences are well known (Coluccia & Louse, 2004), so that we chose to focus on male participants in this study. The game minimized interaction effects with other variables (e.g., memory effects).

**Stimulus Video.** People were shown a video of others playing the game to keep the stimuli consistent across players. The video was not instructional and gave no hints. It featured a player playing the game and their mistake made. Each video was approximately a minute in length.

**Measures.** Player performance was measured in time it takes to play the level. Electroencephalography (EEG). EEG was collected using the Emotiv EPOC headset, featuring 14 electrodes with corresponding reference and ground electrodes for a total of 16 electrodes to collect data. The electrodes are positioned according to the 10-20 map. This study will focus of the Mu rhythm between 8-12Hz. The electrodes that overlap the motor cortex were of the most interest and only data from electrodes T7, T8, FC4 and FC5 were used. Initial notch filtering of the EEG data was done to remove 50-60 Hz interference. Data was bandpass filtered to isolate for Mu between 8-12 Hz. No further filtration was applied. Fast Fourier Transform (FFT) was used to separate and

assess the power of the different frequency bands that summate to the raw data. The average of the FFT was taken for each condition. Hemispheric alpha activity (Coan & Allen, 2004) was calculated using the absolute value of the difference of the frontal electrodes on each opposing sides: AF3, F3, F7, FC5, FC6, AF4, F8, and F4. EEG was chosen because compared to other measures, such as Galvanic Skin Response (GSR) (Cacioppo et al., 2007), it is a diverse measure. Future studies will seek to use multiple arousal analyses to give a comprehensive picture of EEG and GSR.

## Results

The results of the performance measures, and the EEG were analyzed after subtracting the baseline activity. The EEG data was analyzed using two different methodologies: Frequency analysis and HFAA. Our study seeks to assess the order effects of the stimuli on the measures. Order A is the video-first condition; order B is the play-first condition. The statistical differences between orders were analyzed using a one-way Analysis of Variance (ANOVA) procedure.

**Completion Time.** The participants' puzzle completion time was also recorded. On average participants in Order A is 9.01 seconds. Participants in order B on average completed the Puzzle in 13.55 seconds. The cumulative mean is 11.28. The ANOVA was not significant  $F(1, 95) = 3.936$ ,  $p = 0.067$ .

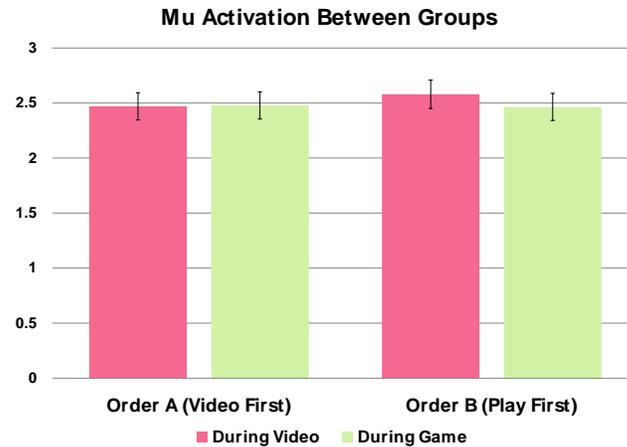
## EEG Results

**Play.** The cumulative mean of the Mu FFT for each participant in order A is  $2.48 \mu V^2$  and the mean Order B is  $2.46 \mu V^2$  during play. A one-way ANOVA revealed no significance  $F(1, 95) = 0.107$ ;  $p = 0.748$ , see Figure 4.

**Video.** The cumulative mean of the FFT of the Mu for order A was  $2.47 \mu V^2$ . In order B, the cumulative mean for Mu FFT is  $2.58 \mu V^2$ . To assess the significant difference in Mu FFT depending on order of video and task competition an ANOVA was calculated. The average Mu values of participants using Order A versus Order B were compared. The ANOVA returned a significant

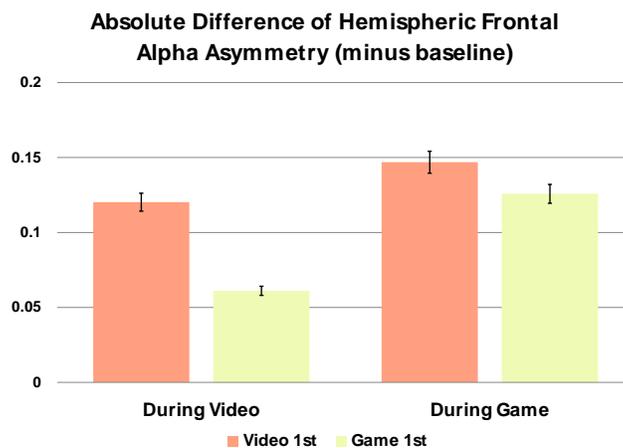
score of  $F(1, 95) = 8.183$ ;  $p = 0.013$ . The average Mu rhythm was significantly different depending on order. Order B has greater Mu activation during the video. Figure 4 shows the comparisons of the Mu frequency based on order in each experimental condition.

**Figure 4: Comparisons using frequency analysis ( $\mu V2$ )**



The above graph shows Order A and B compared using Mu rhythms.

**HFAA.** The average value of the participants' FFT for each lobe was calculated and the absolute value of the difference was taken. The ANOVA was not significant between groups during game play;  $F(1, 95) = 0.399$ ;  $p = 0.538$ . ANOVA was significant during the video;  $F(1, 95) = 20.476$ ;  $p < 0.001$  (see Figure 5).

**Figure 5: Comparison using HFAA ( $\mu\text{V}^2$ )**

The above graph shows the comparison between conditions using HFAA.

**Left Lobe.** During gameplay the HFAA in the left lobe between groups was not significant  $F(1, 95) = 0.125$ ;  $p=0.729$ . In addition,  $F(1, 95) = 0.637$ ;  $p=0.438$ . Overall, results indicated no significant differences between groups for the left lobe.

**Right Lobe.** During video between groups comparison of the means showed that the right lobe of the participants  $F(1, 95) = 5.569$ ,  $p=0.033$ . However, during gameplay significant differences between right lobe activation was not found  $F(1, 95) = 0.640$ ,  $p=0.437$ .

## Discussion

The results of the study show that the order of watching a person play and playing yourself matters, so it cannot fully support the null hypothesis  $H_0$ . Part of this might be explained by Koster's fun of gaming theory (Koster, 2005), where learning in games provides fun by trial and error. Similarly, we might enjoy figuring out a game when somebody else plays it. There was a higher rate of firing where  $\mu$  suppression was expected. According to our hypothesis  $H_1$ , this finding is surprising and warrants further study. Performance measures did not indicate differences between conditions.  $H_2$  is therefore, rejected. The HFAA results show that there is a significant difference in

arousal. However, arousal during the video may indicate either increased interest or frustration (Coan & Allen, 2004; M. J. Salminen et al., 2009; M. Salminen & Ravaja, 2008; Verona et al., 2009). Although we are able to reject the null hypothesis, H3 was not conclusive. The HFAA results indicate arousal and should be compared to another measure to best explain this. In addition, significant arousal levels during gameplay were not found (M. J. Salminen et al., 2009). If order can help players learn, then it may also be possible to add more complex mechanisms to games, because players may be better able to understand them when they shadow other players or watch them play a difficult part first. Game designers may want to consider the placement of promotional or opening videos and game videos to increase the arousal level of players.

### **Study Limitations and Future Work**

Future work should include questionnaires to compare with the EEG data (Coan & Allen, 2004; M. J. Salminen et al., 2009; Verona et al., 2009). If the stimulus is frustrating, it may be introducing a confounding variable to the study. The game used was directed to casual gamers. Future studies will study this effect with more complex games. It may be that the game chosen was simple enough, so no tutorial was necessary. Furthermore, future studies may wish to modify the tasks so that participants can play the game a third time after watching the video in the 'play first' condition.

### **Conclusion**

The study presented in this chapter reveals information on how the tutorials affect the social learning and player arousal levels, ultimately modulating the player experience. It goes beyond these findings to exhibit the use of HFAA along with other EEG techniques to make conclusions relevant to the field of GUR, further exemplifying the mixed-measures EEG HFAA approach presented in this thesis.

## *Chapter 4: Mario Party*

### **Introduction**

In the previous chapter EEG, techniques were used to assess the player experience in games using both HFAA and Mu rhythms. However, the use of EEG alone limited the analysis; using a mixed measures approach can provide more information about the valence of the arousal.

The previous chapter suggests that social learning can be simulated in games by substituting a video tutorial; additionally EEG is used to understand not only learning but also arousal in games using HFAA. Consequently using HFAA to understand arousal can facilitate an investigation of how the social condition affects the player experience in games.

Video games go beyond single-player or multiplayer gameplay. Multiplayer hand-to-hand games, such as the *Soul Calibur* series (Namco Bandai Inc., 1998-2013) prominently feature a multiplayer mode, but also have a single-player option. Additionally, traditionally single-player games, such as platform games have moved online or added multiplayer options. For example, the Sonic the Hedgehog series (Sega., 1991-2013) started as a single-player game, but has evolved to include multiplayer.

The first topic that this thesis seeks to understand is the social context or social condition of play. My question in particular is if the social context is comparable or if there are social conditions that affect the player experience more significantly.

In the study presented in this chapter, the effects of the social context in which people play are studied physiologically to better understand how player experience is affected by social context. Cardiovascular and electrodermal measures can be used to better understand the player's physiological reaction during play. Physiological measures such as EEG can be used to understand player experience by understanding the player's brain state during game events. Within EEG, HFAA can be used to better understand a participant's arousal level (Allen, Coan, & Nazarian, 2004; Allen,

Urry, Hitt, & Coan, 2004; Coan & Allen, 2004). A study by Salminen et al. (2009) explores how game events change the participant's arousal levels. The study also divides the playing conditions into cooperative and competitive gameplay. The authors use HFAA to understand the arousal levels of the player. The authors recommend more arousing games as more enjoyable (M. J. Salminen et al., 2009). HFAA was also used in a paper by Wehbe et al. (2013) which used arousal levels to understand player experience. This study is presented in chapter 5 of this thesis.

However, HFAA should be compared to a secondary measure to anchor the results because it is multivalent as shown by Verona et al. (Verona et al., 2009). For a more detailed examination of previous literature, please refer to Chapter Two.

This chapter of the thesis presents a study of social context and their effect on the player using HFAA. This technique is demonstrated in the following study and supported by the use of complimentary physiological measures.

At this point in the thesis, HFAA, Cardiovascular Measures such as Heart Rate (HR) and Heart Rate Variability (HRV), as well as, Skin Conductance (SC) are combined to better understand player experience. The study presented in this chapter explores the effects of the social setting - cooperative, competitive and artificially intelligent computer-controlled players - on the arousal and motivation of the participant - ultimately changing player experience. The study seeks to obtain information on how game designers can design games to maximize the player experience by modulating the social conditions.

Humans are always in a social environment. The social context is likely to affect the player experience. Previous literature shows that social settings can affect gaming (Chanel, Kivikangas, & Ravaja, 2012). For example, a study reported that playing against a computer can even cause players to be more aggressive than when facing human players (Williams & Clippinger, 2002). Therefore, the first hypotheses **H0** and **H1**, listed in the hypothesis section of this chapter, examine the

differences in social situations and their deviation from the control condition playing with computer controlled characters or artificial intelligence (AI).

### **Related Work**

Emmerich 2013 took a qualitative approach to understanding the effect of the social condition on player experience. Emmerich claims that the social play experience can be affected by a six of factors including the number of players present, the relationship between players (i.e. friends or strangers), the interaction imposed on players by the game itself (e.g. competition or cooperation), the communication mechanism of the game (e.g. chat versus face-to-face communication) as well as the attendance of players and spectators.

One study explores how the cooperation and competition affects player experience by creating a game that allows for consistency between game modes to make the variable (social interaction) comparable. In the game, they found that cooperation tended to inspire empathy when compared to competition, which had high positive affect and similar to the study by (Williams & Clippinger, 2002); which showed that the competitive condition had higher effect and also higher in aggression (Emmerich, 2013). The study shows that there is a measurable difference on the user experience depending on the social context. However, the study relied on self-report data.

Both, William et al. (2002) and Emmerich et al. (2013) indicate that there is an increase in aggression arising in the competitive gameplay scenarios. Therefore, **H3** assumes it is likely that competitive gameplay leads to higher arousal with more negative valence.

Additionally, studies have also shown that winning may be modulated by the social condition the player is encountering (Ravaja, Saari, & Turpeinen, 2006). The relationship may be reciprocal, motivating **H4**.

## Hypotheses

The study seeks to understand whether or not the different social playing conditions (cooperative with another player against computer-controlled players, competitive with another player while both are assisted by computer-controlled characters and alone with and against computer-controlled characters) affect player experience. For this, we measured the differences in arousal using questionnaires and physiological measures (SC, HR, and EEG).

**H0:** Social playing conditions (competitive, cooperative and computer-controlled character) will not be significantly different on any arousal tests.

**H1:** Social playing conditions (competitive, cooperative and computer-controlled character) will be significantly different on any arousal tests.

**H2:** The competitive and cooperative condition will be more arousing in comparison to the computer-controlled character condition.

**H3:** The competitive condition will elicit more negative valence in comparison to the cooperative condition.

**H4:** Winning or losing will modulate the effect of the social playing condition on arousal.

## Methodology

This study uses a three-level factorial within-participants design. Each factor level represents a different social playing condition (cooperative, competitive, and computer-controlled character). In the cooperative condition, the player's character and the confederate's character were on the same team and are competing against two computer-controlled characters. In the competitive condition, the player competes with the confederate. In this condition, the player's character is assisted by one computer-controlled character and faces the confederate, who is assisted by one computer-controlled character. In the computer-controlled character condition, the player competes against

two computer-controlled characters but is assisted by a computer-controlled character partner. In all experimental conditions, the player is seated physically next to the confederate. The confederate sits in the same place for consistency but does not interact with the player outside of the game. In all conditions, the confederate was instructed to keep social interactions to a minimum (talking, instructing) and only respond to the player briefly if addressed. The play style of the confederate was consistent with the same number of mistakes made each session and using the same difficulty setting. The study was designed this way to reduce the inconsistencies between conditions by having the same consistent confederate and using the same game. However because the player is always playing the same game, it may be possible that the player is able to learn and get better at the game (i.e., learning effects). Although learning effects could possibly influence the validity of the study design, they were minimized by randomizing the conditions.

**Participants.** In total, 32 participants were invited to participate in the study. Two participants were excluded because of equipment failure, leaving a total of 30 participants: 15 female and 15 male. The average age of participants was 21 years, ranging from 18- 34 years (since participants had to be 18 or older to participate). All participants reported that they have been playing video games for over five years. The majority of participants (all but one) identified playing games every day. The majority of participants reported playing greater than one but less than two hours a day.

Due to physiological data collection problems, some of the conditions did not have usable physiological data (problems with sensor recordings). Some participant data were excluded from the EEG analysis, leaving the data of 23 participants. Only participants who had data collected for every condition were used in the final analysis.

**Mario Party History.** In total, participants reported playing Mario Party once a month or less. Additionally, only five out of 30 participants reported having played the stimulus game before.

**Game.** The game used for the study was *Dungeon Duos*, a mini game in Nintendo's *Mario Party 4* game. The game was originally released for Game Cube, but was played on a Nintendo Wii in the experiment. The game features two opposing teams: On each team, players have to cooperate to pass safely through obstacles in the fastest way possible. The fastest team escapes the dungeon and wins the race. The computer-controlled characters were consistently set to easy difficulty.

**Environment.** The lab was set up to be ecologically valid. As a result, the room simulated a living room with carpet and pastel paint. The participant was comfortably seated on a couch in front of a coffee table, which faced the television set and game console.

**Measures.** To better understand the effects the game had on the participant, different physiological sensors were used to understand the participant's physiological state during gameplay. All measures that were used can provide information on the participant's level of arousal: SC, HR, and EEG sensors. To anchor these results the participants were also given the Self Assessment Manikin (SAM) (Lang, 1980a).

**EEG.** The ANT ASA system that was used for the collection of EEG data in this study features a 64-channel gel-based electrode cap and a 2048Hz sampling rate. An ANT-Neuro ASA system was used to collect data from the frontal electrodes for comparison in HFAA. The electrodes are arranged according to the 10-20 system described in chapter 2. The electrodes used correspond to the frontal lobe on opposite sides of the head in order to be compared in HFAA. The electrodes used are: FP1, AF7, AF3, F7, F5, F3, F1, FT7, FC5, and FC3 in comparison to FP2, AF4, AF8, F2, F4, F6, F8, FC2, FC4, FC6, and FT8 on the other side. HFAA was used to understand the arousal of the participant (Coan & Allen, 2004; M. J. Salminen et al., 2009; Wehbe et al., 2013).

**Heart Rate and Heart Rate Variability.** A Nexus 2 Mark 10 device was used to obtain physiological signals using silver electrodes with a 256 Hz sampling rate. Heart rate (HR) was

collected by placing sensors along the arms. For the raw data both HR and HRV were calculated for each condition to understand the arousal.

**Skin Conductance.** The Nexus system was also used to measure skin conductance with a 256Hz sampling rate. Electrodes were placed on the ring and pinky finger of the participants. The skin conductance level of the participant was used as another measure of arousal in this study.

**SAM.** The Self-Assessment Manikin (SAM) (Lang, 1980b) was used to better understand the participant's perception of their perceived dominance, pleasure and arousal. The questionnaire uses five visual representations across a nine-point scale. Combinations of this survey can help the player report how they are feeling. For example, a low pleasure but high arousal score may indicate frustration. The questionnaires are important, not only because they give us a self-reported measure of arousal, which acts as a point of reference for the physiological measures, but also because they indicate the valence of the arousal.

**Protocol.** Participants were walked through the study by the experimenter. They were shown the equipment and were reminded that they were free to withdraw at any time, that the data were anonymous and the study data were analyzed as part of a large group statistic. Then the participants read and signed the consent form. A copy of the consent was given to the participant for their records. After agreeing to participate, they were asked to fill out an online survey, which collected information about the participants' demographics, gameplay history, and history playing the Mario Party games. Participants were then set up with the physiological equipment. All equipment (EEG, SC, and HR) recordings were started at the same time to sync the recordings. Participants then played the game and the Self-Assessment Manikin (SAM) was administered in between. The order of conditions followed a Latin square design, where wins and losses were noted. Upon completion of the gameplay, the participants were given a brief exit survey and thanked for their participation.

