COMPARATIVE STUDY OF BRAIN CHARACTERISTICS IN REWARD MECHANISM AMONG COMPUTER GAMERS TOWARDS ADDICTIVE BEHAVIOUR

CHIKO WONG

A thesis submitted in fulfilment of the
requirements for the award of the degree of
Master of Philosophy (Biomedical Engineering)

Faculty of Biosciences and Medical Engineering
Universiti Teknologi Malaysia

JUN 2017

To my beloved mother and father

ACKNOWLEDGEMENT

The very special thank you goes to my beloved and helpful supervisor, Dr. Nugraha P. Utama, and co-supervisor, Dr. Hau Yuan Wen, who had guided me through all the process to prepare this project and consultation for the whole study. The supervision, materials and support that he gave truly help me. The co-operation is much indeed appreciated.

Besides, my grateful thanks also goes to my lab members, who had guided me in the process of learning. The guidance was very helpful indeed in my study. The experience makes me realized the value of working together as a team, which always comes out with a better idea rather than doing the project alone. The whole progress really brought us together to appreciate the value of teamwork and respect of each other.

Great appreciation also goes to my family members who gave material and spiritual support. Not forget, I also appreciate the assistance and comments for my study given by other friends, which was very great and helpful indeed. Lastly, I appreciate the co-operation and help from the participants in my study. Without them, I could not manage to finish my study.

This research receives ethical endorsement and was approved by Research Managerment Centre, UTM, reference number UTM.J.45.01/25.10/3(68) and UTM.J.091104/18.11/1/2(1).

ABSTRACT

This research is basically a comparative study of brain characteristics in reward mechanism towards addictive behaviour among active and non-active computer game players. There were fifteen active and fifteen non-active computer game players, which were classified using Video Game Addiction Test (VAT), participated in the experiment. Electroencephalography (EEG) system was used to record the brain signals. The modified Go-NoGo task combined with event-related potential paradigm were applied during the experiment, where the reaction time with the effect of different contrast levels (2.5% and 25%) and presence of performance feedback (no-feedback, positive feedback, negative feedback, monetary feedback) were recorded. EEGLab and sLORETA software were used in data pre-processing and analysing. EEG results concluded that active gamers activated the brain seed regions (superior frontal gyrus (SFG), posterior cingulate (PCC), anterior cingulate (ACC), insula and orbitofrontal cortex (OFC)) during game play with generally faster activation compared to non-active gamers. It can be concluded that monetary rewards, negative feedback and positive feedback are potential external cues which can induce addictive behaviour, whereby positive feedback has the highest potential and especially more on active gamers compared to non-active gamers. The reaction time of both group of active gamers and non-active gamers are shorter in responding during stimuli presentation which displayed 25% (higher) contrast level compared to 2.5% (lower) contrast level. Besides that, the average reaction time decreased throughout the four conditions (no-feedback > positive feedback > negative feedback > monetary feedback) in 25% stimuli contrast level for both active and non-active gamers.

ABSTRAK

Kajian ini adalah satu kajian perbandingan ciri-ciri otak dalam mekanisme ganjaran terhadap tingkah laku ketagihan di kalangan pemain permainan komputer yang aktif dan tidak aktif. Terdapat lima belas aktif dan lima belas tidak aktif pemain permainan komputer yang telah diklasifikasikan menggunakan Video Game Addiction Test (VAT) menyertai dalam kajian ini. Sistem electroencephalography (EEG) telah digunakan untuk merakam isyarat otak. Tugas Go-Nogo yang diubah suai digabungkan dengan acara yang berkaitan dengan potensi paradigma telah digunakan semasa eksperimen, di mana masa tindak balas dengan kesan tahap kontras yang berbeza (2.5% dan 25%) dan kehadiran maklum balas prestasi (tiada maklum balas, maklum balas positif, maklum balas negatif, maklum balas kewangan) telah direkodkan. EEGLab dan sLORETA telah digunakan dalam data pra-pemprosesan dan menganalisis. Keputusan EEG membuat kesimpulan bahawa pemain aktif diaktifkan kawasan benih otak (superior frontal gyrus (SFG), cingulate posterior (PCC), cingulate anterior (ACC), insula dan korteks orbitofrontal (OFC)) semasa Tugas Go-Nogo. Selain itu, pengaktifan dalam pemain aktif umumnya lebih cepat berbanding pemain yang tidak aktif. Kesimpulannya, ganjaran kewangan, ganjaran negatif dan ganjaran positif berpotensi menjadi isyarat luaran yang boleh menyebabkan tingkah laku ketagihan, terutamanya ganjaran positif and lebih kepada pemain aktif berbanding pemain yang tidak aktif. Masa tindak balas kedua-dua kumpulan pemain aktif dan pemain tidak aktif adalah lebih pendek dalam bertindak balas semasa pembentangan rangsangan yang mempamerkan 25% tahap kontras berbanding 2.5% tahap kontras. Selain itu, masa tindak balas purata menurun sepanjang empat syarat (tiada maklum balas> ganjaran positif > ganjaran negatif> ganjaran kewangan) dalam 25% tahap kontras rangsangan untuk kedua-dua pemain yang aktif dan tidak aktif.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ACC	-	Anterior Cingulate
EEG	-	Electroencephalography
ERP	-	Event Related Potential
ICA	-	Independent Component Analysis (ICA)
mPFC	-	Medial Prefrontal Cortex
MRI	-	Magnetic Resonance Imaging
OFC	-	Orbitofrontal Cortex
PCC	-	Posterior Cingulate
PET	-	Positron Emission Tomography
PFC	-	Prefrontal Cortex
SFG	-	Superior Frontal Gyrus
sLORETA	-	Standardized Low Resolution Brain Electromagnetic Tomography
VAT	-	Video Game Addiction Test

