NEUROPHYSIOLOGICAL CHARACTERISTICS OF INHIBITORY CONTROL DEFICIT AMONG INDIVIDUALS WITH AND WITHOUT INTERNET GAMING DISORDER

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2024

NEUROPHYSIOLOGICAL CHARACTERISTICS OF INHIBITORY CONTROL DEFICIT AMONG INDIVIDUALS WITH AND WITHOUT INTERNET GAMING DISORDER

by

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**Thesis submitted in fulfilment of the requirements
for the degree of
Doctor of Philosophy**

November 2024

ACKNOWLEDGEMENT

I am deeply grateful to the many individuals who supported me throughout my doctoral studies. First and foremost, I extend my heartfelt thanks to my supervisor, Dr. Nor Shuhada Binti Murad @ Mansor, for her invaluable guidance, unwavering support, and patience throughout my PhD journey. Meeting you through a paper in the summer of 2021 and becoming your student was a great honour. Your expertise and insightful feedback have been crucial in shaping this dissertation. I also sincerely thank Dr. Mohammad Farris Iman Leong Bin Abdullah for his valuable suggestions for my ethics defence and my thesis. My gratitude extends to Associate Professor Dr. Zhao Lijun for her generous assistance in data collection in China.

Additionally, I am grateful to the interns who supported my research by helping gather data. Their support as teammates and their encouragement as friends were invaluable during my PhD journey. I am also thankful to my internal and external reviewers for their insightful comments, constructive feedback, and thoughtful suggestions, which significantly enriched the quality of my research. I deeply appreciate your expertise in helping me achieve a higher standard of academic excellence.

Finally, I am profoundly grateful to my family, especially my parents, for their unwavering love, support, and encouragement, which kept my spirits high and motivated me to complete my PhD. Finally, I am profoundly grateful to my family, especially my parents, for their unwavering love, support, and encouragement, which kept my spirits high and motivated me to complete my PhD.

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LIST OF SYMBOLS

%	Percentage
p	Probability
df	Degrees of Freedom
F	"Fisher's F statistic
β	Beta
t	T statistic
r	Pearson Correlation Coefficient
R	Multiple Correlation Coefficient
R^2	R-squared
$\triangle R^2$	Delta R-squared
Sig.	Significance
Min	Minimum
Max	Maximum
M	Mean
SD	Standard Deviation
N	Number
μv	Micro Volt

LIST OF ABBREVIATIONS

ERP	Event-related potential
EEG	Electroencephalography
TMS	Transcranial Magnetic Stimulation
fNIRS	Functional Near-Infrared Spectroscopy
fMRI	Functional Magnetic Resonance Imaging
MRI	Magnetic Resonance Imaging
MEG	Magnetoencephalography
EMG	Electromyography
EOG	Electrooculography
ECG	Electrocardiography
IGD	Internet Gaming Disorder
HC	Healthy control
DSM-5	Diagnostic and Statistical Manual of Mental Disorders, 5th edition
BIS-11	Barratt Impulsiveness Scale, version 11
USM	Universiti Sains Malaysia

LIST OF APPENDICES

CIRI-CIRI NEUROFISIOLOGI PADA DEFISIT KAWALAN PERENCATAN DALAM KALANGAN INDIVIDU YANG ADA DAN TIADA GANGGUAN PERMAINAN INTERNET

ABSTRAK

Pada pertengahan tahun 2018, Pertubuhan Kesihatan Sedunia (WHO) menekankan bahawa tingkah laku bermain permainan video boleh menyebabkan tekanan yang ketara atau menjejaskan fungsi dalam pelbagai aspek kehidupan. Gangguan permainan internet (Internet Gaming Disorder, IGD) adalah satu bentuk ketagihan internet yang dicirikan oleh hilangnya kawalan terhadap permainan, sehingga mengabaikan minat dan aktiviti harian yang lain. Pada masa ini, kekurangan paradigma penyelidikan yang sistematik untuk mengkaji IGD dan keupayaan kawalan inhibisi telah menghadkan pemahaman tentang gangguan kawalan inhibisi dalam pesakit IGD. Selain itu, tiada kajian yang telah membandingkan jenis-jenis kawalan inhibisi yang berbeza (gangguan pengalih perhatian dan kawalan respons utama) untuk menentukan ciri tingkah laku dan neurofisiologi yang berbeza dalam IGD. Bagi mengatasi jurang penyelidikan ini, kajian ini meneliti fungsi kawalan inhibisi dalam individu dengan IGD menggunakan tinjauan soal selidik, eksperimen kognitif, dan eksperimen ERP. Peserta kajian dipilih daripada 817 pelajar universiti di China. Tinjauan soal selidik, yang merupakan kajian rentas, menggunakan IGD-20 dan DSM-V untuk mendiagnosis IGD serta menilai faktor sosiodemografi dan psikologi yang berkaitan. Hasil kajian menunjukkan bahawa individu dengan IGD cenderung lebih muda, kebanyakannya lelaki, mempunyai tahap pendidikan yang lebih rendah, sejarah bermain permainan yang lebih lama, dan menghabiskan lebih banyak masa bermain permainan setiap hari. Mereka juga menunjukkan kawalan impuls yang lemah,