## Results

Arousal was studied using EEG, Mean Heart Rate (HR), Heart Rate Variability (HRV), Skin Conductance Level, and the Self-Assessment Manikin (SAM) questionnaire.

**HR.** The changes in mean HR were investigated by social condition. A within-participants, general linear model repeated-measures analysis was conducted. The analysis of variance (ANOVA) was used to assess significant differences between the experimental conditions. Before conducting the ANOVA, the sample was checked using Mauchly's test of sphericity. This test ensures that the variances are equal for all possible comparisons and is a fundamental assumption of the within-subjects ANOVA. Mauchly's test of Sphericity  $X^2(2) = 22.952, p = 0$  was violated, and therefore, the within-subjects ANOVA was corrected with a Greenhouse-Geisser estimate.  $F(1.201, 26.430) = 1.614, p = 0.218, \eta_p^2 = 0.068$ . Thus, the mean HR was not significantly different between the conditions. In other words, all conditions elicited HR that was statistically similar.

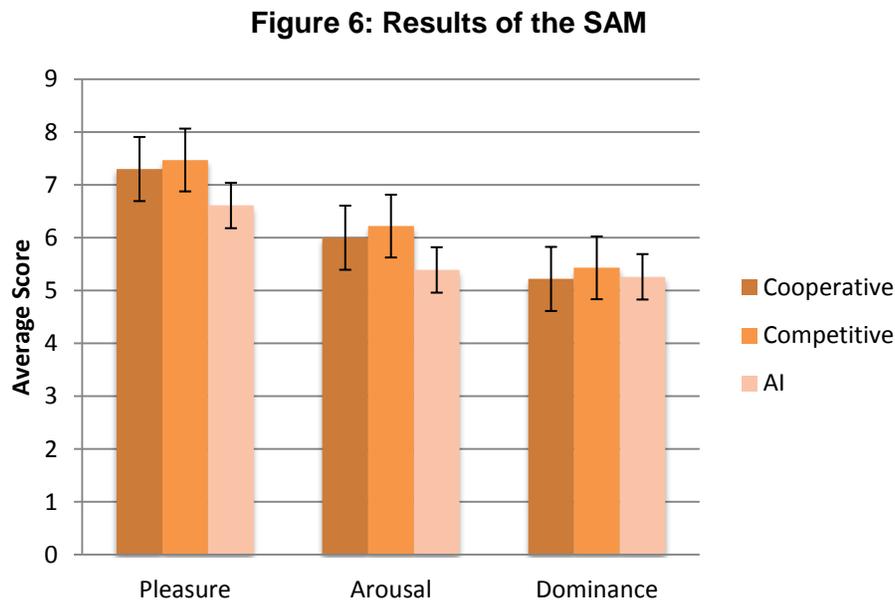
**Heart Rate Variability.** This data was also analyzed using a within-subjects ANOVA. The data also violated Mauchly's test of Sphericity  $X^2(2) = 39.442, p < 0.000$ . Therefore, the ANOVA was calculated using Greenhouse-Geisser estimates.  $F(1.083, 23.821) = 0.658, p = 0.437, \eta_p^2 = 0.029$ . Therefore, the HRV was significantly different between the experimental conditions.

**Galvanic Skin Response.** A within-measures ANOVA was also calculated for GSR. The data also violated Mauchly's test of Sphericity  $X^2(2) = 107.928, p < 0.000$ . The ANOVA with Greenhouse-Geisser correction was again not significant  $F(1.003, 22.065) = 1.059, p = 0.315, \eta_p^2 = 0.046$ .

**EEG.** HFAA was calculated from the raw data. The data was exported from the ASA software after using the FFT function to divide the waves into their component frequency bands. Using Matlab, the electrode data were divided into right and left hemisphere, having the baseline subtracted (as well as logarithmic normalization of the data). The final calculation used was:

$\ln R - \ln L = \ln (R/L)$  in accordance with Allen, Coan, et al., (2004); Coan & Allen, (2004). The data was then analyzed in the IBM SPSS statistics software using a repeated measures general linear model because of the within participants 3-factor design. The data for three different social playing conditions (computer-controlled, cooperative and competitive) were calculated using HFAA. Mauchly's test of sphericity  $X^2(2) = 3.746, p = 0.154$  was not violated and sphericity was assumed. The test of within-participants effects with sphericity assumed was not significant,  $F(2, 44) = 0.661, p = 0.521, \eta_p^2 = 0.029$ .

**SAM.** The Self-Assessment Manikin (SAM) was used to get a self-reported measure of arousal. Figure 6 shows the results of the SAM.



The above graph shows the results of SAM by condition.

**Pleasure.** The data were run with a repeated measures (RM) ANOVA. Mauchly's test of sphericity was not significant,  $X^2(2) = 3.693, p = 0.158$ . The ANOVA resulted in  $F(2, 44) = 3.021, p = 0.059, \eta_p^2 = 0.121$ . The pleasure dimension was not significantly different between conditions.

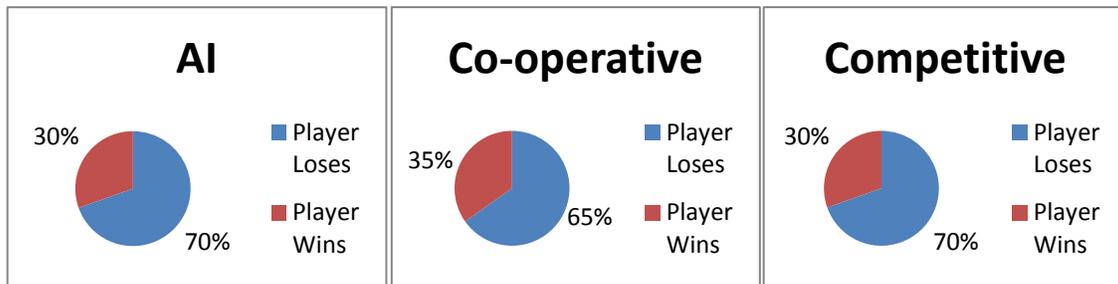
**Arousal.** Arousal data were tested for significant differences using an RM ANOVA.

Mauchly's test of sphericity was not significant,  $X^2(2) = 6.827, p = 0.033$ . The RM ANOVA was also not significant,  $F(2, 44) = 3.847, p = 0.29, \eta_p^2 = 0.149$ .

**Dominance.** The data were analyzed with a RM ANOVA. Mauchly's test of sphericity was not significant,  $X^2(2) = 1.250, p = 0.535$ , neither was the RM ANOVA,  $F(2, 44) = 0.113, p = 0.893, \eta_p^2 = 0.005$ . Therefore, there is no significant difference between conditions and feeling of dominance.

**Winning and Losing.** This study also explored the effects of winning and losing on the arousal and motivation of the participant. The results are summarized in Figure 7.

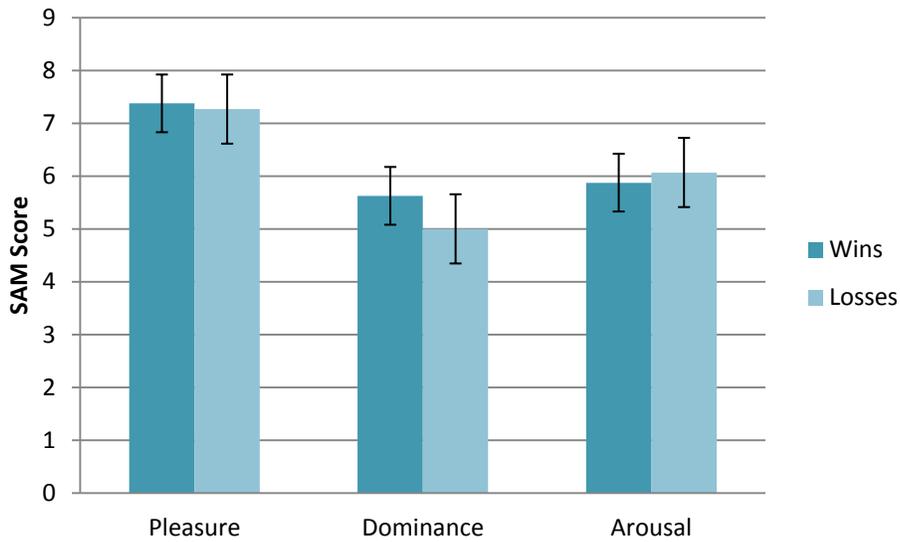
**Figure 7: Wins and Losses by Condition**



The above pie charts show the ratio of winning and losing by condition.

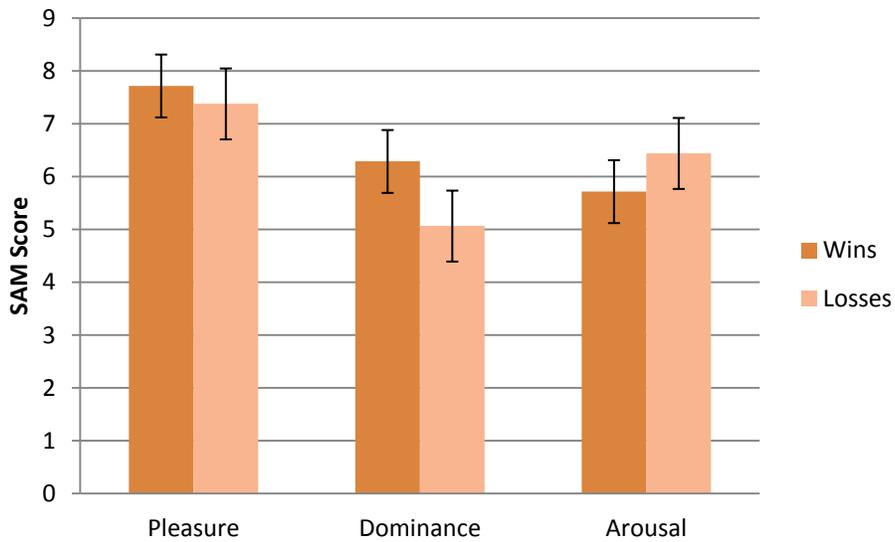
The results of the SAM were looked at for each condition. As stated above no condition had significant differences between groups. Figure 8, Figure 9, and Figure 10 summarize the results of the SAM and wins and losses per condition.

**Figure 8: Average Wins and Losses and SAM Responses for the Cooperative Condition**



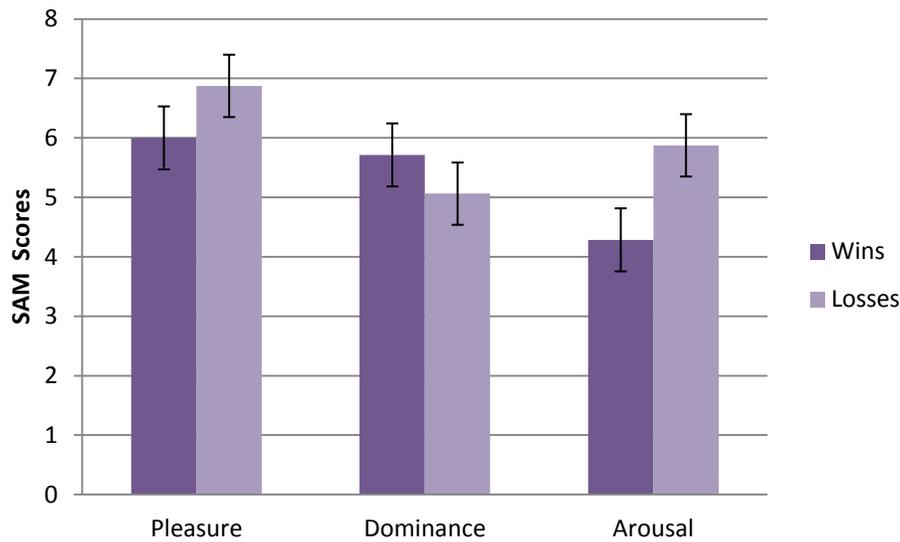
The above graph shows the comparison between the SAM responses and success of the player in the cooperative social condition.

**Figure 9: Average Wins and Losses and SAM Responses for the Competitive Condition**



The above graph shows the comparison between the SAM responses and success of the player in the competitive social condition.

**Figure 10: Average Wins and Losses and SAM Responses for the Computer-Controlled Player Condition**



The above graph shows the comparison between the SAM responses and success of the player in the computer-controlled social condition.

## Discussion

The hypotheses examined the differences in arousal per social condition. According to **H1**, there would be a significant difference between social conditions. **H2** stated that there would be a significant difference in comparison to the computer-controlled character condition. Additionally, **H3** highlighted a significant difference in negative valence in the competitive condition versus the cooperative condition. However, since no significant differences were found between conditions for any test of arousal, the study failed to support any of the formulated hypothesis. The results found no significant differences in arousal between playing with computers and playing with human players in a cooperative versus competitive setting, which supports **H0** that there are no differences between the experimental conditions. Thus, it does not matter from a perspective of player arousal whether or not the players play together cooperatively or competitively or against a computer-controlled character. This is a somewhat surprising result that could be attributed to either the general fun factor of the Mario Party mini-game (everything is equally exciting) or the use of an easy

difficulty in the study (without a significant challenge from the computer, we do not witness arousal stemming from possible frustration). On the other hand, each condition includes computer-controlled characters in some cooperative or competitive form, which might result in equalizing any skill-based discrepancies between players that we might have been able to witness otherwise.

The literature in the field has shown there to be a reported difference on measures such as self-reported enjoyment and aggression between playing with a person compared to playing with a computer controlled character (Emmerich, 2013; Williams & Clippinger, 2002). Therefore, this study sought to show this difference objectively using arousal. However, the results of this study show that there is no difference in the physiological arousal state of the player between conditions. Neither condition in our experiment is more arousing.

In addition, the literature supports that the relationship with the person that the player is interacting with impacts the player (Ravaja et al., 2006). However, according to the results of our study, player arousal did not change when playing with a human or playing with a computer. Further research is thus needed to determine whether it is specifically playing against a stranger that does not differ from playing with a computer-controlled character. In other words, further research is needed to determine if the same effect would be found among friends. Possible differences may be found with friends considering that the previous history of interactions, shared humor as well as comfort may contribute to the social experience.

According to the results of this study, physiologically it does not matter if the game is competitive or cooperative. Neither condition is more exciting. Therefore, game designers may want to consider reducing the cost of production further by being frugal with the gameplay options available. Designers may instead choose to focus one player mode intently instead of making a multiplayer mode available. This has been successful in past games, but can be complicated from a gameplay perspective depending on the game genre that the game is being developed for.

Often, game production comes down to resources and time management. Poor time management and adherence to design can lead to last minute design additions or *feature creep*. Feature creep can also occur as last minute addition designers implement to stay competitive. This practice can cause resources to be spread too thinly and delays in production (Brathwaite & Schreiber, 2009). If designers were to consider the findings of this study, they may feel more comfortable using their limited resources to create well thought-out multiplayer and single player components instead of attempting to simultaneously produce single player and multiple player game components. Therefore, if designers plan to create multiple gameplay modes, the design team should decide before production of the game is well underway. Design decisions should not change due to feature creep. By both planning outright and adhering to findings from the GUR community game designers increase the game's likelihood of success.

Additionally, the designers should consider the cost of production when they design games that include computer-controlled players. Computer-controlled players can increase the production cost but they allow players to play single-player modes in the absence of friends. A game with only human players is less costly to create, because they can avoid programming computer-controlled players, but this limits the gameplay. Additionally, in a game with no computer-controlled players, the human player must find friends to play the game with, producing a waiting time before the game can be played. However, a game incorporating both computer-controlled and player-versus-player gameplay has the advantages of both modes, but increases the cost and the length of production. Therefore, the decision to add multiple game modes is important to both the cost and success of a game. Additionally, playing with other players is thought to create a different experience. However, if a social condition does not change the arousal of the player, game designers may be able to base their game design by cost versus benefit. Therefore, instead of adding both multiplayer and single player modes, they could settle for only one of those modes, likely leaving player experience

unchanged. To understand if this is the case, a follow up study is necessary. Chapter Four extends the current study to understand the effects of the player's expectations on the player experience.

If participants are reporting a difference between playing with friends and playing computers, then the question becomes: why are the results of the study inconsistent with the self reports of players playing the game? Fundamentally, if the players report a difference between playing with computers versus playing with other players then the study is inconsistent with the literature's fundamental reports of player's reported experiences. Future studies may uncover whether or not this reported difference can be seen physiologically, or if it is a *placebo effect* or an effect only arising from the expectations of the player.

### **Limitations**

The study seeks to understand a player's level of arousal to draw conclusions about player experience. This is in accordance to the literature, which studies arousal as an indicator of excitement. The premise is arousing games are more exciting (Kivikangas et al., 2011; M. J. Salminen et al., 2009). However, all permutations of the environment, game choice and study design are not explored. The study conducted in this chapter only explores conditions where the human confederate was seated beside the player and did not explore permutations, such as playing online.

Furthermore, to better understand the results of this study, other controlled conditions may be explored. To compare between cooperative and competitive gameplay it may be insightful to use a non-gaming control condition. By changing the control condition to a non-gaming condition the researcher can test the validity of the stimulus. In other words, the research can assess if the game is arousing before testing the social contexts.

Also the study conditions (cooperative, competitive and computer-controlled) always had at computer-controlled players present, which may be a potential confound. However, having the computer-controlled players ensured consistency between the single player (computer-controlled)

and multiplayer (cooperative and competitive) conditions. Furthermore, there was only one game selected for use in the study. Further research using different games may yield different results.

Additionally, the confederate in the study was instructed not to communicate with the player during gameplay, but simply to answer and to provide instruction when needed. This was to ensure consistency between participants. However, the interaction between people when playing a game, such as trash-talking or encouragement can be more arousing in a non-laboratory environment. Therefore, this problem with ecological validity may have affected the outcome of the study. Notwithstanding, if the confederate was instructed to show enthusiasm, then it may have caused a confounding factor in the study: the player's arousal may have originated from the competitor and from not the game itself. Because of this, follow-up studies may wish to seat the confederate separately from the participants to minimize interaction and reduce possible confounds. However, the removing the confederate from the room will not emulate co-located play, so this could change the intent of the research from that which was introduced in this study.