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Introduction

Nowadays, countries all over the world are rapidly adopting the newest technologies, especially smartphones and increasingly tablets. This is one of the main reasons which cause the game industry to grow exponentially across the globe. Games are now a source of entertainment in this technology-dominated world. It is a way of relaxation stepping out from the daily routine. This phenomenon has led to games becoming an important part of many people's lives, and gaming as a popular culture in this era. In year 2012, more than one billion individuals played computer gamers, which fuelled the 8% growth of the computer gaming industry in the same year (Kuss, 2013).

Since there are more and more people who play games, there are news and reports in the media about excessive use of video games. Media starts to warn about the potential dangers of video game playing, including potential addiction, violent and aggressive behaviour. A growing body of research suggests that excessive game playing is associated with negative outcomes, such as obesity, sleep abnormalities, job loss, decreased academic achievement, stress, lower psychosocial wellbeing, depression and anxiety (Littel et al., 2012). Some researches had been carried out to examine the effects of games on human health, personalities, behaviours and the brain (D. A. Gentile et al., 2009; Han, Kim, Lee, Min, & Renshaw, 2010; Han, Lyoo, &

Renshaw, 2012; Spekman, Konijn, & Roelofsma, 2012; Wattanasoontorn, Boada, García, & Sbert, 2013).

Mark Griffiths, who is a leading researcher in behavioural addiction, believes that excessive game playing can lead to game addiction, since the continuous rewards provided by games can be potentially addictive although there is absence of psychoactive substance (MD Griffiths, 2008). Soper and Miller (1983) also stated that "video-game addiction" was like any other behavioural addiction, and consisted of a compulsive behavioural involvement, a lack of interest in other activities, association mainly with other addicts, and physical and mental symptoms when attempting to stop the behaviour.

However, playing games also bring some benefits. A small but significant body of research has begun to emerge, mostly in last seven years, documenting these benefits (Granic, Lobel, & Engels, 2013). Despite the negative effects of gaming, some researches claimed that games can help in developing problem-solving skills, enhance creativity and promote a wide range of cognitive skills (Granic et al., 2013). Playing games could help children with attention deficit disorders (Han et al., 2009). Games also help people recovering from physical injuries, gain motor skills and hand-eye coordination, as well as increase one's response to stimuli and brings about emotional stability (O'Banion, 2012). Studies show that video gamers show improved skills in vision, attention and certain aspects of cognition. The same study concluded the video gamers perform better than non-gamers on certain tests of attention, speed, accuracy, vision and multitasking (C. Green & Bavelier, 2012).

In short, a coin has two sides. Since both advantages and disadvantages always come together, it is a need to avoid disadvantages and seek for the advantages for our own good.

1.2 Problem Background

In simple definition, addiction is a condition that results when a person ingests a substance (e.g., alcohol, cocaine, nicotine) or engages in an activity (e.g., gambling, sex, gaming) that can be pleasurable but the continued use/act of which becomes compulsive and interferes with ordinary life responsibilities, such as work, relationships, or health. The addicts usually do not have control over what they are doing, taking or using. In another view from neurobiology, addiction is a primary, chronic disease of brain reward, motivation, memory and related circuitry. Addiction affects neurotransmission and interactions within the brain regions associated with reward, including the nucleus accumbens, anterior cingulate cortex, basal forebrain and amygdala, such that motivational hierarchies are altered and addictive behaviours supplant healthy, self-care related behaviours. Addiction also affects neurotransmission and interactions between cortical and hippocampal circuits and brain reward structures, such that the memory of previous exposures to rewards (such as food, sex, alcohol and other drugs) leads to a biological and behavioural response to external cues, in turn triggering craving and/or engagement in addictive behaviours.