keinginan yang lebih kuat untuk bermain permainan, kecenderungan mengambil risiko yang lebih tinggi, tingkah laku kompulsif, serta keupayaan kawalan diri dan perhatian yang rendah. Kajian kognitif ini, yang merupakan kajian kes-kawalan, membandingkan gangguan pengalih perhatian dan kawalan respons antara individu dengan IGD dan kumpulan kawalan yang sihat menggunakan tugasan Flanker dan Go/No-Go. Reka bentuk kajian campuran dua faktor yang melibatkan jenis tugas dan jenis peserta menunjukkan bahawa peserta IGD mempunyai kawalan inhibisi yang lebih lemah, yang dikaitkan dengan defisit dalam perhatian (gangguan pengalih perhatian) dan kawalan tingkah laku (respons inhibisi). Kajian ERP, yang juga merupakan kajian kes-kawalan, meneroka ciri-ciri neurofisiologi kawalan inhibisi dalam IGD. Kajian ini menggunakan reka bentuk campuran tiga faktor yang melibatkan elektrod, jenis tugas, dan jenis peserta. Hasil kajian menunjukkan bahawa peserta IGD memerlukan usaha kognitif yang lebih besar untuk melengkapkan tugas kawalan inhibisi, yang ditunjukkan oleh amplitud N2 dan P3 yang lebih tinggi serta peningkatan pengaktifan otak di lobus frontal, prefrontal, dan oksipital. Gangguan inhibisi berlaku lebih awal semasa pemprosesan persepsi, manakala kawalan respons berkait dengan pemprosesan memori yang lebih lewat. Penemuan ini memberikan pandangan tentang mekanisme neurofisiologi yang mendasari IGD dan boleh memandu pembangunan intervensi yang berkesan untuk gangguan ini.

**NEUROPHYSIOLOGICAL CHARACTERISTICS OF INHIBITORY
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ABSTRACT

In mid-2018, the World Health Organisation (WHO) highlighted that gaming behaviour can cause significant distress or impair functioning in various aspects of life. Internet gaming disorder (IGD) is a form of Internet addiction characterized by losing control over gaming, leading to neglect of other interests and daily activities. Currently, the lack of systematic research paradigms to study IGD and its inhibitory control abilities limits the understanding of impaired inhibitory control in IGD patients. Moreover, no studies have compared different types of inhibitory control (distractor interference inhibitory control and prepotent response inhibitory control) to determine their distinct behavioural and neurophysiological characteristics in IGD. To address this research gap, the current study examines the inhibitory control functions in individuals with IGD using questionnaire surveys, cognitive experiments, and ERP experiments. The study participants were selected from 817 university students in China. The questionnaire survey, a cross-sectional study, used the IGD-20 and DSM-V to diagnose IGD and assess relevant sociodemographic and psychological factors. The findings indicate that individuals with IGD are younger, predominantly male, have less education, longer gaming history, and spend more time gaming daily. They also exhibit poorer impulse control, stronger cravings, higher risk-taking, compulsive behaviour, and reduced self-control and attention abilities. The cognitive study, a case-control study, compared distractor interference and response inhibitory control between individuals with IGD and healthy controls using the Flanker and Go/No-Go

tasks, respectively. A two-factor mixed design involving task type and participant type revealed that IGD participants have poorer inhibitory control, linked to deficits in attention (distractor interference inhibitory control) and behavioural control (prepotent response inhibitory control). The ERP study, also a case-control study, explored the neurophysiological characteristics of inhibitory control in IGD. It used a three-factor mixed design with electrodes, task type, and participant type. Results showed that IGD participants required greater cognitive effort to complete inhibitory control tasks, indicated by greater N2 and P3 amplitudes and increased brain activation in the frontal, prefrontal, and occipital lobes. Distractor interference inhibitory control occurs early during perceptual processing, while prepotent response inhibitory control is linked to later memory processing. These findings provide insights into the neurophysiological mechanisms underlying IGD and may guide the development of effective interventions for this disorder.