## **Conclusion**

The above findings show that there are no physiological differences in arousal between playing with friends or computer characters competitively or cooperatively. In addition, the study shows no differences in playing with humans versus playing with computers. This finding is of value to the game design community when considering that different game modes are equally arousing and might not be necessary. In addition, the study is of interest to those studying games, because the results indicate that there is a possibility that both playing with people and playing with computers is only a difference of expectation but not a difference in experience.

## *Chapter 5: Perception of Human versus Computer Controlled Players in Games*

### **Introduction**

The previous study results were unexpected. The participants seemed indifferent to the presence of computer-controlled versus human players. As a result, this chapter focuses on a follow-up study. This study was run to follow up and better understand if the presence of human players mattered or if just the expectation of human players was a key factor in the physiological state of the players.

To understand the player's arousal through the brain waves that are part of the physiological state of the player, HFAA is combined with other physiological measures (heart rate and skin conductance level). These measures compliment the methodology by verifying the EEG findings. The methodology was double-blinded, meaning the acting experimenter did not know the true hypothesis of the experiment. Double-blinding the experimental team reduces bias to test a hypotheses following from the previous study.

To further understand the player's thoughts and feelings, this study also explored using a qualitative measure in the form of interviews. In contrast to quantitative measures, qualitative measures provide rich information about each individual player's thoughts and feelings. The rich information extracted from the interviews compliments the quantitative EEG measure. It allows researchers to synthesize all information to better understand the player. The two results are complimentary due to their different strengths and weaknesses.

Major game console publishers are focusing on online multiplayer experiences in this console generation. Multiplayer gaming is a market of growing importance. However, it is currently not well understood how the experience of a player changes whether the perceived partner is human or computer. In this chapter, I and other researchers investigate whether the social aspects of playing

with other players moderates the player experience or whether only the idea of playing with other players moderates the individual player experience and the perceived sociability of the game. Additionally, we question whether computer-controlled players are less desirable because of their perceived intellectual limitations, which can limit the feelings of togetherness and perceived sociability.

### **Related Work**

The study in this chapter seeks to understand how the perceived social condition changes the player experience of the game. Previous research has come close to understanding this question.

Research has shown that there are advantages to playing against humans, especially friends. Playing games with friends was shown to change player experience. Researchers studied the effects of other human players versus computer players on presence, flow and enjoyment (Weibel, Wissmath, Habegger, Steiner, & Groner, 2008). The findings from this study showed an increase in all three experience factors (flow, presence and enjoyment) when playing with a human versus a computer. The researchers convinced users that they were indeed playing against the opponent that they expected to play against. The experimenters verified that the players believed the experimental condition specified. Their study found significant results for presence, flow and enjoyment.

However, the question remains whether these factors are dependent on presence of the human players or if they are linked to a player's expectations when interpreting a gameplay situation. The study also uses only questionnaires, which are self-reported measures. The current study examines the physiological condition of the player to understand the changes in player experience.

In another study, spatial presence and emotion of the player were examined as a function of the player's opponent. Differences found were claimed to be a result of changes in attention and arousal (Ravaja et al., 2006).

**Sociability.** De Kort and Ijsselsteijn (2008) review literature on human interaction related to video games and sociability of games. The authors considered literature on emotion, arousal, behaviour and human-computer interaction to understand the factors of playing (i.e., playing a digital game) with another person. The researchers state that gaming with another person can influence the player experience because of factors such as involvement in another person's social group or social affordances allowed through the interaction. The authors discussed the differences between players being co-located and having a mediated interaction in their paper. In other words: if the players are in the same place or not. The authors assess the influence of an environment for co-located play to understand its effectiveness. For example, if the players are co-located but not situated in a traditional face-to-face interaction model.

Stenros, Paavilainen, and Mäyrä (2009) explored the sociability of single-player, two-player, multiplayer and massive online multiplayer (MMO) games. The authors discuss how games - from online to traditional board games - embody social rules as well as rules of the game. For example, a player losing a game is still socially obliged to see the game through to its end. The authors also mention that logically a player losing the game should not care who among the remaining players wins, yet they still do. The authors also described a one-player game as being non-individualistic. They argued that in one-player games there is still an awareness of other people playing the game and of their progress – whether playing in parallel or playing as a performance scenario. Furthermore, the awareness of other people may make it a competitive scenario, which they describe using the terms "gaming capital" and "status".

In the same paper, the authors discussed games intended for two players and considered the organization of the environmental space facilitating gaming as well as timing of the game. For example, the researchers questioned how playing from different places at different times affects player experience.

Additionally, in multiplayer games the interaction may change the social environment. The social environment is defined by the authors as cooperation, competition and collaboration, where collaboration is a temporary state of cooperation in a competitive environment. The authors discuss classifying these environments as either always 'antagonistic' or as having an antagonistic end goal, which requires short term cooperation or complete collaboration. The authors examine how to some extent there is always some form of collaboration required to play the game but that the play style does not strictly depend on game mechanics and players can choose their own strategy. Games are never strictly a certain type of social experience (Stenros, Paavilainen, & Mäyrä, 2009).

Researchers have also examined the differences of players' psychological states using galvanic skin response (GSR), cardiovascular measures, respiratory measures and electromyography of the jaw. GSR was used to understand players' arousal through the activation of the sweat glands in the skin. Cardiovascular measures were used to understand the valence of the arousal as well as the stress response of the participants. Respiratory measures were used to understand emotional arousal and facial EMG was used to evaluate emotional responses during gameplay. The researchers studied players' physiological responses to better understand their gaming reactions. Researchers found a difference in players' physiological states when playing with humans versus playing with a computer (Mandryk, Inkpen, & Calvert, 2006).

**Sociability and Physiological Measures.** Understanding the sociability of players is a complex matter. The study presented in this chapter investigates player experience while gaming to determine if changes in social conditions affect the player. Additionally, this study investigates how a player's perception of the social context changes how they are experiencing the gameplay. Arousal has been reported as important to player experience (Salminen et al., 2009) as well as sociability (Ravaja et al., 2006). Therefore, the study in this chapter will focus on measuring arousal using physiological measures. Arousal has been used to better understand player experience. In a study by

Salminen et al. (2009), HFAA was used to better understand the effect of game events on players. The researchers suggest that more arousing game events will be more exciting to the player and modulate player experience (Salminen et al., 2009). HFAA was also used by Wehbe et al. (2013) to assess the effect of gaming conditions using a between-participants design. HFAA can be used to understand arousal together with valence, and has been used to determine negative valence and arousal before (Verona et al., 2009). Nacke et al. used skin conductance as well as heart rate to understand arousal (L. E. Nacke et al., 2009; L. E. Nacke, 2013). Additionally, the self-assessment manikin (SAM) are also be used to understand arousal as part of player experience assessment reports (Mirza-Babaei, Nacke, et al., 2013).

## **Hypotheses**

This study presented in this chapter used a double-blind methodology to understand the effects of the condition or treatment on the results.

The research question whether being told that the opponent is another human player has the same effect as playing with another human player. In other words: is playing with someone is the only way to affect player experience or can a placebo effect be caused by telling a player that they are playing with another player (when in fact that are really playing with a computer)? The research question here asks if the treatment (playing with a human) is really the cause of the difference in player experience or if the idea alone causes the effect.

The following section outlines the methodology to test this research question. In this experiment, the treatment condition is informing the player that they are playing together with humans. The placebo group is told that they are playing together with humans but are instead playing together with computers.

The methodology mirrors the design of a drug trial. In a drug trial, there are three groups. The first group (control) progresses without any treatment. The second group (placebo) is given a sugar pill or inert substance. The last group (treatment) is given the new drug to be tested. Comparisons are made between groups to assess the effectiveness of the treatment by comparing it to no treatment (control) and by controlling for the expectations associated with doing a treatment (placebo).

**H0:** There is no difference between conditions. Treatment equals control.

There is no effect between people playing together with a computer and people playing together with other players. Psychological arousal measured using HFAA is not significantly different between all conditions.

**H1:** The placebo condition will equal the control condition. Treatment is effective.

Players that are told they are playing with another human player will rate the experience the same as playing with a computer-controlled player or vice versa. Therefore, treatment is effective and no placebo effect is observed. Arousal is not significantly different for the control group and the placebo group.

**H2:** The placebo condition equals the treatment condition and therefore, the placebo effect is observed and the treatment is not effective.

Participants rate playing in the placebo condition (i.e., thinking they are playing with humans, but actually playing with computer players) as higher in player experience than playing in the control condition (where they are being told they are playing with a computer) or in the placebo condition as being equal to the treatment condition (actually playing with human player). Therefore, a placebo effect is observed and treatment is not effective. Arousal in this condition is not significantly different than the treatment condition.

## Materials and Methods

### Setup

To test the hypotheses stated above, the study employs a double-blind between-participants design. The placebo group corresponds to the player *expectation*. The 30 participants were divided into 3 groups:

- Group 1 = Computer-controlled players (play with computer-controlled players and told they are playing with computer-controlled character);
- Group 2 = Placebo (play with human players or computer-controlled characters, participants told were given false information about the true nature of their companion characters);
- Group 3 = Human-controlled players (play with humans, participants are told they are playing with humans);

**Protocol.** First, participants were given a walk-through of the experiment and all questions they had were answered. Informed consent was obtained. Participants were asked to fill out a questionnaire so that we may better understand the demographics of our participant population. They were then asked to play a game while wearing a 16-channel wireless EEG headset (Emotiv EPOC), galvanic skin response sensors and heart rate sensors (Nexus 10 Mark II). Participants

played Valve Corporation's *Left 4 Dead 2* online with three other non-participant players (confederates).

The study featured a control group, a placebo group and a treatment group. In the control group, there was no deception of participants. Participants were told they are playing the non-treatment condition. The placebo group was told they are playing the treatment condition but in reality they were running the same treatment as the corresponding control group. The treatment group was correctly informed that they are playing the treatment condition.

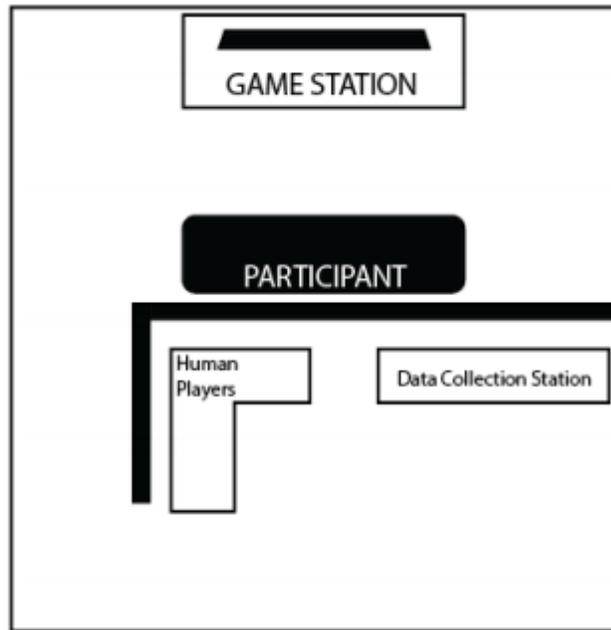
Following the gameplay, participants were asked to fill out a SAM questionnaire. Participants were interviewed, debriefed, given a cool down period and thanked for their time. The study was reviewed by the UOIT Ethics board and approved. Protocol outlined in the documentation was followed rigorously.

**Controlled Experimental Setup and Communication.** To control for confounding variables, participants were seated apart from three human players (confederates). No verbal, chat or out-of-game exchanges were allowed between players and confederates. All players were asked if they were ready before playing – with the exception of conditions, in which participants were told they were playing with the computer. Following this, the human confederate players played the game. However, the human players and the participants were not always in the same game. The confederate human players and participant players may play in the same game or in two separate games depending on the experimental condition. The human confederates were needed in all conditions to control the environment and protect against confounds, such as having observers in the room. Confederates were also used to enforce the information that players are given (e.g., when a participant is told they will be playing with human players).

Specific game events were scripted, such as activating car alarms, startling witches (in-game enemies that are strong), acquiring health packs, or encountering special infected enemies (with

special abilities that make them harder to defeat). This was done to ensure consistency across participants. See Figure 11 for the room layout used in the experiment.

**Figure 11: Room Setup**



The above drawing shows the layout of the room.

**Double Blind Methodology.** To reduce experimental bias and other confounding variables a double-blind methodology was employed. In other words, the experimenter, who directly interacted with the participants, was not aware of the experimental hypotheses. Instead, the experimenter was told that there were only two conditions: computer controlled (AI) and human controlled player condition. The experimenter made notes on the amount of interactions with game characters and events. The closing interview and debriefing was done by a second experimenter, whose primary role was to set up the game and to lead the confederate play team.

**Game and Modifications.** We used *Left 4 Dead 2* (L4D2) played on Steam (Valve Corporation) as a stimulus. The game is a first person shooter (FPS) that involves four players

escaping from the zombie apocalypse. The game is rated M for violence and only participants 18 years and older were invited to participate.

The researchers added a modification<sup>11</sup> to ensure that the game protocol did not indicate the social environment. Therefore, ensuring the placebo was not revealed. These modifications included not ending the game if the participant's character dies.

Additionally, the characters' names were always their default character names (i.e., no Steam player names were used). This ensured that player names did not reveal the placebo condition.

**Confederate Play-Style and Instructions.** Human players were of different skill levels. They played consistently (i.e., their gameplay actions were enacted) and were told to make the same mistakes every time. One player acted as beginner, one as intermediate and one as an advanced player. They were told to activate game events, such as startling the witch in the game or triggering car alarms. They were asked to stay within range of the player because of the team-like nature of the game. Players were asked not to communicate with the participant in any way. To keep background activity constant, if the confederated were not playing with the participant, the confederates would still play L4D2 on their own server.

**Participants.** A total of 33 participants were asked to participate, three were excluded due to equipment failures. After excluding participants, the study consisted of 15 males and 15 females. All participants were over the age of 18. The mode age range was 20-24. Ages ranged from 18 to over 45+. Skill level or experience with the game was not an exclusion criterion.

Out of the thirty participants not excluded, two identified themselves as complete beginners, four as novice players, four as moderate, nine as intermediate, eight as advanced, and three as skilled. Twenty-five participants were PC gamers, and twenty-five claimed to have at least one game console

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<sup>11</sup> Dziggy (n.d.). Improved Bots (Advanced) <http://www.l4dmaps.com/details.php?file=15461>

in their household that they use regularly for games. Sixteen participants had played a first-person shooter game before, and twenty-four participants played at least one other genre of games.

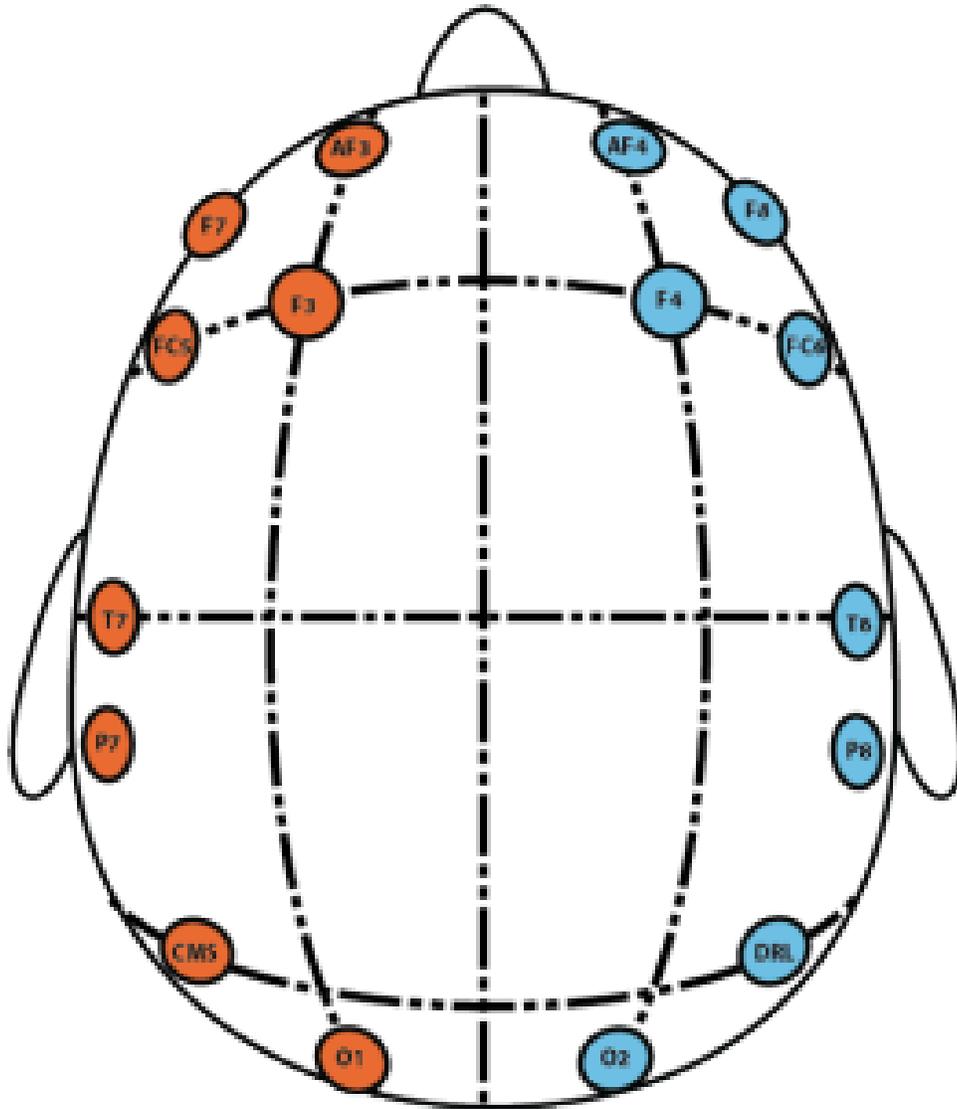
Fourteen of the participants had previously played *Left 4 Dead 1*, while another fourteen – with some overlap – also played *Left 4 Dead 2* prior to participating in the study.