Addiction can be divided into substance-related or non-substance-related. The substance-related addiction includes drug, alcohol, nicotine addiction and *etc*, whereas the non-substance-related addiction includes sex, gambling, internet, gaming addiction and *etc*. The substance-related addictions usually involve both psychological and physiological addiction, but the non-substance-related addictions, especially game addiction, are often viewed as an impulse control problem involving psychological addiction only. However, unlike substance-related addiction problem in which the explanation in the psychological background is straightforward, the game addiction does not really lead much insight into the mind of compulsive gamers. For instance, previous studies suggested that the use of drugs, such as ecstasy or similar stimulants, could increase the dopamine production in human brain, which can lead to satisfaction and stimulate the repetitive behaviour until it could be described as “addicted”. But game addiction cannot be attributed to a chemical imbalance within the brain. Other factors involve and play the roles in contributing the addictive behaviours, such as psychological need or desire to play.

Unlike substance-related addiction such as drugs and alcohol, which are taken by the addicts, thereby activate the reward system in direct, people do not take any substances into their body. However, the compulsive act of playing video games can lead to addiction. Questions come into mind: What makes a video game addictive? Are there certain characteristics of the game make it addictive compared to other games? Games are always designed to be just difficult enough to be truly challenging, while allowing players still able to achieve small accomplishments that compel them to keep playing. The "hooks", which built into the games with the intent of making players feel addictive, include the high score, monetary reward, beat the game and *etc*. These elements can be actually considered as a "feedback loop", either positive or negative one, to the game players. As an example, in a shooting game, players got rewarded with power-ups at the end of each level based on the score: the higher the score, the more power-ups the players got for the next level. This is a positive feedback loop. Meanwhile the negative feedback loop is the reverse. Both types of feedback affect the performance of the players, and players learn from the feedback to perform better at next trial.

1.3 Problem Statement

Previous studies suggested that the brain activation of teen video gamers looks similar to those of drug and alcohol addicts. The brain reward circuit, which links to the emotional and motivational aspects of behaviour, is the common and important circuit related to addiction. A systematic literature search was conducted to identify 18 studies (Daria J Kuss & Mark D Griffiths, 2012), which used different neuroimaging systems to study the addictive brain activity in internet and game addiction. However, those results make premature conclusions due to different design methodologies and data analysis methods.

In the fifth edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-V), Internet Gaming Disorder is identified in Section III as a condition warranting more clinical research and experience before it might be considered for inclusion in the main book as a formal disorder (American Psychiatric Association, 2013). Therefore, more researches and studies are needed to be carried out in order to provide more evidence and understand the neuronal correlates associated with the development of addictive behaviours related to game playing.

Besides that, human learn from the feedback in game and perform better at next trial. It is believed that the feedback somehow contributes in brain activation in brain reward system. Since it is claimed that activation of brain reward system induce addictive behaviour and lead to addiction, it would be interesting to investigate the relationship of the feedbacks and the brain reward system in inducing addictive behaviour, in terms of spatial and temporal characteristics. It is hypothesised that with the effect of different types of performance feedback, the reaction time in game/task performance will be affected, in which difference of the effects in active and non-active computer game players might be significant.

Since the cognitive effects in game playing are still debatable, complementary methodology design could be done to explore the cognitive effects on active gamers compared to non-active gamers. It is also hypothesised that with different level of stimuli contrast level, the task performance will also be affected.

1.4 Aim and Objectives

The aim of this study is to investigate and analyse human brain characteristics in reward mechanism between active and non-active computer game players towards addictive behaviour. Through the aim, there are three objectives to be achieved.

1. To study the activated areas in human brain during modified Go-NoGo task.
2. To compare the effect of monetary, positive and negative performance feedbacks in brain reward mechanism of both active and non-active computer game players.

3. To investigate the reaction time in active and non-active computer game players, with the effect of different contrast levels of stimuli and the presence of the performance feedback.

1.5 Scope

Throughout this study, human brain characteristics in reward mechanism among both active and non-active computer game players towards addictive behaviour were studied. There were fifteen subjects selected as active computer game players and fifteen subjects selected as non-active computer game players through their score for Video game Addiction Test (VAT). Experiment was conducted based on modified Go-NoGo task paradigm under two different contrast levels (2.5% and 25%) and four different types of feedback (no-feedback, positive feedback, negative feedback, and monetary feedback). Psychtoolbox software was used for letters and numbers presentation. Throughout the experiment, the modified Go-NoGo task paradigm was conducted in different contrast levels and presence/absence of performance feedback. The reaction time was recorded and analysed. Electroencelophalography (EEG) system was used to record the brain activity characteristics during the experiment. EEGLAB, an interactive Matlab toolbox, will be used for processing continuous and event-related EEG and analyses. sLORETA will be used to compute images of electric neuronal activity from EEG.

1.6 Significance of Study

This study allows us a deeper understanding about brain reward mechanism which can lead to addiction. Besides that, by acknowledged with this study, researchers can effectively prevent any bad effects on physical or mental health caused by excessive games. This study is designed to hopefully contribute to future research and will pave the way for the development of addiction treatment approaches.

1.7 Outline of Thesis

The structure of the thesis is summarised as following. The thesis consists of introduction (motivation, objectives, scope and significance of study – Chapter 1), literature review (Chapter 2), research methodology (experimental design and procedure, software used – Chapter 3), results and discussions (Chapter 4), conclusion, limitations and recommendation (Chapter 5).

Chapter 2 presents literature review on core components of addiction, brain reward system as well as reward processing in human brain, recent neurobiology studies of reward-related brain structures and proposed brain circuits and neurocircuitry.

Chapter 3 proposes the research flow, instruments used for this study, experimental design and procedure, data collection, data pre-processing and source localization analysis.

Chapter 4 discusses the EEG result, which is comparison in brain characteristics of active gamers and non-active gamers during Go and NoGo tasks, as well as the brain characteristics of active gamers and non-active gamers with different types of feedback given (positive feedback, negative feedback and monetary feedback) and with stimuli of different contrast level (2.5% and 25%) during Go and NoGo Tasks. Then, behavioral result such as the reaction time and accuracy is discussed between active gamers and non-active gamers.

Chapter 5 summaries the research findings and limitations faced during the research. Some recommendations for future works which might be useful for further development and improvement of the experimental design and data analysis methods are discussed.

REFERENCES

Adolphs, R., Tranel, D., Damasio, H., & Damasio, A. (1994). Impaired recognition of emotion in facial expressions following bilateral damage to the human amygdala. *Nature, 372*(6507), 669-672.

American Psychiatric Association. (2013). *The Diagnostic and Statistical Manual of Mental Disorders: DSM 5*: bookpointUS.

Arbel, Y., Murphy, A., & Donchin, E. (2014). On the utility of positive and negative feedback in a paired-associate learning task. *Journal of cognitive neuroscience, 26*(7), 1445-1453.

Arnould-Taylor, W. (1998). *A textbook of anatomy and physiology*: Nelson Thornes.

Aron, A. R., Shohamy, D., Clark, J., Myers, C., Gluck, M. A., & Poldrack, R. A. (2004). Human midbrain sensitivity to cognitive feedback and uncertainty during classification learning. *Journal of neurophysiology, 92*(2), 1144-1152.

Ashby, F. G., & O'Brien, J. R. B. (2007). The effects of positive versus negative feedback on information-integration category learning. *Perception & Psychophysics, 69*(6), 865-878.

Berridge, K. C., & Robinson, T. E. (1998). What is the role of dopamine in reward: hedonic impact, reward learning, or incentive salience? *Brain Research Reviews, 28*(3), 309-369.

Bickel, W. K., Odum, A. L., & Madden, G. J. (1999). Impulsivity and cigarette smoking: delay discounting in current, never, and ex-smokers. *Psychopharmacology, 146*(4), 447-454.

Brainard, D. H. (1997). The psychophysics toolbox. *Spatial vision, 10*, 433-436.

Brunoni, A. R., Moffa, A. H., Fregni, F., Palm, U., Padberg, F., Blumberger, D. M., . . . Alonzo, A. (2016). Transcranial direct current stimulation for acute major depressive episodes: meta-analysis of individual patient data. *The British Journal of Psychiatry*, bjp. bp. 115.164715.

Charlton, J. P., & Danforth, I. D. (2007). Distinguishing addiction and high engagement in the context of online game playing. *Computers in Human Behavior, 23*(3), 1531-1548.

Cragg, L., & Nation, K. (2008). Go or no-go? Developmental improvements in the efficiency of response inhibition in mid-childhood. *Developmental Science, 11*(6), 819-827.

Di Chiara, G., & Imperato, A. (1988). Drugs abused by humans preferentially increase synaptic dopamine concentrations in the mesolimbic system of freely moving rats. *Proceedings of the National Academy of Sciences, 85*(14), 5274-5278.

Dong, G., Huang, J., & Du, X. (2011). Enhanced reward sensitivity and decreased loss sensitivity in Internet addicts: an fMRI study during a guessing task. *Journal of Psychiatric Research, 45*(11), 1525-1529.

Drueke, B., Weichert, L., Forkmann, T., Mainz, V., Gauggel, S., & Boecker, M. (2015). Neural correlates of positive and negative performance feedback in younger and older adults. *Behavioral and Brain Functions, 11*(1), 17.