### **Measures and Equipment**

**Electroencephalography (EEG).** EEG was collected using the EPOC Emotiv headset. The Emotiv is a 16-channel EEG headset, which uses saline solution and is referenced using Driven-Right Leg (DRL) and Common-Mode Sensing (CMS) references. See

Figure 12 for electrode map. The electrode placement corresponds with the 10-20 system. By default the sampling rate of the Emotiv is 128 Hz.

Figure 12: EPOC Emotiv Electrode Map



The above drawing shows the EEG map of the EPOC Emotiv headset with the electrodes labeled.

HFAA will be used to better understand player experience. To properly interpret the results, HFAA findings will be compared to other measures including questionnaires, skin conductance and heart rate measures.

*Hemispheric Frontal Alpha Asymmetry.* Since HFAA compares the left side to the right side of the scalp, the electrodes were analyzed depending on their spatial orientation on the cap. For the left side of the scalp, electrodes used were: AF3, F3, F7, and FC5. The right side used AF4, F4, FC6, and F8. HFAA was calculated by converting the '.edf' files to '.cvs' and analyzing the data in Matlab. Matlab was also used to remove blank rows – a rarely occurring artefact sent from the Epcoc. The data was filtered using band pass filtering from 8 to 13Hz to separate the alpha band, which is of interest in this analysis technique. Then a Fast Fourier Transform (FFT) was applied to the data to separate the EEG into frequency bands. Alpha was defined as 8-13Hz (Cacioppo et al., 2007). After the natural logarithm was taken to each side as explained by Allen, Coan, & Nazarian (2004):  $\ln R - \ln L$  which equates to  $\ln (R/L)$ . To understand the differences between the two brain hemispheres (Allen, Coan, et al., 2004; Allen, Urry, et al., 2004; Coan & Allen, 2004), the data was also calculated as absolute differences between the two lobes.

**Questionnaires.** An initial survey was used to collect information about player demographics, player gaming history, and experience with first person shooters, and L4D2. The full demographic questionnaire can be found in the Appendix.

The Self-Assessment Manikin (SAM) was administered at the end of the play session. The SAM was used to better understand participants' emotional state. The SAM asks the player to rate themselves on a Likert-type scale accompanied by visual representations of the emotional state. The player is asked to rate their level of pleasure, arousal, and dominance.

**Skin conductance and Galvanic Skin Response (GSR).** To measure arousal levels skin conductance, specifically galvanic skin response (GSR), was used. Data was collected using the

Nexus 10 Mark II system, which uses silver electrodes. Electrodes were placed on the middle of the player's ring and little finger on the right hand.

**Heart Rate.** Heart rate was also measured using the NEXUS 10 Mark II, silver electrodes. Heart rate data was obtained using a setup along the arms of the participant.

**Interview.** The interview focuses on the thoughts and feelings on the player regarding the social experience as well as their perception of who they thought they were playing with. The interviewer also asks about their thoughts and feelings following the reveal of the condition in a placebo group. The researchers are interested in knowing in retrospect does the debriefing change their player experience. For example one of the questions was: “Do you believe [who you were playing with] affected your level of enjoyment in the game?” and “who do you believe you were playing with?” The full questionnaire can be found in the Appendix.

**Observations.** Observations were recorded during the session. Participant's verbal interaction with the game and spoken reactions were recorded. Actions of particular interest included attempted discussion with received human or computer-controlled character teammates.

## Results

**Number of special infected appearing.** The number of special infected computer players is a non-controlled variable generated by the game. therefore to check for an significant changes in difficulty the number of special infected computer players appearing was compared per condition using an Levene's test (significance =0.342) and ANOVA was not significant  $F(2, 27) = 0.422$ , significance = 0.660; both tests showed non-significance, therefore no significant differences were present per condition.

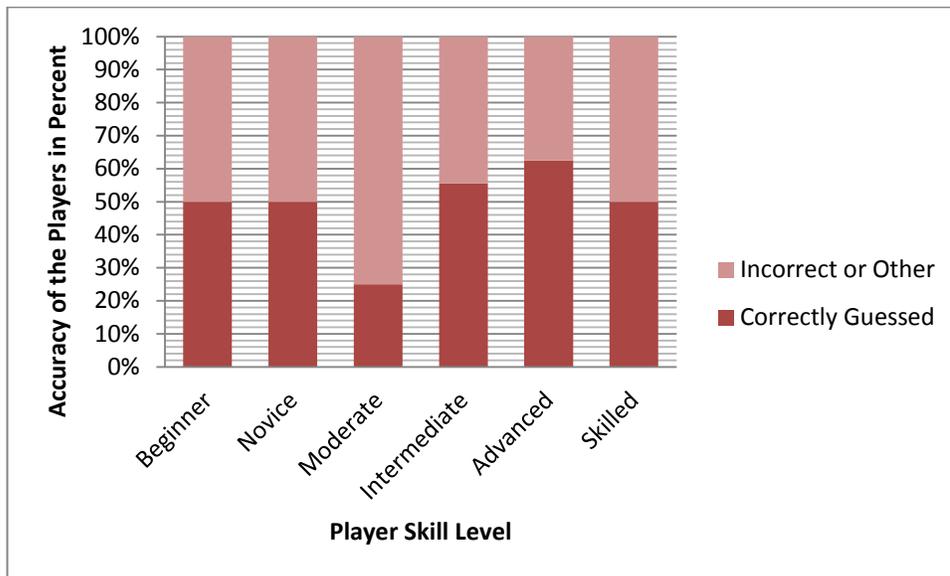
**SAM.** For each variable, the Levene's test was calculated. The Levene's test checks for equality of variance between groups, which is an underlying assumption of an ANOVA. The violation of a Levene's test indicates that there needs to be corrections due to the unequal variances.

Levene's test was not significant for arousal (0.997) or dominance (0.569). Pleasure shows significance (0.023). A one-way ANOVA was conducted for arousal  $F(2, 27) = 0.293$ , significance = 0.748 not significant. Dominance  $F(2, 27) = 0.006$ , significance = 0.994, therefore not significant. In One-way ANOVA of pleasure was also not significant  $F(2, 27) = 0.663$ , significance = 0.523. **HR and HRV.** The Levene's test was not significant for HR significance = 0.494. However the ANOVA was not significant between groups  $F(2, 27) = 0.992$ , significance = 0.384. The Levene's test was not significant for HRV (significance = 0.304). Additionally, the ANOVA for HRV was not significant  $F(2, 27) = 0.155$ , significance = 0.585.

**GSR.** Mean GSR Levene's test was also not significant (significance = 0.151). The ANOVA was also not significant  $F(2, 27) = 1.701$ , significance = 0.201.

**EEG.** Levene's test for the ln R- ln L score was not significant (0.07). However, the ANOVA was not significant  $F(2, 27) = 2.382$ , significance = 0.111.

**Skill Level and Ability to Guess.** To better understand if skill level affected the player's ability to accurately guess the social condition, the skill level of players was compared with accuracy of guesses. Guesses were sorted into correct or incorrect, indecisive or other. One participant noted as "Other" felt sure of their assumption regarding who they played with; until their belief was challenged in the interview, at which point they became unsure and considered both possibilities. See Figure 13 below.

**Figure 13: Players' Ability to Guess by Skill Level**

The above graph shows the players ability to guess who they were playing with by skill level.

### Interview

**Participant Preferences.** Participants were introduced to the interview gently with the first question asking about their preferences regarding computer-controlled versus human-controlled players (friends or strangers).

Participants in this experiment mainly answered that they prefer to play with their friends (17/30). Participants stated various reasons for their choices ranging from enjoyment to trust levels. One participant stated that they feel guilty playing a game alone when they could have played with friends: “I also feel like a [bad person] whenever I play a game by myself, and my friends are like, ‘Dude, we could’ve played a game together!’

In contrast 9/30 participants prefer to play alone. People, who preferred playing with computer-controlled character stated reasons such as predictability, meaning that computer-

controlled characters allow for a constant, reliable experience. Participants also stated they felt less pressure for them to help and save teammates.

Some participants (4/30) specified that they prefer to play with strangers. In this case the participant stated reasons such as building their skill level, competing with others, and also more practical reasons like the game being easier to play with strangers than gathering friends for a match. A second participant liked that there were no outside repercussions if they were to be unhelpful or purposely antagonizing. This participant stated they like to play with friends as well.

Many of the above participants did not fall into exclusive categories. Some participants had reasons for preferring more than one of the settings. One participant stated that there was value to all activities. Additionally, one participant stated that:

“[I prefer] multiplayer with friends. Um, multiplayer with friends and single-player are kind of tied; it’s just that usually I like to play with friends. And the reason I like that more than playing with strangers or many people online is just because I have a good kind of relationship with my friends so it’s always fun to just be ridiculous”. In this participant’s case, it was not humans or computer-controlled character that made the difference, they are equally interesting unless friends are involved.

**Participants Beliefs.** Before debriefing the participants, the experimenters asked participants, who they believed they were playing with. Half of the participants (15/30) correctly identified who they were playing with. A fair amount (9/30) believed they were playing with computer-controlled character and did. One participant thought that real people would not have stood that close unless they were trying to act like AI. Another participant was not fooled and believed it was computer-controlled characters, because he felt in control and forced to be the leader of the group. One participant stated that they believed they were playing with computer-controlled characters (and were correct) until the experimenter asked this question, causing the participant to doubt their judgement.

Six participants (6/30) believed they played with humans and did. One participant felt that the players were supporting her and not out for themselves; she believes computer-controlled characters do not stay with the player to support them: “Because they were supporting their team members... It didn’t seem like they were out for themselves. They seemed more like a team kind of.” Another participant felt even though he could not communicate, the player felt like people to him; they were not machines that could target zombies halfway across the map: “It was still like a person, right? It still stood out as behaviour of what a person would do instead of [a computer-controlled character] who knows where people are and just \*he gestures a motion of shooting something\*”.

One participant in the human condition stated: “...I felt like it was humans. Just like their movements made me feel like it was humans, I feel the [computer-controlled character] would be a bit less... just doing whatever.” Another participant, who incorrectly identified the players as computer-controlled characters in the placebo condition stated:

“Well, in the fact like they knew exactly where they were going, and like, I could almost see which behaviour they were acting in. Like Zoey had the aggressive behaviour, Louis had the whole defensive behaviour and was constantly behind, and Bill [he means Francis] was kind of in the middle there. So... like I could definitely tell who was showing which characteristic.” Overall, seven participants (7/30) incorrectly believed they were playing with computer-controlled characters and six (6/30) had held incorrect beliefs that were revealed when they stated that they played with computer-controlled character and when in reality they did not. When asked them why and participants listed a range of reasons as simple as, “the experimenter said so” or, “they seemed to know everything” to as complex as their companions feeling ‘human’. One participant felt her teammates were helping her and covering her back. She also stated that her trust in the experimenter was also a factor:

“I trust that you’re telling me the truth, so I knew there were people that knew how to play the game... So if you weren’t telling me the truth, and it was computer-generated people that I was working with... I would just feel the same. Knowing they were covering my back kind of thing.”

One participant felt that they were playing with computer-controlled character due to the communication limitations, which limited their coordination. There was one case, where the participant was told they were playing with humans (not in the deception condition) but falsely assumed it was AI.

An additional 5 were completely uncertain. One participant believed at first it was AI, but then reconsidered mid-game because he thought the computer-controlled character was not “capable of being this good.” The participant was also convinced because he felt there was typing in the background.

In this cluster there were participants who felt that there was a mix of computer-controlled character and humans. Often they categorized the computer-controlled character human player based on playing behaviours such as proximity to the main player. There were also participants who felt that there was a combination. One participant believed they were playing with one computer-controlled character and possibly two humans because the character ‘Louis’ in particular kept up with him. Another believed there was one computer-controlled character because it managed to stay close to him, following him blindly into danger.

Furthermore, many participants who - when their established belief was pressed - began to reassess their experience and doubt themselves. One participant was convinced that their teammates were computer-controlled characters until given the possibility of human players. The participant reasoned that this may be because the players avoided dangerous areas, as if the computer-controlled characters were incapable of this:

“Well I noticed sometimes they would move away from a dangerous area (i.e. fire or poison flooring), which seemed a little weird. Like the thing that shot green stuff like they would move away from it after so they wouldn’t get injured. Which I thought was a kinda unusual for an AI. They just sort of ‘Oh I’m getting shot now, might as well just die.’”

In some cases participants were upset over the possibility of misinterpreting the condition. During gameplay one character was being pummelled. Earlier in the interview the participant had said she was both unable and unwilling to help the endangered individual, instead saying, "Sorry but you're AI". When presented with the possibility that it might be a human player the participant felt guilt. “I assumed they were [AI] so I didn’t really pay much attention so I didn’t feel bad. Now I feel a little bit bad that I let them die.”

**Predicted Preferences.** Participants were asked if they felt their experience would have changed if they had played with the opposite type of player (computer or human controlled).

When participants were asked whether or not they believed the experience would be changed if they played in the opposite condition, many participants had multiple arguments and are represented twice in the following numbers. The majority 16/30 argued that the opposite condition would change their experience entirely. People felt that humans could give more input, are fun to interact with, and make the game more unpredictable. One participant felt humans were more forgivable than AI. They felt they would be less frustrated with humans, because computer-controlled characters are programmed to do things, and if they make mistakes that is frustrating. But humans make mistakes and he understands that.

“I wouldn’t feel as angry because people make mistakes. Computers are programmed. It’s like taking power away from me, and if it’s say giving it to the computer I’ll be angry, if it’s giving it to another person I’m like ‘Well people make mistakes’ empathy sort of thing.”

One participant who felt the game would be more fun with humans looking back said: “I kind of feel the same, but I still would’ve liked to play with humans because it’s more fun playing with people.” Another participant felt if it was all computer-controlled characters instead of humans, it would change the experience. They found that the computer-controlled characters experience was generic and would play differently if playing with actual people:

“A couple times I reflected on the game, and I’m like: ‘Oh this is just so generic that I’m playing a level with [computer-controlled character] for some data collection.’ But if I would’ve known they were people I probably would’ve felt more like... you know the team needed me, like I needed to actually... I guess you could say play more seriously.”

In contrast, there were participants who believed the opposite condition would not affect their experience (7/30) or were indifferent (11/30). Participants who thought it would not affect their experience reasoned that the computer-controlled character was there to help them either way, or that communication was limited so there was no difference. One participant felt the experience was the same either way, but appreciated the other survivors' help. As long as she had some form of entity protecting her. A participant stated: “They’re programmed to help you, which your friends would probably do I assume.” One participant felt they would have enjoyed the game either way. One participant said the humans felt like AI, stating just that it felt like computer-controlled character because the experimenter had told her so.

One participant felt that the lack of communication with teammates made the experience the same either way. In contrast, one participant felt that there was personality in the characters. They

felt that the computer-controlled characters and humans acted the same way: one player was defensive, one was aggressive, and one held back regardless of computer or human.

“I could almost see which behaviour they were acting in. Like Zoey had the aggressive behaviour, Louis had the whole defensive behaviour and was constantly behind, and Bill [he means Francis] was kind of in the middle there. So... like I could definitely tell who was showing which characteristic.”

After the truth was revealed, the same participant stated, “I still hold to my point that Zoey knew where she was going, Francis was in the middle, and Louis kind of held back”.

Another participant stated that her choice was not about preference and was instead goal dependant. This participant felt that overall enjoyment depends on your goal; she would enjoy playing by herself to explore with or without AI, but might equally enjoy a human game where they just charge forward (as it was the case in the game she played).

“Sometimes you just want to get through the map, and by going straight through you just hit most the zombies and you’re good... Sometimes when you want to explore everything and everyone’s rushing ahead, then you get splintered off. So it depends on who you’re playing with and what your goal for the session is.”

**Communication.** Communication was a reoccurring theme. Overall, Some felt the lack of communication was not a problem (5/30). One participant got the impression that she felt we were guiding her despite not actually saying anything to her. Some participants (6/30) felt that the most essential point of the game is communication and a lack thereof meant the game might as well have been played with AI. One participant said it is the same kind of game, because you are playing with people you cannot communicate with and wished he had played with voice chat: “It’s the same kind of game. You’re playing with people you can’t communicate with.” Others felt that because they

could not communicate it was like they were just following a computer. Some participants stated that socially this is the same for both human-controlled and computer-controlled partners

On an individual level, one participant expressed that the problem was being unable to communicate with computer-controlled character team members. The participant felt alone because the computer-controlled character did questionable things, and they were unable to berate them for it: “Uh, if I was playing with people I would’ve yelled at you more because yelling is part of the fun.” One participant felt the in-game dialogue helped her to play, and the appearance of names above the players made the experience feel more personal:

“The fact that there was some dialogue in there I think was a big one. So I could hear someone telling me to get into a room that I couldn’t get into. And reminding me, I think that they heard things around the corner... Someone in there sounded like they had a crabby attitude, so that was kind of more real. It wasn’t just that they all acted the same. They used name a lot so it seemed a little more personal.”

One participant - certain he was playing with humans - proceeded to *'troll'* the other players, meaning that he antagonized them without discernible reason, by throwing them into dangerous situations with the intention of annoying them regardless of the removal of voice chat.

**Feeling alone.** Another interesting trend is that some participants felt that the presence of computer-controlled characters made them feel less alone. One participant didn't feel alone, because the computer-controlled character was helping kill the horde of zombies. Even knowing they were really computer-controlled, the very presences of people made another participant feel much better, safe and protected. Another participant in the placebo condition treats the computer-controlled character as people:

“If you tell me ‘Oh there’s no people playing!’ I still feel kind of obligated to pretend they’re people because I’m thinking that they’re my allies and they’re probably going to help me out later;

because if I get hurt they help me out, right.” One participant said that although they are not people, he still feels they contribute to the game. "Objectively they're not going to help you that much and essentially they are just walking ammunition boxes. But for a sense of character, or atmosphere, they're people right. Sure they are controlled by AI, but they're not completely devoid of any meaning. So I'm going to kind of keep them alive or whatever."