Engelmann, J. B., Damaraju, E., Padmala, S., & Pessoa, L. (2009). Combined effects of attention and motivation on visual task performance: transient and sustained motivational effects. *Frontiers in human neuroscience, 3*, 4.

Ferdinand, N. K., & Opitz, B. (2014). Different aspects of performance feedback engage different brain areas: Disentangling valence and expectancy in feedback processing. *Scientific reports, 4*.

Fibiger, H., & Phillips, A. (1986). Reward, motivation, cognition: psychobiology of mesotelencephalic dopamine systems. *Comprehensive Physiology*.

Field, M., Santarcangelo, M., Sumnall, H., Goudie, A., & Cole, J. (2006). Delay discounting and the behavioural economics of cigarette purchases in smokers: the effects of nicotine deprivation. *Psychopharmacology, 186*(2), 255-263.

Fillmore, M. T. (2003). Drug abuse as a problem of impaired control: current approaches and findings. *Behavioral and Cognitive Neuroscience Reviews, 2*(3), 179-197.

Fox, M. D., Corbetta, M., Snyder, A. Z., Vincent, J. L., & Raichle, M. E. (2006). Spontaneous neuronal activity distinguishes human dorsal and ventral attention systems. *Proceedings of the National Academy of Sciences, 103*(26), 10046-10051.

Fudge, J. L., & Haber, S. N. (2002). Defining the caudal ventral striatum in primates: cellular and histochemical features. *The Journal of Neuroscience, 22*(23), 10078-10082.

Garey, L. J. (1994). *Brodmann's 'localisation in the cerebral cortex'*: World Scientific.

Gentile, D. (2009). Pathological video-game use among youth ages 8 to 18: a national study. *Psychological science, 20*(5), 594-602.

Gentile, D. A., Anderson, C. A., Yukawa, S., Ihori, N., Saleem, M., Ming, L. K., . . . Bushman, B. J. (2009). The effects of prosocial video games on prosocial behaviors: International evidence from correlational, longitudinal, and experimental studies. *Personality and Social Psychology Bulletin*.

Gloor, P., Olivier, A., Quesney, L. F., Andermann, F., & Horowitz, S. (1982). The role of the limbic system in experiential phenomena of temporal lobe epilepsy. *Annals of neurology, 12*(2), 129-144.

Goldberg, I. I., Harel, M., & Malach, R. (2006). When the brain loses its self: prefrontal inactivation during sensorimotor processing. *Neuron, 50*(2), 329-339.

Goldstein, R. Z., Alia-Klein, N., Tomasi, D., Carrillo, J. H., Maloney, T., Woicik, P. A., . . . Volkow, N. D. (2009). Anterior cingulate cortex hypoactivations to an emotionally salient task in cocaine addiction. *Proceedings of the National Academy of Sciences, 106*(23), 9453-9458.

Goldstein, R. Z., & Volkow, N. D. (2002). Drug addiction and its underlying neurobiological basis: neuroimaging evidence for the involvement of the frontal cortex. *American Journal of Psychiatry, 159*(10), 1642-1652.

Goldstein, R. Z., & Volkow, N. D. (2011). Dysfunction of the prefrontal cortex in addiction: neuroimaging findings and clinical implications. *Nature reviews neuroscience, 12*(11), 652-669.

Gottfried, J. A., O'Doherty, J., & Dolan, R. J. (2002). Appetitive and aversive olfactory learning in humans studied using event-related functional magnetic resonance imaging. *The Journal of Neuroscience, 22*(24), 10829-10837.

Granic, I., Lobel, A., & Engels, R. C. (2013). The benefits of playing video games.

Green, C., & Bavelier, D. (2012). Learning, attentional control, and action video games. *Current Biology, 22*(6), R197-R206.

Green, C. S., & Bavelier, D. (2007). Action-video-game experience alters the spatial resolution of vision. *Psychological science, 18*(1), 88-94.

Green, C. S., Pouget, A., & Bavelier, D. (2010). Improved probabilistic inference as a general learning mechanism with action video games. *Current Biology, 20*(17), 1573-1579.

Griffiths, M. (2004). Betting your life on it: Problem gambling has clear health related consequences. *BMJ: British Medical Journal, 329*(7474), 1055.

Griffiths, M. (2005). A'components' model of addiction within a biopsychosocial framework. *Journal of Substance Use, 10*(4), 191-197.

Griffiths, M. (2008). Internet and video-game addiction. *Adolescent addiction: Epidemiology, assessment and treatment*, 231-267.

Gusnard, D. A., & Raichle, M. E. (2001). Searching for a baseline: functional imaging and the resting human brain. *Nature reviews neuroscience, 2*(10), 685-694.

Haber, S. N., Kim, K.-S., Mailly, P., & Calzavara, R. (2006). Reward-related cortical inputs define a large striatal region in primates that interface with associative cortical connections, providing a substrate for incentive-based learning. *The Journal of Neuroscience, 26*(32), 8368-8376.

Hampson, M., Driesen, N. R., Skudlarski, P., Gore, J. C., & Constable, R. T. (2006). Brain connectivity related to working memory performance. *Journal of Neuroscience, 26*(51), 13338-13343.

Han, D. H., Kim, Y. S., Lee, Y. S., Min, K. J., & Renshaw, P. F. (2010). Changes in cue-induced, prefrontal cortex activity with video-game play. *Cyberpsychology, Behavior, and Social Networking, 13*(6), 655-661.

Han, D. H., Lee, Y. S., Na, C., Ahn, J. Y., Chung, U. S., Daniels, M. A., . . . Renshaw, P. F. (2009). The effect of methylphenidate on Internet video game play in children with attention-deficit/hyperactivity disorder. *Comprehensive psychiatry, 50*(3), 251-256.

Han, D. H., Lyoo, I. K., & Renshaw, P. F. (2012). Differential regional gray matter volumes in patients with on-line game addiction and professional gamers. *Journal of Psychiatric Research, 46*(4), 507-515.

Hoeft, F., Watson, C. L., Kesler, S. R., Bettinger, K. E., & Reiss, A. L. (2008). Gender differences in the mesocorticolimbic system during computer game-play. *Journal of Psychiatric Research, 42*(4), 253-258.

Holmes, A. P., Blair, R., Watson, J., & Ford, I. (1996). Nonparametric analysis of statistic images from functional mapping experiments. *Journal of Cerebral Blood Flow & Metabolism, 16*(1), 7-22.

Hosokawa, T., Kato, K., Inoue, M., & Mikami, A. (2007). Neurons in the macaque orbitofrontal cortex code relative preference of both rewarding and aversive outcomes. *Neuroscience research, 57*(3), 434-445.

Ikemoto, S. (2007). Dopamine reward circuitry: two projection systems from the ventral midbrain to the nucleus accumbens–olfactory tubercle complex. *Brain Research Reviews, 56*(1), 27-78.

Ikemoto, S. (2010). Brain reward circuitry beyond the mesolimbic dopamine system: a neurobiological theory. *Neuroscience & Biobehavioral Reviews, 35*(2), 129-150.

Ikemoto, S., & Panksepp, J. (1999). The role of nucleus accumbens dopamine in motivated behavior: a unifying interpretation with special reference to reward-seeking. *Brain Research Reviews, 31*(1), 6-41.

Jasper, H. H. (1958). The ten twenty electrode system of the international federation. *Electroencephalography and clinical neurophysiology, 10*, 371-375.

Jentsch, J. D., & Taylor, J. R. (1999). Impulsivity resulting from frontostriatal dysfunction in drug abuse: implications for the control of behavior by reward-related stimuli. *Psychopharmacology, 146*(4), 373-390.

Knutson, B., Fong, G. W., Bennett, S. M., Adams, C. M., & Hommer, D. (2003). A region of mesial prefrontal cortex tracks monetarily rewarding outcomes: characterization with rapid event-related fMRI. *Neuroimage, 18*(2), 263-272.

Ko, C.-H., Liu, G.-C., Hsiao, S., Yen, J.-Y., Yang, M.-J., Lin, W.-C., . . . Chen, C.-S. (2009). Brain activities associated with gaming urge of online gaming addiction. *Journal of Psychiatric Research, 43*(7), 739-747.

Koob, G. F. (1992). Drugs of abuse: anatomy, pharmacology and function of reward pathways. *Trends in pharmacological sciences, 13*, 177-184.

Koob, G. F., & Le Moal, M. (2008). Addiction and the brain antireward system. *Annu. Rev. Psychol., 59*, 29-53.

Koob, G. F., & Volkow, N. D. (2009). Neurocircuitry of addiction. *Neuropsychopharmacology, 35*(1), 217-238.

Kringelbach, M. L. (2005). The human orbitofrontal cortex: linking reward to hedonic experience. *Nature reviews neuroscience, 6*(9), 691-702.

Kringelbach, M. L., O'Doherty, J., Rolls, E. T., & Andrews, C. (2003). Activation of the human orbitofrontal cortex to a liquid food stimulus is correlated with its subjective pleasantness. *Cerebral Cortex, 13*(10), 1064-1071.

Kuss, D. J. (2013). Internet gaming addiction: current perspectives. *Psychology research and behavior management, 6*, 125.

Kuss, D. J., & Griffiths, M. D. (2012). Internet and gaming addiction: a systematic literature review of neuroimaging studies. *Brain Sciences, 2*(3), 347-374.