Once again, Two participants felt that the presence of computer-controlled characters – visibly or vocally - made them feel not alone. One participant followed what they believed to be AI, as they had no idea where to go on their own. One participant said that while the computer-controlled character frustrated him, he was glad they were here to rescue him:

“Whether or not it was AI, there were still those moments where like ‘Ah you’ve got to be kidding me’... and there were those moments where it’s like ‘Well, I’m glad they’re here because if they weren’t I’d probably have lost already.’”

**Behaviours.** Generally, players retained complete focus on the gameplay and thus did not speak up or give any extreme emotional reactions during their sessions. The discouragement of communicating with other players likely played some role in this, as some participants were silent through the duration of gameplay. Of those that did speak, many opted to speak to themselves about their concerns and observations.

Despite the social limitation, participants did indeed have moments of dialogue and/or expression. Participants were free to voice their internal thoughts about action depicted within the game, such as one participant who said, “Oh not you, I’ve heard stories about you” towards the witch enemy. Participants also voiced their concerns with situations in the game, including the occasional “Oops” when incapacitated by an enemy, “I am so bad at navigating” after becoming lost within the game level, and “What [on earth] are you?” when encountering new monsters.

Where monsters and the game level itself tended to elicit a self-directed reaction within players, six participants displayed behaviours targeted towards entities within the game itself. One participant became low on health only to have an AI-controlled survivor stop them to help them recover. The participant smiled and said, “Thank you, Zoey” despite being fully aware they were playing with computers. One participant in particular was very vocal with the computer-controlled character throughout the experience, even facing their teammates in-game to say, “Okay boys and girls, where do you want to go?” or apologise for nearly shooting their allies in the midst of combat. An additional participant noticed two of the characters had fallen behind and were under attack by a Charger enemy, at which point he says aloud, “What the heck are you all the way up there for?” This same participant expressed his discomfort when his character was lit on fire by a Molotov cocktail.

Participants would also react to dialogue spoken by avatars in the game. In one example a character in the game said, “Let’s do it” prompting the participant to reply, “Wait what are we doing? Ok what do you people want me to do? I’m just going to start following you around” despite the fact that the participant was with computer-controlled players.

Some participants also engage in social interaction with the game characters regardless of the experiment condition. These interactions ranged from a short-lived “Hi Francis” or “Aww Zoey” when observing teammates to laughter and guilt when characters complained about friendly fire incidents. One participant stated that regardless of the social condition they would talk to the screen either way: “I would’ve talked to the screen no matter what. Like, “Thanks Zoey, or Thanks whatever.’ I would have.”

Some participants did engaged in conversation with the experimenter. Generally this was to query their confusion with the game, such as “How do I open doors?” or “Guys this game is freaking me out!” Two participants required experimenter assistance with navigating sections of the level. One participant continued to shoot a monster after it had stopped moving until the

experimenter said, “Uh I think it’s dead,” to which she replied with a laugh, “I was just practicing. Okay, no I wasn’t.”

One participant in particular was healed by a computer-controlled ally, at which point she turned to face the back of the room and said, “Thank you” to the experimenters. The participant was aware of a computer-controlled character condition, yet still seemed to feel compelled to direct this gratitude towards someone. This same participant also expressed shock while nearly shooting her teammate in the process of getting accustomed to the game’s controls.

**Debriefing the Blind Experimenter.** The blind experimenter was interviewed and debriefed. The experimenter asked if the blind experimenter was able to differentiate between computer-controlled character and human conditions after repetitive exposure to the game. Additionally, the experimenter was asked about their perception of the true hypothesis.

The blind experimenter was not aware of the presence of six conditions but in retrospect found points of suspicion. “Well I may have suspected something, but I always thought that they played computer-controlled character and I didn’t know any different.” The blind experimenter also said when introducing the conditions “I told them this in the sincerity that I thought that they would be doing this.”

The blind experimenter was also unable to distinguish between the computer-controlled character and computer controlled conditions. After the revelation of the true hypothesis, the experimenter was able to identify points of suspicion that originally were just a bit odd, but were not in focus.

“I remember a few occasions where I thought like, the AI; why are they spreading out so much? Because I thought like this is what humans do, but I don’t know the game that well, so I don’t know what the [computer-controlled character] is really capable of. So, I thought the [computer-controlled character] would always just stand around and sometimes they would just-

You told me [computer-controlled character] and I thought it was [computer-controlled character] but they would just go off like to the next screen and start shooting people and stuff and I thought well ok whatever. Sometimes, you told me humans and there were some of these [participants] who got stuck and they may've needed a little pushing in a certain direction and then I thought like why are the guys not helping her?"

## **Discussion**

The hypothesis H1 states that, if playing with humans is an effective treatment, then the results of the placebo group (computer-controlled characters) will mimic that of the treatment group (human players). H1 was not supported. In contrast, the hypothesis H2 also states that, if the treatment (human players) is not effective, then the placebo group who were given false information about who they will play with, will equal the control group (computer-controlled characters). H2 was also not supported. Therefore, the study fails to reject the null hypothesis.

Physiological data from the presented study demonstrates

people experience human-controlled and computer-controlled social conditions similarly regardless of who they believe they are playing with. According to the physiological measures reported in the study, there was no difference between the tested conditions. Therefore, telling someone they are playing with a computer-controlled character is not going to yield significant differences if you are: a) actually playing with computer-controlled character and are told so; b) are given false information; or c) if you are playing with humans and told so. Therefore, according to the physiological measures of both experiments, this study fails to reject the null hypothesis, concluding that the social context does not affect the level of sociality in video games.

This finding is puzzling, because interviewed participants do report preferences between playing alone and playing with other people, a fact that is well documented in the literature (Ravaja

et al., 2006). In general, the majority of participants, 21 out of 30 individuals, believed they would enjoy playing with other humans more than playing with computer controlled AI.

If this finding is so robust, then the fact that participants are only correct when guessing who they were playing with about half the time, 16 out of 30 times according to this study's results, is an interesting finding. One would expect that if the difference between playing with humans and computer-controlled character is so important to our perception of the game, then there would be more people correctly guessing their condition.

Players are not always able to differentiate between human-controlled and computer-controlled interactions accurately regardless of player skill level. The confederates were careful never to simulate or act as AI. Instead, the participants began mistaking Artificial Intelligence (AI) controlled character actions and phrases as 'human' actions. A total of nine (9/30) participants began to reassess their experience when their beliefs were challenged; nearly a third of the participant sample. Some participants began to attribute human factors to the computer-controlled character players or computer-controlled character traits to human players. This included participants stating they either believed that their group was a mix of human and computer-controlled characters, or they felt that scripted computer-controlled character dialogue was attributed to human players. Therefore, it may be a possibility that players prefer to be told they are playing with humans regardless of the actual setting. This is an interesting finding for multiplayer online games. These games could yield a more enjoyable experience if players believe they are playing with humans. If computer-controlled characters may be used to fill in for human players when teams are short, it may decrease matching –making wait time without changing the player experience. Additionally, this can also improve player experience without hindering it with the frustration of waiting for a full human player team to be assembled.

One of the most interesting findings that participants reported was that having the computer-controlled character made them feel like they were in company of others within the game (5/30). This perceived sociability makes the case for multiplayer games that feature player-supporting computer players. This finding may be of interest to people studying the believability of computer-controlled characters (Bates, 1994). If it is the case that being in the company of computer-controlled characters in a game setting can have an emotional factor, then it may be possible to change the perceived difficulty of games by empowering the participant, allowing computer-controlled characters to accompany them, instead of the traditional methods of decreasing difficulty. Techniques to empower the player have been used in Zumba, a Latin dance fitness game. In the game, increased effort allows you to gain additional background dancers on your screen. Another example of the application of this concept is prevalent in Role Playing Games (RPGs), where, as the player progresses, the player gains additional party members. In this sense, it may be the case that people can feel togetherness, regardless if the people whom they are together with are real or computer-controlled.

Additionally, some participants felt that there was an implied social contract, expressing guilt at leaving behind or being unable to support human-controlled players. However some participants believed that they would have felt that way with computer-controlled players, others stating the opposite. This finding contributes to the feeling of sociability and may give game designers insight creating emotional moments in games. It may also help the GUR community understand why actions such as burning the companion cube (an inanimate cube described as the player's friend) in Portal (Valve Cooperation, 2007) had the impact it did.

In the stimulus game, in Left4Dead2 (L4D2) the characters are programmed to speak with the player's character by default, regardless if the character is being computer-controlled or controlled by another human. The vocalizations of the characters communicate direction, healing, polite

exchanges or even strategy. In this sense, the computer-controlled characters are creating a simulated feeling of togetherness in the game.

The participants reported feeling that the pre-programmed dialogue caused them to feel they were supported or in a group during the computer-controlled character conditions. The participants stated that feeling supported, as well the typical computer-controlled character functions and dialogue, contributed to their feelings of togetherness.

Participants also stated that the dialogue contributed to their feeling of togetherness even when playing with humans. This finding is also unexpected, because it implies that the players' feelings of togetherness could be attributed to the dialogue even in the human condition. In part the sociability felt in the human condition is still a function of the game design.

The sense of closeness in a game can be real or simulated. Therefore, the actual social condition is not what affects sociality, but instead sociality is affected by the player's perception of the story, narration, dialogue or even the idea that the player is under similar circumstances as another player regardless if that player is a real person or computer controlled. It is only important that the player feels that they are in the same virtual place as the other computer-controlled or human player.

The game L4D2 has made an environment that negates the need for real people. Therefore, these game design principles can be applied to other games to improve the player experience.

### **Limitations**

One limitation of the study was the relationship between the participants and the confederate L4D2 team. The study confederates were strangers to the participants. Communication is often best observed with people, who often socialize together or are acquainted with one another. A future follow-up study may wish to examine whether being told you are playing with friends or strangers affects the way, in which the participants respond to the game and their player experience.

Future research may also explore the amount of correct guesses by player skill level as the main focus. This may help us understand the relationship between gameplay experience and sociability.

Additionally, expert players may have felt more reason to perform over and above the requirements of the first level. This was seen in the player, who checked the pings before playing a practical joke on the confederate team. Future studies may decide to only focus on one skill level to better understand the relationship between skill level and cooperative and competitive actions taken in game.

The presented study is also limited because of the imposed restrictions on communication. Due to the necessary deception in this study, the design could not allow communication between teammates. Communication is a large factor in the sociability of games. However, if one were to believe they are playing with computer-controlled characters, they would also believe they are unable to communicate. This study found that the lack of communication with either computer-controlled character or humans is a factor. This may mean that simulated communication may cause players to feel like the computer-controlled characters are closer to the level of desirability than human teammates are. In future studies, it may be necessary to allow communication and during the computer-controlled character condition have a conversation partner out of the game. A future follow up study should simulate conversation with the participant to see if resolving the issue of communication leads to a more believable AI. If conversation is the only factor in increasing believability, then player experience in offline modes may be more easily improved.

## **Conclusion**

The study sought to understand the effects of the perceived social context on player experience. Specifically, the study explored the feeling of sociability in the game as a result of the

perceived condition. Perceived sociability affects player experience changing the player's perception of a game.

Physiological data reveals that there are no physiological differences between the different social conditions. The qualitative data was also in support of these findings. The qualitative data revealed that physiologically there is no difference in the experience, the player's perception is what changes player experience. Participants are unable to accurately identify the conditions.

Therefore, the researchers conclude that sociability is not affected by the presence of human versus computer-controlled characters. Instead sociability is affected by the patterns of behaviour presented and the simulated feeling of togetherness, which contributes to the believability of the computer-controlled characters.

## Chapter 6: Thesis Discussion

This thesis explored the use of electroencephalography (EEG) for Games User Research (GUR) and to get insight into social behaviour of players. Hemispheric frontal alpha asymmetry (HFAA) was used to better understand the arousal of the player to determine the level of excitement or frustration. By using EEG for GUR, the studies included in this thesis, reveal new information about the social and cognitive factors in games.

Games are entertainment applications. The main purpose of a game is to have fun (Pagulayan & Keeker, 2003). The source of fun in games can be a combination of multiple factors. For this reason both game designers and GUR need to work closely together to better understand and improve the player experience in games (Pagulayan & Steury, 2004).

Player experience can add value to a product because experience with the product causes humans to attribute added value (Hassenzahl, 2005). Therefore, player experience can enhance the success of a game and in turn be pivotal to the vitality of the games industry. Games with a poor player experience may have a very negative effect and this can possibly badly reflect on the company releasing the game. As a result, there is a need to understand player experience during all stages of development and before the release of the game.

GUR is a young field combining methodologies from both HCI and psychology (Bernhaupt, 2010; Isbister & Schaffer, 2008). The topics of interest are currently not fully explored. Often methodology in use in research can be very broad and unspecific: it does not pinpoint exact areas of interest but instead generally occurring trends. In contrast, industry standards often include focusing on specific problems by taking the simplistic approaches and conclusions that are game-specific. Industry standards of user testing are not held to the same rigor as academia and often use the method of evaluation with the least initial start-up cost or lowest barrier of entry. However, GUR can be vastly improved by using more specific evaluation techniques to collect information.

Academia may also benefit by moving towards understanding specific aspects of the game and accurately pinpointing important aspects of the player experience, such as the effects of the social situation or the cognitive factors associated with the gameplay.

Qualitative techniques are well suited to examine the experience of players, but limited by their subjectivity. Questionnaires and qualitative measures are also retrospective of gameplay causing the player to recall aspects of the player experience and communicate the situation, which they have experienced. Interrupting the gameplay can distract the players and interrupt their experience as well as the flow of the game (Csikszentmihalyi, 1990), which can affect player experience and bias the results. Additionally, these measures are subjected to the social context of the interview. In an attempt to please the researchers in the study, players may answer according to how they feel the interviewer would prefer.

Psychophysiological measures solve some of these problems by collecting data in real time. As a result, the researcher can understand the specific situations, which cause a physiological reaction. Psychophysiological techniques currently in use are often unspecific or limited in scope. Specific measures such as heart rate, respiration, galvanic skin response and eye tracking are useful for gaining information about the player's level of arousal and excitement. However, in comparison, EEG can provide a larger amount of data. Additionally, depending on the analysis technique used, EEG can also offer diverse data and make many conclusions from the same set of data. This technique is extended upon further in the future work section.

This thesis explores the different ways EEG can be used to study and evaluate video games using HFAA to understand a player's arousal level. Studying arousal can help GUR understand player experience, which is an important concept because of the attachment to products due to the internalization of their value (Hassenzahl, 2005).

Chapter Two of this thesis focused on different techniques that allow researchers a more detailed investigation into on how to best analyze the brain's output in accordance with the task at hand to achieve accurate results. The thesis itself focused on the use of HFAA because of the scope constraints coming with a Master's thesis. The presented studies expand the literature beyond the basic FFT analysis to explore the more complex analyses available and exhibiting their use.

Chapter One and two outline both motivations but also review the literature to help readers understand the basics of EEG methodology and its current use. The advantages and disadvantages of using EEG are outlined. In this chapter, the reasons for more complex analysis are made clear. In the following chapters three, four and five, HFAA is combined with other measures for mixed methods analysis a gameplay interactions.

In Chapter Three, HFAA is outlined and explored in conjunction with mu rhythms to better understand the arousal levels of the player as well as learning effects. The study *EEG-Based Assessment of Video and In-Game Learning* shows how EEG can be used to examine learning in games. This work is short, but can lead to new applications and easier methods of testing learning in games. The real time collection makes it easy to better comprehend how players understand the material presented without relying on retrospective self-report.

In Chapter Four, HFAA is used again in a *Mario Party Study*. In this chapter, HFAA is combined with questionnaires and other physiological measures to understand the player's brain state during different social contexts of play. The data of this study can be used by GURs to understand how having multiplayer versus single player interaction changes player experience. Additionally, the study also investigated how playing with another player cooperatively versus competitively affected them.

In Chapter Five, Perception of Human versus Computer Controlled Players in Games, HFAA is again combined with questionnaires, other physiological measures and interviews. The study

presented in Chapter Five explores whether or not a player's social context or if the players perceived social context affects a player physiologically or if it is the player's expectation that causes a difference in the self-report measures. In this study, EEG was used to help GURs understand how our perceptions of player interaction in games influence their experience. This in turn allows game designers to understand how to address concerns either by redesigning segments of the game or by understanding the influence of automated feedback and how it may affect the player.

These studies also show a developed of a mixed methodology technique to understand the player experience in video games. In the first study presented in Chapter Four, the methodology was heavily quantitatively based. As a result, the valence of the results could not be determined. Chapter Five provides both supporting qualitative and quantitative measures to better understand the valence of the result but when the findings were in contrast to the literature the study could not provide more detailed information. Finally, the study in Chapter Five pulls together both quantitative and qualitative techniques to give both an objective understanding of the player experience as well as detailed information about the thoughts of the user in a mixed measures design. In summary, all these techniques allow us to better understand our players and how they are affected by the games they play. This thesis contributes a methodology to the field of GUR leading to new associated analysis techniques to progress into finding usable research findings. These studies also demonstrate how EEG can be used to find results that allow us to make conclusions about the social and cognitive factors associated with gameplay in a mixed- measures methodology. Each chapter discusses the results of each study individually. However, common themes have emerged from this work. The results of these studies can help game designers understand their players and allow them to make decisions about the design to deliver the best player experience.

The study in Chapter Three simulates social learning to better understand learning in games. These findings can help game designers make decisions on how to arrange segments of their game

to make them more informative and accessible for the player to learn. This also contributes to the player experience by giving players access to the game and helps lead the player to mastery of the basic mechanics or interface. The study in Chapter Four shows that – despite different self-reports – physiologically there is no difference between playing with humans versus computer-controlled characters. The study presented in Chapter Five goes a step further to show that, even when given false information, there is no significant difference between the social conditions. Additionally, the study shows that having computer-controlled characters still made players feel less alone. Therefore, it's possible that game designers can make decisions about how to distribute their resources to focus on specific game mechanics while still achieving a positive player experience

Each of these studies helps game designers and the GUR community understand the ways that human interaction can be simulated. In all of the studies presented in this thesis, a portion of human interaction – be it competition, collaboration or social learning – is simulated to better understand the function of human interaction on gameplay. All studies have the same general conclusion as each study exhibits that fundamentally some human interaction can be simulated. In the Mario Party study, interactions for competition was shown to have no effect in comparison to actually player versus player interaction. In the Perception of Human versus Computer Controlled Players in Games Study the collaboration and feelings of sociability were simulated. Additionally, the study demonstrated that the effect of having human team mates was purely a mental phenomenon and can be evoked by the circumstances. The *EEG-Based Assessment of Video and In-Game Learning* study presented in Chapter Three shows how learning circumstances can change based on design decisions but it simulates social learning by showing users a video of someone else playing the game as the only form of information. The study has implications for exploring how people learn together as part of couch cooperation, discussion or conversation.

These studies show that interactions and feelings of sociality can be simulated to a degree. However, players still reported that having humans to interact is integral to their perceived experience. However, if they are misinformed – as they were in the Perception of Human versus Computer-Controlled Players in Games Study – the results are inconsistent with these self-reports. Therefore, this thesis recommends leveraging this information when making game design decisions.

EEG in particular compared to other physiological measures allows for a wide range of different types of information that can be explored through one device. EEG data can give us different information based on the data analysis used. For example, in the *EEG-Based Assessment of Video and In-Game Learning* study, from the same set of data we can see both information about learning, as well as information about a player's arousal level. With further analysis and timestamps, the same stimulus can be examined using multiple techniques.

This thesis opens new questions for further research. As with all studies, this thesis is not without its limitations. In this thesis, the chat function or communication widgets were not studied due to the research design. Future work may wish to explore communication systems with a similar methodology to understand the effect or to run the study with communication settings and try and understand the impact of the addition of communication.

The techniques explored in this thesis can extend the GUR knowledge base. However, EEG techniques can also be applied to classical HCI. For example, by understanding points of high arousal during use of a webpage, program or application, HCI researchers may find points of interest and points of improvement for the program in question. In addition, EEG may also be used to develop real time dynamic difficulty systems.

## **Future Work**

To further facilitate the use of EEG in a mixed measures approach some techniques should be taken into consideration. Firstly, Larger sample sizes per group may increase the statistical power of the sample increasingly the likelihood of significant results.

Additionally, a comparative analysis of the different physiological measures and questionnaires will allow researchers to choose the appropriate research methodology in accordance to the research question posed.

Lastly, follow up studies suggested in the individual sections may seek to support the null results and further understand the disparity between the studies presented and the literature.

## **Conclusion**

In summary, this thesis reviewed some ways that EEG can be used for the evaluation of video games in a mixed measures approach. This thesis contributes a new methodology in to the field of GUR. Additionally, this thesis contributes a new approach to understanding learning in games using EEG and uses this technique to uncover information that can help games designers make fundamental concepts more accessible to the player. Additionally, it also contributed new information about the effect of the social condition or environment on user experience. In conclusion, this thesis explored the literature and the current analysis techniques, examined the advantages and disadvantages of the system and summarized techniques that can be used to allow research and game designers a comprehensive look in to the brain state of the players.

### Contributions to the Field

Wehbe, R. R. & Nacke, L. E. (2014). Mario Party Study.

I lead this research project. I designed the experiment, collected the data with some assistance from Abdulaziz Almeahmadi who is acknowledged along with Jens Johannsmeier who wrote a code to import the data. I analyzed the statistics. Wrote the majority of the paper along with the second author, my supervisor Lennart E. Nacke.

Wehbe, R. R. & Nacke, L. E. (2013). Perception of Human versus Computer Controlled Players in Games. Special Issue of Computers in Human Behavior: “Designing and Evaluating Sociability in Online Video Games”. Paper in progress.

I lead this research project. In this paper, I designed the experiment, reviewed the literature, defined and wrote up the methodology, and trained research assistant assist in the collection of data using the equipment and measures I selected. After acquiring the data, I prepared the EEG data, ran the statistics for all the data. With the help of a research assistant, Eddie Shearer, the interview data and behavioural data was transcribed. The entire process was supervised by the second author. All authors proofread the paper.

Wehbe, R. R., Schakermann, M. H., Eddie S., Rojas, D., Johannsmeier, J., & Nacke, E. (2013).

Understanding the cognitive Impact of Missing Targets in Platform Games. Human Computer Interface. Special Issue on HCI and Games. Paper in Progress.

I lead this research project. In this paper, I proposed the hypothesis and designed the study, which was submitted for consideration as a proposal. I designed a game to have a suitable stimulus. The second and third authors programmed and developed the game. I collected the data along with the help of the second author and the 4th author. I did the data preparation including artifact removal, filtering and data analysis with the assistance of the second author. The 5th author assisted with the statistics. The final write up was written with contributions from the 2nd and 4th author. Proof reading was completed by the 3rd author. All authors were given the opportunity to read the paper before submission. The last author supervised the research, oversaw the study and edited the paper.

Wehbe, R. R. & Nacke, L. E. (2013). An Introduction to EEG Analysis Techniques and Brain Computer Interfaces for Games User Researchers. In Proc. of DIGRA '13.

*<http://www.digra.org/digital-library/publications/an-introduction-to-eeeg-analysis-techniques-and-brain-computer-interfaces-for-games-user-researchers/>*

I wrote the paper as a general review of the field. The last author contributed to the paper, edited and supervised the research. The last author also presented the paper at the conference.

Costa, J., Wehbe, R., Robb, J. and Nacke, L. "Time's Up: Studying Leaderboards for Engaging Punctual Behaviour", Gamification 2013, Stratford ON, Canada (in press).

As second author, assisted with the design of the study, as well as the final write up of the study.

Wehbe, R. R., Kappen, D., Rojas, D., Kapralos, B., & Nacke, L. E. (2013). EEG-Based Assessment of Video and In-Game Learning. In Proc. of CHI EA'13. ACM, 2013.

doi:10.1145/2468356.2468474. <http://dl.acm.org/citation.cfm?id=2468474>.

I lead this study. I designed the study, proposed the hypothesis, collected the data, analyzed the data post data preparation and wrote the paper. The data analysis was done with the assistance of the third author. The literature review was completed with the assistance of the second author. The fourth and the last author oversaw the study.

Kappen, D. L., Gregory, J., Stepchenko, D., Wehbe, R. R., & Nacke, L. E. (2013). Exploring social interaction in co-located multiplayer games. CHI '13 Extended Abstracts on Human Factors in Computing Systems on - CHI EA '13, 1119. doi:10.1145/2468356.2468556

I assisted in the final write up of the paper. I also presented the poster at CHI'13.

Wehbe, R. R., and Nacke, L.E. (2013). GUR using EEG Techniques. Submitted to CHI2013 Workshop on Game User Research: Practice, Methods and Applications.

I wrote the paper as a general review of the field. The last author contributed to the paper, supervised the research, edited and approved the paper.

Wehbe, R. R. & Nacke, L. E. (2013). EEG my Class! Not published.

I wrote the paper as a general review of the field. The last author supervised the research, contributed to the paper, edited and approved the paper.

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## *References*

- 2013 *Essential Facts about the Canadian Video Game Industry*. (2013) (pp. 1–19). Retrieved from [www.theesa.ca](http://www.theesa.ca)
- Aftanas, L. I., Varlamov, A. a, Pavlov, S. V, Makhnev, V. P., & Reva, N. V. (2002). Time-dependent cortical asymmetries induced by emotional arousal: EEG analysis of event-related synchronization and desynchronization in individually defined frequency bands. *International Journal of Psychophysiology: Official Journal of the International Organization of Psychophysiology*, *44*(1), 67–82. Retrieved from <http://www.ncbi.nlm.nih.gov/pubmed/11852158>
- Allen, J. J. B., Coan, J. a, & Nazarian, M. (2004). Issues and assumptions on the road from raw signals to metrics of frontal EEG asymmetry in emotion. *Biological Psychology*, *67*(1-2), 183–218. doi:10.1016/j.biopsycho.2004.03.007
- Allen, J. J. B., Urry, H. L., Hitt, S. K., & Coan, J. a. (2004). The stability of resting frontal electroencephalographic asymmetry in depression. *Psychophysiology*, *41*(2), 269–80. doi:10.1111/j.1469-8986.2003.00149.x
- Andersen, E., O'Rourke, E., Liu, Y.-E., Snider, R., Lowdermilk, J., Truong, D., ... Popovic, Z. (2012). The impact of tutorials on games of varying complexity. In *Proceedings of the 2012 ACM annual conference on Human Factors in Computing Systems - CHI '12* (p. 59). New York, New York, USA: ACM Press. doi:10.1145/2207676.2207687
- Bandura, A., & Jeffrey, R. (1973). Role of symbolic coding and rehearsal processes in observational learning. *Journal of Personality and Social Psychology*, *26*(1), 122–130. Retrieved from <http://psycnet.apa.org/journals/psp/26/1/122/>
- Bates, J. (1994). *The Role of Emotion in Believable Agents* Joseph Bates, (April).
- Bernhaupt, R. (2010). *Evaluating user experience in games* (p. 277). Springer. Retrieved from <http://link.springer.com/content/pdf/10.1007/978-1-84882-963-3.pdf>
- Bødker, S. (2006). When second wave HCI meets third wave challenges. In *NordiCHI* (pp. 14–18). Retrieved from <http://dl.acm.org/citation.cfm?id=1182476>
- Brathwaite, B., & Schreiber, I. (2009). *Challenges for game designers* (first edit.). Charles River Media. Retrieved from <http://books.google.com/books?hl=en&lr=&id=Pa4LAAAAQBAJ&oi=fnd&pg=PR5&dq=Challenges+for+Game+Designers&ots=lq4J9Un4ty&sig=dT2gMgEwNoeYoS0zifG2MKCa6Vk>
- Brockmyer, J.H., Fox, C.M., Curtiss, K.A., McBroom, E., Burkhart, K.M., Pidruzny, J. N. (2009). The Development of the Game Engagement Questionnaire: A measure of engagement in video game-playing. *Journal of Experimental Social Psychology*, *45*, 624–634.

- Brody, G., Lahey, B., & Combs, M. (1978). Effects of intermittent modelling on observational learning. *Journal of Applied Behavior Analysis*, *11*(1), 87–90. Retrieved from <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1311271/>
- Buzsaki, G. (2009). *Rhythms of the Brain*. Oxford University Press. Retrieved from [http://books.google.com/books?hl=en&lr=&id=DDq5eRNHGrcC&oi=fnd&pg=PR15&dq=Rhythms+of+the+Brain&ots=iILFcar4jA&sig=OQFWyU8o\\_rs9wS6CEtQBZ36Jd30](http://books.google.com/books?hl=en&lr=&id=DDq5eRNHGrcC&oi=fnd&pg=PR15&dq=Rhythms+of+the+Brain&ots=iILFcar4jA&sig=OQFWyU8o_rs9wS6CEtQBZ36Jd30)
- Cacioppo, J., Tassinary, L. G., & Berntson, G. G. (2007). *Handbook of Psychophysiology* (3rd ed.). Cambridge University Press.
- Cahn, B. R., & Polich, J. (2006). Meditation states and traits: EEG, ERP, and neuroimaging studies. *Psychological Bulletin*, *132*(2), 180–211. doi:10.1037/0033-2909.132.2.180
- Canossa, A., & Drachen, A. (2010). Arrrrgghh!!! - Blending Quantitative and Qualitative Methods to Detect Player Frustration, 61–68.
- Chalfoun, P. (2013). Biometrics In Games For Actionable Results. In *MIGS'13 Panel*. Montreal, Canada.
- Chanel, G., Kivikangas, J. M., & Ravaja, N. (2012). Physiological compliance for social gaming analysis: Cooperative versus competitive play. *Interacting with Computers*, *24*(4), 306–316. doi:10.1016/j.intcom.2012.04.012
- Coan, J. a, & Allen, J. J. B. (2004). Frontal EEG asymmetry as a moderator and mediator of emotion. *Biological Psychology*, *67*(1-2), 7–49. doi:10.1016/j.biopsycho.2004.03.002
- Coben, R., & Hudspeth, W. J. (2008). Introduction to Advances in EEG Connectivity. *Journal of Neurotherapy: Investigations in Neuromodulation, Neurofeedback and Applied Neuroscience*, *12*(2-3), 93–98. doi:10.1080/10874200802429843
- Coluccia, E., & Louse, G. (2004). Gender differences in spatial orientation: A review. *Journal of Environmental Psychology*, *24*(3), 329–340. doi:10.1016/j.jenvp.2004.08.006
- Crowley, K., Sliney, A., Pitt, I., & Murphy, D. (2010). Evaluating a Brain-Computer Interface to Categorise Human Emotional Response. *2010 10th IEEE International Conference on Advanced Learning Technologies*, 276–278. doi:10.1109/ICALT.2010.81
- Csikszentmihalyi, M. (1990). *The Psychology of Optimal Experience*. New York: Harper and Row.
- Delorme, A., Mullen, T., Kothe, C., Akalin Acar, Z., Bigdely-Shamlo, N., Vankov, A., & Makeig, S. (2011). EEGLAB, SIFT, NFI, BCILAB, and ERICA: new tools for advanced EEG processing. *Computational Intelligence and Neuroscience*, *2011*, 130714. doi:10.1155/2011/130714
- Dietrich, A. (2004a). Neurocognitive mechanisms underlying the experience of flow. *Consciousness and Cognition*, *13*(4), 746–61. doi:10.1016/j.concog.2004.07.002

- Dietrich, A. (2004b). The cognitive neuroscience of creativity. *Psychonomic Bulletin & Review*, 11(6), 1011–26. Retrieved from <http://www.ncbi.nlm.nih.gov/pubmed/15875970>
- Dietrich, A., & Kanso, R. (2010). A review of EEG, ERP, and neuroimaging studies of creativity and insight. *Psychological Bulletin*, 136(5), 822–48. doi:10.1037/a0019749
- Ducheneaut, N., Yee, N., Nickell, E., & Moore, R. J. (2005). “Alone Together?” Exploring the Social Dynamics of Massively Multiplayer Online Games, (March).
- Durka, P. J., Zygierewicz, J., Klekowicz, H., Ginter, J., & Blinowska, K. J. (2004). On the statistical significance of event-related EEG desynchronization and synchronization in the time-frequency plane. *IEEE Transactions on Bio-Medical Engineering*, 51(7), 1167–75. doi:10.1109/TBME.2004.827341
- Emmerich, K. (2013). Helping Friends or Fighting Foes: The Influence of Collaboration and Competition on Player Experience.
- Entertainment Software Association of Canada. (2012). Facts and Research. Retrieved March 21, 2014, from [http://thesa.ca/?page\\_id=22](http://thesa.ca/?page_id=22)
- Ermi, L., & Mäyrä, F. (2005). Fundamental Components of the Gameplay Experience: Analysing Immersion. *Digital Games Research Association's Second International Conference*, 15–27.
- Fairclough, S. H. (2009). Fundamentals of physiological computing. *Interacting with Computers*, 21(1-2), 133–145. doi:10.1016/j.intcom.2008.10.011
- Galotti, K. M. (2008). *Cognitive Psychology: In and Out of the Laboratory*. United States of America: Thomson Wadsworth.
- Gevensleben, H., Holl, B., Albrecht, B., Vogel, C., Schlamp, D., Kratz, O., ... Heinrich, H. (2009). Is neurofeedback an efficacious treatment for ADHD? A randomised controlled clinical trial. *Journal of Child Psychology and Psychiatry, and Allied Disciplines*, 50(7), 780–9. doi:10.1111/j.1469-7610.2008.02033.x
- Haroz, S., & Whitney, D. (2012). How Capacity Limits of Attention Influence Information Visualization Effectiveness. *IEEE Transactions on Visualization and Computer Graphics*, 18(12), 2402–2410. doi:10.1109/TVCG.2012.233
- Hassenzahl, M. (2005). The Thing and I: Understanding the Relationship Between User and Product. In M. Blythe, K. Overbeeke, A. Monk, & P. Wright (Eds.), *Funology SE - 4* (Vol. 3, pp. 31–42). Springer Netherlands. doi:10.1007/1-4020-2967-5\_4
- Hjelm, S. I. (2003). *The Making of Brainball* (Vol. X, pp. 26–34). Stockholm, Sweden.
- Holroyd, C. B., & Coles, M. G. H. (2002). The neural basis of human error processing: Reinforcement learning, dopamine, and the error-related negativity. *Psychological Review*, 109(4), 679–709. doi:10.1037//0033-295X.109.4.679