Kuss, D. J., & Griffiths, M. D. (2012). Internet gaming addiction: A systematic review of empirical research. *International Journal of Mental Health and Addiction, 10*(2), 278-296.

Leech, R., & Sharp, D. J. (2014). The role of the posterior cingulate cortex in cognition and disease. *Brain, 137*(1), 12-32.

Lemos, I. L., Cardoso, A., & Sougey, E. B. (2016). Cross-cultural adaptation and evaluation of the psychometric properties of the Brazilian version of the Video Game Addiction Test. *Computers in Human Behavior, 55*, 207-213.

Li, R., Polat, U., Makous, W., & Bavelier, D. (2009). Enhancing the contrast sensitivity function through action video game training. *Nature neuroscience, 12*(5), 549.

Li, W., Qin, W., Liu, H., Fan, L., Wang, J., Jiang, T., & Yu, C. (2013). Subregions of the human superior frontal gyrus and their connections. *Neuroimage, 78*, 46-58.

Littel, M., Berg, I., Luijten, M., Rooij, A. J., Keemink, L., & Franken, I. H. (2012). Error processing and response inhibition in excessive computer game players: an event-related potential study. *Addiction biology, 17*(5), 934-947.

Maddock, R. J., Garrett, A. S., & Buonocore, M. H. (2001). Remembering familiar people: the posterior cingulate cortex and autobiographical memory retrieval. *Neuroscience, 104*(3), 667-676.

Maddock, R. J., Garrett, A. S., & Buonocore, M. H. (2003). Posterior cingulate cortex activation by emotional words: fMRI evidence from a valence decision task. *Human brain mapping, 18*(1), 30-41.

Martino, J., Gabarrós, A., Deus, J., Juncadella, M., Acebes, J., Torres, A., & Pujol, J. (2011). Intrasurgical mapping of complex motor function in the superior frontal gyrus. *Neuroscience, 179*, 131-142.

McBride, W. J., Murphy, J. M., & Ikemoto, S. (1999). Localization of brain reinforcement mechanisms: intracranial self-administration and intracranial place-conditioning studies. *Behavioural brain research, 101*(2), 129-152.

Meerkerk, G.-J., Van Den Eijnden, R. J., Vermulst, A. A., & Garretsen, H. F. (2009). The compulsive internet use scale (CIUS): some psychometric properties. *CyberPsychology & Behavior, 12*(1), 1-6.

Mitchell, S. H. (1999). Measures of impulsivity in cigarette smokers and non-smokers. *Psychopharmacology, 146*(4), 455-464.

Naqvi, N. H., & Bechara, A. (2009). The hidden island of addiction: the insula. *Trends in neurosciences, 32*(1), 56-67.

Nichols, T. E., & Holmes, A. P. (2002). Nonparametric permutation tests for functional neuroimaging: a primer with examples. *Human brain mapping, 15*(1), 1-25.

Nieuwenhuis, S., Slagter, H. A., Geusau, V., Alting, N. J., Heslenfeld, D. J., & Holroyd, C. B. (2005). Knowing good from bad: differential activation of human cortical areas by positive and negative outcomes. *European Journal of Neuroscience, 21*(11), 3161-3168.

Nosek, B. A., & Banaji, M. R. (2001). The go/no-go association task. *Social cognition, 19*(6), 625-666.

O'Banion, N. A. (2012). *The effects of controlled video game playing experience on the eye-hand coordination and reaction time of second grade children.*

O'Doherty, J., Winston, J., Critchley, H., Perrett, D., Burt, D. M., & Dolan, R. J. (2003). Beauty in a smile: the role of medial orbitofrontal cortex in facial attractiveness. *Neuropsychologia, 41*(2), 147-155.

O'Reardon, J. P., Solvason, H. B., Janicak, P. G., Sampson, S., Isenberg, K. E., Nahas, Z., . . . Loo, C. (2007). Efficacy and safety of transcranial magnetic stimulation in the acute treatment of major depression: a multisite randomized controlled trial. *Biological psychiatry, 62*(11), 1208-1216.

Oldfield, R. C. (1971). The assessment and analysis of handedness: the Edinburgh inventory. *Neuropsychologia, 9*(1), 97-113.

Olds, J., & Milner, P. (1954). Positive reinforcement produced by electrical stimulation of septal area and other regions of rat brain. *Journal of comparative and physiological psychology, 47*(6), 419.

Orford, J. (2001). *Excessive appetites: A psychological view of addictions*: John Wiley & Sons Ltd.

Osman, M. (2008). Positive transfer and negative transfer/antilearning of problem-solving skills. *Journal of Experimental Psychology: General, 137*(1), 97.