- Hwang, H.-J., Kim, K.-H., Jung, Y.-J., Kim, D.-W., Lee, Y.-H., & Im, C.-H. (2011). An EEG-based real-time cortical functional connectivity imaging system. *Medical & Biological Engineering & Computing*, 49(9), 985–95. doi:10.1007/s11517-011-0791-6
- Ibric, V. L., Dragomirescu, L. G., & Hudspeth, W. J. (2009). Real-Time Changes in Connectivities During Neurofeedback. *Journal of Neurotherapy*, 13(3), 156–165. doi:10.1080/10874200903118378
- Ijsselsteijn, W., & de Kort, Y. De. (2007). Characterising and measuring user experiences in digital games. *ACE Conference '07*. Retrieved from [http://lrcm.com.umontreal.ca/Dufresne/COM6535/Ijsselsteijn et al 2007 Characterising and Measuring User Experiences ACE 2007 workshop.pdf](http://lrcm.com.umontreal.ca/Dufresne/COM6535/Ijsselsteijn%20et%20al%202007%20Characterising%20and%20Measuring%20User%20Experiences%20ACE%202007%20workshop.pdf)
- Isbister, K., & Schaffer, N. (2008). *Game usability: Advancing the player experience*. CRC Press.
- Keyesers, C., & Gazzola, V. (2009). Expanding the mirror: vicarious activity for actions, emotions, and sensations. *Current Opinion in Neurobiology*, 19(6), 666–71. doi:10.1016/j.conb.2009.10.006
- Kivikangas, J., Chanel, G., Cowley, B., Ekman, I., Salminen, M., Jarvela, S., & Ravaja, N. (2011). A review of the use of psychophysiological methods in game research. *Proc. Nordic DiGRA'10*, 3(3), 181–199. doi:10.1386/jgvw.3.3.181
- Koshino, H., Kana, R. K., Keller, T. a, Cherkassky, V. L., Minshew, N. J., & Just, M. A. (2008). fMRI investigation of working memory for faces in autism: visual coding and underconnectivity with frontal areas. *Cerebral Cortex (New York, N.Y.: 1991)*, 18(2), 289–300. doi:10.1093/cercor/bhm054
- Koster, R. (2005). *A theory of fun for game design*. Phoenix, AR: Paraglyph Press.
- Kouijzer, M., & Moor, J. de. (2009). Neurofeedback improves executive functioning in children with autism spectrum disorders. *Research in Autism Spectrum Disorders*, 1, 145–162. Retrieved from <http://www.sciencedirect.com/science/article/pii/S1750946708000512>
- Krepki, R., Blankertz, B., Curio, G., & Müller, K.-R. (2007). The Berlin Brain-Computer Interface (BBCI) – towards a new communication channel for online control in gaming applications. *Multimedia Tools and Applications*, 33(1), 73–90. doi:10.1007/s11042-006-0094-3
- Krugman, H. (1971). Brain wave measures of media involvement. *Journal of Advertising Research*. Retrieved from [http://www.thedryingroom.com/tv/Brain Wave Measures of Media Involvement - Herbert E. Krugman.pdf](http://www.thedryingroom.com/tv/Brain%20Wave%20Measures%20of%20Media%20Involvement%20-%20Herbert%20E.%20Krugman.pdf)
- Lalor, E., Kelly, S., Finucane, C., Burke, R., Smith, R., Reilly, R., & McDarby, G. (2005). Brain computer interface based on the steady-state VEP for immersive gaming control. *Journal EURASIP Journal on Applied Signal Processing*, 3156–3164. Retrieved from [http://bme.ccny.cuny.edu/faculty/skelly/MyPDFs/LalorKellyMcDarby\\_BTz\\_04.pdf](http://bme.ccny.cuny.edu/faculty/skelly/MyPDFs/LalorKellyMcDarby_BTz_04.pdf)

- Landolt, H., Dijk, D., Gaus, S., & Borbély, A. (1995). Caffeine reduces low-frequency delta activity in the human sleep EEG. *Neuropsychopharmacology*. Retrieved from <http://www.sciencedirect.com/science/article/pii/0893133X9400079F>
- Lang, P. J. (1980a). *Behavioral treatment and bio-behavioral assessment: Computer applications. Technology in Mental Health Care Delivery Systems*. (B. Sidowski, J. Johnson, & T. Williams, Eds.) (pp. 119–137). Norwood, New Jersey, USA: Ablex Pub. Corp.
- Lang, P. J. (1980b). *Behavioral treatment and bio-behavioral assessment: Computer applications. Technology in Mental Health Care Delivery Systems*. (B. Sidowski, J. Johnson, & T. Williams, Eds.) (pp. 119–137). Norwood, New Jersey, USA: Ablex Pub. Corp.
- Li, H., Seo, J., Kham, K., & Lee, S. (2008). Measurement of 3D visual fatigue using event-related potential (ERP): 3D oddball paradigm. *3DTV Convention*, 213–216. Retrieved from [http://ieeexplore.ieee.org/xpls/abs\\_all.jsp?arnumber=4547846](http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=4547846)
- Logothetis, N. K. (2008). What we can do and what we cannot do with fMRI. *Nature*, 453(7197), 869–878. Retrieved from <http://www.ncbi.nlm.nih.gov/pubmed/18548064>
- Lubar, J. F., Swartwood, M. O., Swartwood, J. N., & O'Donnell, P. H. (1995). Evaluation of the effectiveness of EEG neurofeedback training for ADHD in a clinical setting as measured by changes in T.O.V.A. scores, behavioral ratings, and WISC-R performance. *Biofeedback and Self-Regulation*, 20(1), 83–99. Retrieved from <http://www.ncbi.nlm.nih.gov/pubmed/7786929>
- Luck, S. J. (2005). *An Introduction to the Event-Related Potential Technique*. Cambridge, Massachusetts: Massachusetts Institute of Technology.
- Malik, A., Pauzi, D. A. O. A. A., & Khairuddin, R. (2012). Investigating brain activation with respect to playing video games on large screens. *2012 4th International Conference on Intelligent and Advanced Systems (ICIAS2012)*, 86–90. Retrieved from [http://ieeexplore.ieee.org/xpls/abs\\_all.jsp?arnumber=6306165](http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=6306165)
- Mandryk, R. L., Inkpen, K. M., & Calvert, T. W. (2006). Using psychophysiological techniques to measure user experience with entertainment technologies. *Behaviour & Information Technology*, 25(2), 141–158. doi:10.1080/01449290500331156
- Martinovic, I., Davies, D., & Frank, M. (2012). On the feasibility of side-channel attacks with brain-computer interfaces. *NeuroFocus Press Release*. Retrieved from <https://www.usenix.org/system/files/conference/usenixsecurity12/sec12-final56.pdf>
- Masterpasqua, F., & Healey, K. N. (2003). Neurofeedback in Psychological Practice. *Professional Psychology: Research and Practice*, 34(6), 652–656. doi:10.1037/0735-7028.34.6.652
- McFarland, D. J., Miner, L. a, Vaughan, T. M., & Wolpaw, J. R. (2000). Mu and beta rhythm topographies during motor imagery and actual movements. *Brain Topography*, 12(3), 177–86. Retrieved from <http://www.ncbi.nlm.nih.gov/pubmed/10791681>

- Mirza-Babaei, P., Nacke, L. E., Gregory, J., Collins, N., & Fitzpatrick, G. (2013). How does it play better?: exploring user testing and biometric storyboards in games user research. *Proc. CHI'13*, (May). Retrieved from <http://dl.acm.org/citation.cfm?id=2466200>
- Mirza-Babaei, P., Zammito, V., Niesenhaus, J., Sangin, M., & Nacke, L. E. (2013). Games user research: practice, methods, and applications. *Proc. CHI'13 Extended Abstracts*, 3219–3222. Retrieved from <http://dl.acm.org/citation.cfm?id=2479651>
- Nacke, L., & Drachen, A. (2011). Towards a framework of player experience research. *Proc. EPEX'11 Workshop on Evaluating Player Experience in Games*. Retrieved from <http://hci.usask.ca/uploads/230-NackeDrachenPXFframework.pdf>
- Nacke, L. E. (2013). An Introduction to Physiological Player Metrics for Evaluating Games. In M. S. El-Nasr, A. Drachen, & A. Canossa (Eds.), *Game Analytics Maximizing the Value of Player Data* (pp. 585–619). Springer-Verlag London.
- Nacke, L. E., Drachen, A., & Kuikkaniemi, K. (2009). Playability and player experience research. *Proc. DIGRA'09*. Retrieved from [http://www.bth.se/fou/forskinfor/nsf/all/e0a8cdd8cfc0c7e6c125762c005557c0/\\$file/Nacke-et-al-Panel-Playability-and-Player-Experience.pdf](http://www.bth.se/fou/forskinfor/nsf/all/e0a8cdd8cfc0c7e6c125762c005557c0/$file/Nacke-et-al-Panel-Playability-and-Player-Experience.pdf)
- Nacke, L. E., Stellmach, S., & Lindley, C. a. (2010). Electroencephalographic Assessment of Player Experience: A Pilot Study in Affective Ludology. *Simulation & Gaming*, 42(5), 632–655. doi:10.1177/1046878110378140
- Nielsen, J. (1994a). Enhancing the explanatory power of usability heuristics. *Conference Companion on Human Factors in Computing Systems - CHI '94*, 210. doi:10.1145/259963.260333
- Nielsen, J. (1994b). Usability inspection methods. *Proc. CHI'94*, 413–414. Retrieved from <http://dl.acm.org/citation.cfm?id=260531>
- Nielsen, J. (1994c). Usability inspection methods. *Proc. CHI'95*, 377–378. Retrieved from <http://dl.acm.org/citation.cfm?id=260531>
- Nielsen, J., & Molich, R. (1990). Heuristic evaluation of user interfaces. *CHI'90 Proceedings of the SIGCHI Conference on Human Computer Interaction 1990*, (April), 249–256. Retrieved from <http://dl.acm.org/citation.cfm?id=97281>
- Nijholt, A., Erp, J. van, & Heylen, D. (2008). BrainGain: BCI for HCI and Games, 32–35. Retrieved from <http://eprints.eemcs.utwente.nl/12172/>
- Nolte, G., Bai, O., Wheaton, L., Mari, Z., Vorbach, S., & Hallett, M. (2004). Identifying true brain interaction from EEG data using the imaginary part of coherency. *Clinical Neurophysiology: Official Journal of the International Federation of Clinical Neurophysiology*, 115(10), 2292–307. doi:10.1016/j.clinph.2004.04.029

- Nunez, P. (1974). The brain wave equation: a model for the EEG. *Mathematical Biosciences*, 291, 279–297. Retrieved from <http://www.sciencedirect.com/science/article/pii/0025556474900200>
- Nunez, P. L., Silberstein, R. B., Cadusch, P. J., Wijesinghe, R. S., Westdorp, A. F., & Srinivasan, R. (1994). A theoretical and experimental study of high resolution EEG based on surface Laplacians and cortical imaging. *Electroencephalography and Clinical Neurophysiology*, 90(1), 40–57. Retrieved from <http://www.ncbi.nlm.nih.gov/pubmed/7509273>
- Nunez, P. L., Silberstein, R. B., Shi, Z., Carpenter, M. R., Srinivasan, R., Tucker, D. M., ... Wijesinghe, R. S. (1999). EEG coherency II: experimental comparisons of multiple measures. *Clinical Neurophysiology : Official Journal of the International Federation of Clinical Neurophysiology*, 110(3), 469–86. Retrieved from <http://www.ncbi.nlm.nih.gov/pubmed/10363771>
- Nunez, P. L., Srinivasan, R., Westdorp, A. F., Wijesinghe, R. S., Tucker, D. M., Silberstein, R. B., & Cadusch, P. J. (1997). EEG coherency: I: statistics, reference electrode, volume conduction, Laplacians, cortical imaging, and interpretation at multiple scales. *Electroencephalography and Clinical Neurophysiology*, (103), 499–515. Retrieved from <http://www.sciencedirect.com/science/article/pii/S0013469497000667>
- Nyström, P., Ljunghammar, T., Rosander, K., & Hofsten, C. Von. (2011). Using mu rhythm perturbations to measure mirror neuron activity in infants. *Dev. Sci*, 14(2), 327–355.
- Pagulayan, R., & Keeker, K. (2003). User-centered design in games. *Handbook in Computer Interaction*, 1–46. Retrieved from [http://www.studiosuserresearch.com/HCI\\_Handbook\\_Chapter.pdf](http://www.studiosuserresearch.com/HCI_Handbook_Chapter.pdf)
- Pagulayan, R., & Steury, K. (2004). Beyond usability in games. *Interactions*, 70–71. Retrieved from <http://dl.acm.org/citation.cfm?id=1015566>
- Pfurtscheller, G., & Lopes da Silva, F. H. (1999). Event-related EEG/MEG synchronization and desynchronization: basic principles. *Clinical Neurophysiology : Official Journal of the International Federation of Clinical Neurophysiology*, 110(11), 1842–57. Retrieved from <http://www.ncbi.nlm.nih.gov/pubmed/10576479>
- Poldrack, R. A. (2006). Can cognitive processes be inferred from neuroimaging data? *Trends in Cognitive Sciences*, 10(2), 59–63. Retrieved from <http://www.ncbi.nlm.nih.gov/pubmed/16406760>
- Powell, D. (2013). Toy helicopter guided by power of thought. *Nature News*. doi:doi:10.1038/nature.2013.13139
- Ravaja, N., Saari, T., & Turpeinen, M. (2006). Spatial presence and emotions during video game playing: Does it matter with whom you play? *Presence*, 327–333. Retrieved from <http://www.mitpressjournals.org/doi/abs/10.1162/pres.15.4.381>
- Rizzolatti, G., & Craighero, L. (2004). The mirror-neuron system. *Annual Review of Neuroscience*, 27, 169–92. doi:10.1146/annurev.neuro.27.070203.144230

- Rizzolatti, G., Fadiga, L., Gallese, V., & Fogassi, L. (1996). Premotor cortex and the recognition of motor actions. *Cognitive Brain Research*. Retrieved from <http://www.sciencedirect.com/science/article/pii/0926641095000380>
- Rizzolatti, G., Fogassi, L., & Gallese, V. (2001). Neurophysiological mechanisms underlying the understanding and imitation of action. *Nature Reviews Neuroscience*, 2(September), 1–10. Retrieved from [http://www.ikw.uni-osnabrueck.de/~NBP/PDFs\\_Publications/Rizzolatti.NNR.01.pdf](http://www.ikw.uni-osnabrueck.de/~NBP/PDFs_Publications/Rizzolatti.NNR.01.pdf)
- Rosnow, Ralph, Rosenthal, R. (2008). *Beginning Behavioral Research: A Conceptual Primer* (6th ed.). Pearson Education International/Prentice Hall.
- Salminen, M. J., Kivikangas, M., Ravaja, N., & Kallinen, K. (2009). Frontal EEG Asymmetry in the Study of Player Experiences during Competitive and Cooperative Play. In K. Blashki (Ed.), *Proceedings of the LADIS International Conference on Game and Entertainment Technologies* (pp. 44–50). International Association for Development of the Information Society.
- Salminen, M., & Ravaja, N. (2008). Increased oscillatory theta activation evoked by violent digital game events. *Neuroscience Letters*, 435(1), 69–72. doi:10.1016/j.neulet.2008.02.009
- Schild, J., LaViola, J., & Masuch, M. (2012). Understanding user experience in stereoscopic 3d games. *Proc. CHI'12*, 89–98. Retrieved from <http://dl.acm.org/citation.cfm?id=2207690>
- Stenros, J., Paavilainen, J., & Mäyrä, F. (2009). The many faces of sociability and social play in games. *Proceedings of the 13th International MindTrek Conference: Everyday Life in the Ubiquitous Era on - MindTrek '09*, 82. doi:10.1145/1621841.1621857
- Sundaram, S. K., Kumar, A., Makki, M. I., Behen, M. E., Chugani, H. T., & Chugani, D. C. (2008). Diffusion tensor imaging of frontal lobe in autism spectrum disorder. *Cerebral Cortex (New York, N.Y. : 1991)*, 18(11), 2659–65. doi:10.1093/cercor/bhn031
- Takatalo, J., Kawai, T., Kaistinen, J., Nyman, G., & Häkkinen, J. (2011). User Experience in 3D Stereoscopic Games. *Media Psychology*, 14(4), 387–414. doi:10.1080/15213269.2011.620538
- Tangemann, M., Schrender, M., Dähne, S., Höhne, J., Regler, S., Ramsay, A., ... Murray-Smith, R. (2011). Optimized stimulation events for a visual ERP BCI. *International Journal of Bioelectromagnetism*, 13(3), 119–120. Retrieved from <http://eprints.pascal-network.org/archive/00009468/>
- Teplan, M. (2002). Fundamentals of EEG measurement. *Measurement Science Review*, 2, 1–11. Retrieved from <http://www.ccs.fau.edu/eeg/teplan2002.pdf>
- Thai, N. jade, Longe, O., & Rippon, G. (2009). Disconnected brains: What is the role of fMRI in connectivity research? *International Journal of Psychophysiology*, 73(1), 27–32. doi:10.1016/j.ijpsycho.2008.12.015

- Thatcher, R. W. (2012). Coherence, Phase Differences, Phase Shift, and Phase Lock in EEG/ERP Analyses. *Developmental Neuropsychology*, 37(6), 476–96. doi:10.1080/87565641.2011.619241
- Ulloa, E. R., & Pineda, J. a. (2007). Recognition of point-light biological motion: mu rhythms and mirror neuron activity. *Behavioural Brain Research*, 183(2), 188–94. doi:10.1016/j.bbr.2007.06.007
- Verona, E., Sadeh, N., & Curtin, J. J. (2009). Stress-induced asymmetric frontal brain activity and aggression risk. *Journal of Abnormal Psychology*, 118(1), 131–45. doi:10.1037/a0014376
- Wehbe, R., Kappen, D., Rojas, D., Klauser, M., Kapralos, B., & Nacke, L. E. (2013). EEG-based assessment of video and in-game learning. *Proc. CHI'13 Extended Abstracts*. doi:10.1145/2468356.2468474
- Weibel, D., Wissmath, B., Habegger, S., Steiner, Y., & Groner, R. (2008). Playing online games against computer- vs. human-controlled opponents: Effects on presence, flow, and enjoyment. *Computers in Human Behavior*, 24(5), 2274–2291. doi:10.1016/j.chb.2007.11.002
- Williams, R. B., & Clippinger, C. a. (2002). Aggression, competition and computer games: computer and human opponents. *Computers in Human Behavior*, 18(5), 495–506. doi:10.1016/S0747-5632(02)00009-2
- Wilson, G., & Russell, C. (2007). Performance enhancement in an uninhabited air vehicle task using psychophysiological adaptive aiding. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, 49(6), 1005–1018. doi:10.1518/001872007X249875.1006

## Appendix

### Demographics and Mario History Survey

There are 19 questions in this survey

Demographics

1 [FMP Number]

Researchers ONLY!

Please Enter: FMP# \*

Please write your answer here:

2 [Gender] \*

Please choose only one of the following:

Male

Female

3 [Age Group] Please select your age group \*

Please choose only one of the following:

10-14

15-19

20-24

25-29

30-34

35-40

41-45

46+

Other

Gaming Background

4 [Years of Gaming] How long have you been playing video games (years)? \*

Please choose only one of the following:

0

<5

<10

<15

<20

<25

25+

Make a comment on your choice here:

5 [Hours per Day] How many hours of video games do you play per day? \*

Please choose only one of the following:

0

- <1
- <2
- <3
- <4
- <5
- 5+

Make a comment on your choice here:

6 [Mobile Games]How many years have you been playing mobile games (Phone, tablet, etc)? \*

Please choose only one of the following:

- 0
- <1
- <5
- <10
- <15
- <20
- 20+

Make a comment on your choice here:

7 [Consoles]What game consoles you own or play on a regular basis? \*

Please choose all that apply:

- Play Station (PS)1
- PS2
- PS3
- PSP
- PS Vita
- XBox
- XBox360
- Nintendo Game Cube
- Nintendo Wii
- Nintendo WiiU
- DS
- DSi
- DSXL
- 3DS
- Gameboy
- Gameboy Advanced
- Gameboy Colour
- None
- Other:

## 8 [Genres]

What genres of games do you play?

\*

Please choose all that apply:

- Action (General)
- Action-Adventure
- 1st Person shooter
- 3rd Person Shooter
- Tactile Shooter
- Adventure
- Fighting (General)
- Competitive Fighting
- Beat 'em Up
- RPG
- Tactical Role Playing
- Arcade Style
- Action Role Playing
- Fighting role Playing
- Platform Games
- Simulation (General)
- Life Simulation
- City building/simulation
- Sports(general)
- Racing (general)
- MMORPG
- MMO
- Music/Dance
- Party
- Puzzle
- Strategy
- Casual
- I don't play games
- Other:

## Mario Party History

9 [MarioHistory]How many years have you been playing mario party? \*

Please choose only one of the following:

- Never
- Under 1 year
- 1-5 years
- 5- 10 years

- 10-15 years
- 15+ years

Make a comment on your choice here:

10 [FrequencyMP]How often do you play Mario Party in a month? \*

Please choose only one of the following:

- Never
- Less than once a month
- Once a month
- Twice per month
- Three times in a month
- Once a week
- Twice a week
- Every other day
- Almost everyday
- Everyday

Make a comment on your choice here:

11 [Versions]What versions of Mario Party have you played? What controllers did you use?

Please write your answer here:

12 [DD]Have you played the minigame Dungeon Duos? \*

Please choose only one of the following:

- Yes
- No

Make a comment on your choice here:

13 [DD frequency]How often do you play Dungeon Duos? \*

Please choose only one of the following:

- Never
- Often
- Sometimes
- Occasionally
- Frequently
- Everyday

Make a comment on your choice here:

Exit Survey

14 [Arousal]Which condition was most exciting? \*

Please choose only one of the following:

- Cooperative

- Competitive
- AI Only
- All equal

Make a comment on your choice here:

15 [Arousal]Which condition was most frustrating? \*

Please choose only one of the following:

- Cooperative
- Competitive
- AI Only
- All equal

Make a comment on your choice here:

16 [Arousal]Which condition was most arousing? \*

Please choose only one of the following:

- Cooperative
- Competitive
- AI Only
- All equal

Make a comment on your choice here:

17 [Pleasure]Which condition did you rate highest in pleasure? \*

Please choose only one of the following:

- Cooperative
- Competitive
- AI Only
- All equal

Make a comment on your choice here:

18 [Dominance ]In which condition did you feel the most dominant? \*

Please choose only one of the following:

- Cooperative
- Competitive
- AI Only
- All equal

Make a comment on your choice here:

19 [Comments]Any other comments, thoughts and feelings?

Please write your answer here:

Thank you for participating!

31.12.1969 – 19:00

Submit your survey.

Thank you for completing this survey.

### **L4D2 Gaming Study**

Welcome

Thank you for participating!

There are 15 questions in this survey

Demographics

1 [MU000ID]

Researchers ONLY!

Please Enter: MU000ID \*

Please write your answer here:

2 [Gender] \*

Please choose only one of the following:

- Male
- Female

3 [Age Group] Please select your age group \*

Please choose only one of the following:

- 18 -19
- 20-24
- 25-29
- 30-34
- 35-40
- 41-45
- 46+
- Other

Gaming Background

4 [Years of Gaming] How long have you been playing video games (years)? \*

Please choose only one of the following:

- 0
- 0-5
- 5-10
- 10-15
- 15-20

20-25

26+

Make a comment on your choice here:

5 [Hours per Day]How many hours of video games do you play per day? \*

Please choose only one of the following:

0

1

2

3

4

5

6+

Make a comment on your choice here:

6 [Mobile Games]How many years have you been playing mobile games (Phone, tablet, etc)? \*

Please choose only one of the following:

0

Less than 1 year

1-5 years

6-10 years

11-15 years

16-20 years

21+

Make a comment on your choice here:

7 [Consoles]What game consoles you own or play on a regular basis? \*

Please choose all that apply:

Computer

Play Station (PS)1

PS2

PS3

PSP

PS Vita

XBox

XBox360

Nintendo Game Cube

Nintendo Wii

- Nintendo WiiU
- DS
- DSi
- DSXL
- 3DS
- Gameboy
- Gameboy Advanced
- Gameboy Colour
- None
- Other:

8 [Genres]

What genres of games do you play?

\*

Please choose all that apply:

- Action (General)
- Action-Adventure
- 1st Person shooter
- 3rd Person Shooter
- Tactile Shooter
- Adventure
- Fighting (General)
- Competitive Fighting
- Beat 'em Up
- RPG
- Tactical Role Playing
- Arcade Style
- Action Role Playing
- Fighting role Playing
- Platform Games
- Simulation (General)
- Life Simulation
- City building/simulation
- Sports(general)
- Racing (general)
- MMORPG
- MMO
- Music/Dance
- Party
- Puzzle
- Strategy
- None
- Other:

First Person Shooters

9 [Do you play fps ]

Do you play First Person Shooters?

Examples: Call of Duty, Halo, Left4Dead, Half Life \*

Please choose only one of the following:

- Yes
- No

10 [hours of FPS]How many hours a week do you play first person shooters? \*

Please write your answer here:

11 [what fps]Have you played: \*

Please choose all that apply:

- Left4Dead Series
- Quake Series
- Halo Series
- Call of Duty Series
- Half Life Series
- Borderlands Series
- Kill zone Series
- Wolfenstein Series
- Team Fortress Series
- Far Cry Series
- Crisis Series
- Counter Strike Series
- Bioshock Series
- Battlefield Series
- Deus Ex Series
- Metal of Honor Series
- None
- Other:

12 [played l4d1]How often do you play Left4Dead(1)? \*

Please choose only one of the following:

- I play every day
- I play at least 5 times a week
- I play at least 2 times a week
- I play at least once a week
- I play at least once a month
- I play at least once a year
- I have never played this game

Make a comment on your choice here:

13 [played l4d2]How often do you play Left4Dead2? \*

Please choose only one of the following:

- I play every day
- I play at least 5 times a week
- I play at least 2 times a week
- I play at least once a week
- I play at least once a month
- I play at least once a year
- I have never played this game

Make a comment on your choice here:

14 [l4d\_time]How many years have you been playing L4D or L4D2? \*

Please write your answer here:

Comments

15 [comment]Any other comments or information?

Please write your answer here:

All Done!

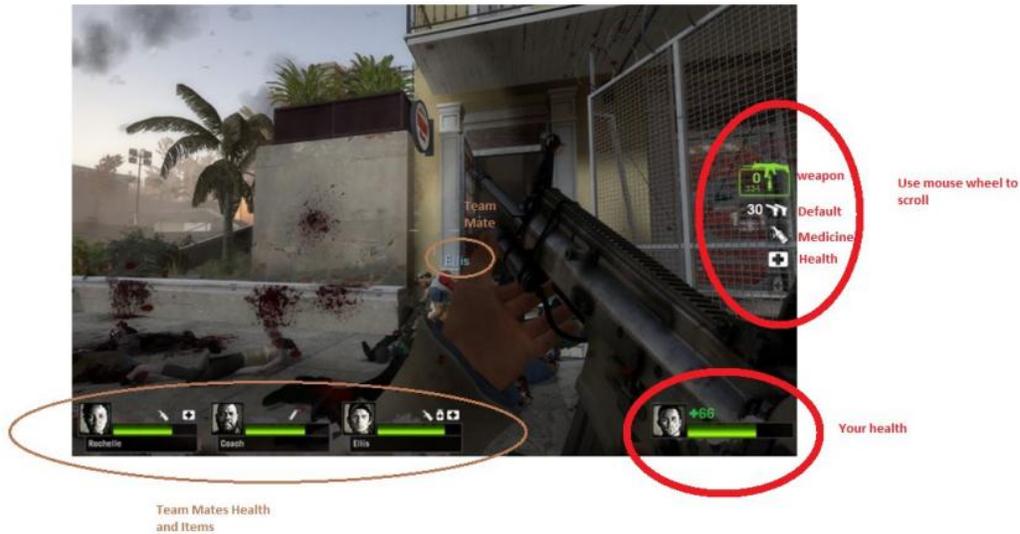
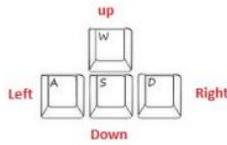
Thank you again for participating!

31.12.1969 – 19:00

Submit your survey.

Thank you for completing this survey.

## Instructions Sheet



## Exit Interview

What do you usually enjoy: Single player, multiplayer with friends, multiplayer with strangers or online?

Why?

Did you enjoy the game settings you just experienced?

Were there any parts of the game that were salient or stand out?

Did you believe the experimenter when they told you who you were playing with?

Who do you believe you were playing with?

Do you believe that affected your level of enjoyment in the game?

\*After debriefing and cool down\*

The game was played with \_\_\_\_\_ does this affect your answers?

## Demographics and Game Play Survey

There are 11 questions in this survey

Demographics

1 [MU000ID]

Researchers ONLY!

Please Enter: MU000ID \*

Please write your answer here:

2 [Gender] \*

Please choose only one of the following:

- Male
- Female
- Other
- No Answer

3 [Age Group]Please select your age group \*

Please choose only one of the following:

- 10-14
- 15-19
- 20-24
- 25-29
- 30-34
- 35-40
- 41-45
- 46+
- Other

Gaming Background

4 [Years of Gaming]How long have you been playing video games (years)? \*

Please choose only one of the following:

- 0
- <5
- <10
- <15
- <20
- <25
- 25+

Make a comment on your choice here:

5 [Hours per Day]How many hours of video games do you play per day? \*

Please choose only one of the following:

- 0
- <1
- <2
- <3
- <4
- <5

5+

Make a comment on your choice here:

6 [Mobile Games]How many years have you been playing mobile games (Phone, tablet, etc)? \*

Please choose only one of the following:

0

<1

<5

<10

<15

<20

20+

Make a comment on your choice here:

7 [Consoles]What game consoles you own or play on a regular basis? \*

Please choose all that apply:

Play Station (PS)1

PS2

PS3

PSP

PS Vita

XBox

XBox360

Nintendo Game Cube

Nintendo Wii

Nintendo WiiU

DS

DSi

DSXL

3DS

Gameboy

Gameboy Advanced

Gameboy Colour

Other:

8 [Genres]

What genres of games do you play?

\*

Please choose all that apply:

Action (General)

Action-Adventure

1st Person shooter

3rd Person Shooter

Tactile Shooter

Adventure

Fighting (General)

Competitive Fighting

Beat 'em Up

- RPG
- Tactical Role Playing
- Arcade Style
- Action Role Playing
- Fighting role Playing
- Platform Games
- Simulation (General)
- Life Simulation
- City building/simulation
- Sports(general)
- Racing (general)
- MMORPG
- MMO
- Music/Dance
- Party
- Puzzle
- Strategy
- Other:

9 [Flow]

Have you ever played Flow for iPad, iPhone or on other devices? \*

Please choose only one of the following:

- Yes
- No

Make a comment on your choice here:

10 [Time\_Flow]

For how long in months? \*

Please choose only one of the following:

- 0
- <1
- <5
- <10
- <12
- 12+

Make a comment on your choice here:

11 [Flow\_day]

How many hours a day on average do you play flow? \*

Please choose only one of the following:

- 0
- <1/2
- <1
- <2
- <3
- <4
- <5
- 5+

Make a comment on your choice here:

Thank you for participating!

31.12.1969 – 19:00

Submit your survey.

Thank you for completing this survey.

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February 2nd, 2014

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Wehbe, RR, DL Kappen, and David Rojas. 2013. "EEG-Based Assessment of Video and in-Game Learning." *CHI'13 Extended ....* doi:10.1145/2468356.2468474. <http://dl.acm.org/citation.cfm?id=2468474>.

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Name: David A. Rojas Title: PhD.c.

Signature: [Handwritten Signature] Date: Feb 5<sup>th</sup> / 2014

February 2nd, 2014

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Kappen, D. L., Gregory, J., Stepchenko, D., Wehbe, R. R., & Nacke, L. E. (2013). Exploring social interaction in co-located multiplayer games. *CHI '13 Extended Abstracts on Human Factors in Computing Systems on - CHI EA '13*, 1119. doi:10.1145/2468356.2468556

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Name: Dennis L. Kappen Title: PhD student

Signature: [Handwritten Signature] Date: 2<sup>nd</sup> FEB 2014

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Yours sincerely,

Rina R. Wehbe

**Re: Copy Write Permission**

Jose P. Zagal [jzagal@cdm.depaul.edu]

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Sent: February 4, 2014 7:08 PM

To: Rina Wehbe

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best,

Jose Zagal  
 DIGRA

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 > The PDF file attached needs to be signed to grant permission.  
 >  
 > Yours sincerely,  
 >  
 >  
 > Rina R. Wehbe

February 2nd, 2014

Dear Eddie (Albert) Shearer,

I am preparing my MSc Computer Science thesis for submission to the Office of Graduate Studies at the University of Ontario Institute of Technology (UOIT) in Oshawa, Ontario, Canada. I am seeking your permission to include a manuscript version of the following paper(s) as a chapter in the thesis:

Wehbe, R. R., Schakermann, M. H., Eddie S., Rojas, D., Johannsmeier, J., & Nacke, E. (2013). Understanding the cognitive Impact of Missing Targets in Platform Games. Human Computer Interface. Special Issue on HCI and Games. Abstract accepted. Full paper in progress. HCI-2013-1537

Wehbe, R. R., Shearer, E. & Nacke, L. E. (2013). Perception of Human versus Computer Controlled Play in Collaborative and Competitive Scenarios. Special Issue of Computers in Human Behavior: "Designing and Evaluating Sociability in Online Video Games". Proposal accepted, full paper currently under review. CHB-D-13-00942

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Yours sincerely,

Rina R. Wehbe

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1) Title: understanding the cognitive impact of missing targets in Platform Games.  
Name: Eddie (Albert) Shearer (PHD) 2) Title: Perception of Human versus Computer Controlled Play in Collaborative and Competitive Scenarios.

Signature: *Madeline Johnson* Date: Feb 5 / 2013

February 2nd, 2014

Dear James Robb,

I am preparing my MSc Computer Science thesis for submission to the Office of Graduate Studies at the University of Ontario Institute of Technology (UOIT) in Oshawa, Ontario, Canada. I am seeking your permission to include a manuscript version of the following paper(s) as a chapter in the thesis:

Costa, J., Wehbe, R., Robb, J. and Nacke, L. "Time's Up: Studying Leaderboards for Engaging Punctual Behaviour", Gamification 2013, Stratford ON, Canada (in press).

Wehbe, R. R., Robb, J., Clarke, J., & Nacke, L. E. (2013). Gamifying Reading.

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Name: James Robb Title: MSc Candidate

Signature:  Date: 04 February 2014

February 2nd, 2014

Dear Jens Johannsmeier ,

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Wehbe, R. R. & Nacke, L. E. (2014). Mario Party Study. Not published.

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Name: Jens Johannsmeier Title: Mr.

Signature: Jens Johannsmeier Date: February 5th 2014

February 2nd, 2014

Dear Jessica Clarke,

I am preparing my MSc Computer Science thesis for submission to the Office of Graduate Studies at the University of Ontario Institute of Technology (UOIT) in Oshawa, Ontario, Canada. I am seeking your permission to include a manuscript version of the following paper(s) as a chapter in the thesis:

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Name: Jessica Clarke Title: Evad Prog. Coord

Signature: [Handwritten Signature] Date: Feb 7, 2014

February 2nd, 2014

Dear Joao Costa,

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Name: João Pedro Botelho Castela da Costa Title: -

Signature: João Pedro Botelho Castela da Costa Date: 04/02/2014

February 2nd, 2014

Dear Lennart E. Nacke,

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Wehbe, R. R. & Nacke, L. E. (2014). Mario Party Study. Not published.

Wehbe, RR, DL Kappen, and David Rojas. 2013. "EEG-Based Assessment of Video and in-Game Learning." *CHI'13 Extended* .... doi:10.1145/2468356.2468474.  
<http://dl.acm.org/citation.cfm?id=2468474>.

Wehbe, R. R., Shearer, E. & Nacke, L. E. (2013). Perception of Human versus Computer Controlled Play in Collaborative and Competitive Scenarios. Special Issue of Computers in Human Behavior: "Designing and Evaluating Sociability in Online Video Games". Proposal accepted, full paper currently under review. CHB-D-13-00942

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Wehbe, R. R. & Nacke, L. E. (2013). An Introduction to EEG Analysis Techniques and Brain Computer Interfaces for Games User Researchers. In Proc. of DIGRA '13.

Wehbe, R. R., Kappen, D., Rojas, D., Kapralos, B., & Nacke, L. E. (2013). EEG-Based Assessment of Video and In-Game Learning. In Proc. of CHI EA '13. ACM, 2013.

Kappen, D. L., Gregory, J., Stepchenko, D., Wehbe, R. R., & Nacke, L. E. (2013). Exploring social interaction in co-located multiplayer games. CHI '13 Extended Abstracts on Human Factors in Computing Systems on - CHI EA '13, 1119. doi:10.1145/2468356.2468556

Wehbe, R. R., and Nacke, L.E. (2013). Games User Research using EEG Techniques. Submitted to CHI2013 Workshop on Game User Research: Practice, Methods and Applications.

Wehbe, R. R. & Nacke, L. E. (2013). EEG my Class! Not published.

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Name: Lennart Nacke Title: Professor

Signature:  2014.02.06 15:30:35 -05'00' Date: \_\_\_\_\_

February 2nd, 2014

Dear Mike Schakermann,

I am preparing my MSc Computer Science thesis for submission to the Office of Graduate Studies at the University of Ontario Institute of Technology (UOIT) in Oshawa, Ontario, Canada. I am seeking your permission to include a manuscript version of the following paper(s) as a chapter in the thesis:

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Name: Mike Schäkermann Title: Mr. cand. med.

Signature:  Date: February 5, 2014