Owen, A. M. (2000). The role of the lateral frontal cortex in mnemonic processing: the contribution of functional neuroimaging *Executive Control and the Frontal Lobe: Current Issues* (pp. 33-43): Springer.

Pascual-Marqui, R. D. (2002). Standardized low-resolution brain electromagnetic tomography (sLORETA): technical details. *Methods Find Exp Clin Pharmacol, 24*(Suppl D), 5-12.

Pascual-Marqui, R. D. (2007). Discrete, 3D distributed, linear imaging methods of electric neuronal activity. Part 1: exact, zero error localization. *arXiv preprint arXiv:0710.3341*.

Pascual-Marqui, R. D. (2009). Theory of the EEG inverse problem. *Quantitative EEG analysis: methods and clinical applications*, 121-140.

Pelli, D. G. (1997). The VideoToolbox software for visual psychophysics: Transforming numbers into movies. *Spatial vision, 10*(4), 437-442.

Pierce, R. C., & Kumaresan, V. (2006). The mesolimbic dopamine system: the final common pathway for the reinforcing effect of drugs of abuse? *Neuroscience & Biobehavioral Reviews, 30*(2), 215-238.

Poldrack, R. A., Clark, J., Pare-Blagoev, E., Shohamy, D., Moyano, J. C., Myers, C., & Gluck, M. A. (2001). Interactive memory systems in the human brain. *Nature, 414*(6863), 546-550.

Porcelli, A. J., & Delgado, M. R. (2009). Reward processing in the human brain: insights from fMRI. *Handbook of reward and decision making*, 165-184.

Rolls, E. T., O'Doherty, J., Kringelbach, M. L., Francis, S., Bowtell, R., & McGlone, F. (2003). Representations of pleasant and painful touch in the human orbitofrontal and cingulate cortices. *Cerebral Cortex, 13*(3), 308-317.

Rushworth, M., Behrens, T., Rudebeck, P., & Walton, M. (2007). Contrasting roles for cingulate and orbitofrontal cortex in decisions and social behaviour. *Trends in cognitive sciences, 11*(4), 168-176.

Small, D. M., Gitelman, D., Simmons, K., Bloise, S. M., Parrish, T., & Mesulam, M.-M. (2005). Monetary incentives enhance processing in brain regions mediating top-down control of attention. *Cerebral Cortex, 15*(12), 1855-1865.

Soper, W. B., & Miller, M. J. (1983). Junk-time junkies: An emerging addiction among students. *The School Counselor*, 40-43.

Spekman, M., Konijn, E., & Roelofsma, P. (2012). *Excessive gaming: healthy enthusiasm or pathological personality.* Paper presented at the Annual Conference of the International Communication Association, Phoenix, AZ.

Tremblay, L., & Schultz, W. (1999). Relative reward preference in primate orbitofrontal cortex. *Nature, 398*(6729), 704-708.

Tricomi, E., & Fiez, J. A. (2012). Information content and reward processing in the human striatum during performance of a declarative memory task. *Cognitive, Affective, & Behavioral Neuroscience, 12*(2), 361-372.

Volkow, N. D., & Fowler, J. S. (2000). Addiction, a disease of compulsion and drive: involvement of the orbitofrontal cortex. *Cerebral Cortex, 10*(3), 318-325.

Volkow, N. D., Fowler, J. S., & Wang, G.-J. (2003). The addicted human brain: insights from imaging studies. *The Journal of clinical investigation, 111*(10), 1444-1451.

Wattanasoontorn, V., Boada, I., García, R., & Sbert, M. (2013). Serious games for health. *Entertainment Computing, 4*(4), 231-247.

Weinstein, A., & Lejoyeux, M. (2010). Internet addiction or excessive internet use. *The American journal of drug and alcohol abuse, 36*(5), 277-283.

White, N. M., & Milner, P. M. (1992). The psychobiology of reinforcers. *Annual review of psychology, 43*(1), 443-471.

Wilbert, J., Grosche, M., & Gerdes, H. (2010). Effects of evaluative feedback on rate of learning and task motivation: an analogue experiment. *Learning Disabilities: A Contemporary Journal, 8*(2), 43-52.

Winston, J. S., O'Doherty, J., Kilner, J. M., Perrett, D. I., & Dolan, R. J. (2007). Brain systems for assessing facial attractiveness. *Neuropsychologia, 45*(1), 195-206.

Wise, R. A. (1982). Neuroleptics and operant behavior: the anhedonia hypothesis. *Behavioral and brain sciences, 5*(01), 39-53.

Wise, R. A., & Bozarth, M. A. (1987). A psychomotor stimulant theory of addiction. *Psychological review, 94*(4), 469.

Young, J. D.-E., & Taylor, E. (1998). Meditation as a voluntary hypometabolic state of biological estivation. *Physiology, 13*(3), 149-153.