CHAPTER 1

INTRODUCTION

1.1   Introduction

This chapter presents the current research on deficits in inhibitory control in Internet Gaming Disorder, covering the research background, problem statement, research questions, research objectives, significance of the study, operational definitions, research hypotheses, and a summary of the thesis overview.

1.2   Background of the Study

The rapid development of Internet technology has penetrated the daily lives of university students, impacting their learning, knowledge-seeking, social cognition, social entertainment, and social communication. First invented in the early 1980s, the enrichment of internet applications through social networks (e.g., Facebook, Microblog, WhatsApp, and WeChat) and gaming platforms has fostered an emergent digital entertainment culture. In November 2023, the International Telecommunication Union (ITU) released its latest report, 'Facts and Figures 2023'. The report highlights that internet usage is increasing globally, with approximately 5.4 billion people currently using the Internet. In 2023, 79% of the global population aged 15-24 are using the Internet, indicating a continuous growth in internet usage among young people. This rate is 14 percentage points higher than other age groups. Furthermore, young people's internet use is diverse, encompassing activities such as online socialising, entertainment, shopping, and learning (ITU, 2023). With the widespread adoption of the internet among young people, online gaming has gradually become an integral part of their daily lives. Due to the immediate feedback, diverse entertainment options, and the opportunity to interact with players globally, many young people

begin to spend significant amounts of time in virtual worlds. However, as their dependence on gaming increases, some young individuals start to exhibit signs of excessive use, a phenomenon that may eventually lead to the development of internet gaming disorder (Dong et al., 2012; Dong et al., 2020). Internet gaming disorder, despite its popularity among young adults, is associated with a wide range of psychological problems, such as addictive behaviours, anxiety and depression issues, social phobia, attention disorders, and impulse control problems (Weinstein & Lejoyeux, 2015; Yen et al., 2017). A systematic review of 50 studies on IGD suggested the prevalence of IGD ranged from 0.7% to 27.5%; the prevalence tends to be higher among male and younger populations (Mihara & Higuchi, 2017). Meanwhile, the meta-analysis of 5550 citations and 160 studies revealed that the prevalence of internet gaming disorder (IGD) varied from 0.21% to 57.50% in general populations, 3.20% to 91.00% in clinical populations, and 50.42% to 79.25% in severe cases populations (Darvesh et al., 2020). In the Fifth Edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-5), published by the American Psychiatric Association (APA) in 2013, internet gaming disorders were categorised as novel mental disorders that required further research. Furthermore, in the eleventh revision of the International Classification of Diseases (ICD-11) released by the World Health Organisation (WHO) in 2018, internet gaming disorders were officially recognised as a new addictive mental disorder. The long-term use of online games leads to dependence, or worse, addiction to online games, which cannot be ignored (Zhou et al., 2010). As research has deepened in recent years, the harm caused by internet gaming disorders has begun to attract the attention of numerous researchers within the university student population (Aziz et al., 2021). Due to the negative impact of online games, it has become the focus of psychological and sociological researchers. Internet gaming

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disorder can lead to the impairment of users' psychological and social functions (Charlton & Danforth, 2007). Research indicates that individuals with internet gaming disorders exhibit cognitive impairments that are comparable to those seen in substance addiction.

1.2.1   Survey

Literature suggests that there is an association between internet gaming disorder and impaired inhibitory functions in individuals. To begin with, inhibitory control abilities in IGD are also reflected in sociodemographic factors. Studies have shown that individuals with internet gaming disorder (IGD) significantly differ from non-IGD participants in terms of sociodemographic characteristics. IGD individuals often have longer gaming histories and spend more time gaming each day, with significant difficulties in regulating their gaming time (Baggio et al., 2016). Excessive gaming time is a major characteristic of IGD, where individuals gradually develop a dependency on the virtual environment over prolonged periods of gaming (Mihara & Higuchi, 2017). This can lead to neglecting other important daily activities, such as physical exercise, social interactions, academics, and relationships. In terms of age, IGD is more common among younger individuals, especially adolescents and young adults, which is linked to their high interest in gaming content. One study highlighted that IGD is particularly prevalent in adolescents, as they are more susceptible to the allure of gaming and may turn to games as a means of escaping emotional and social stressors (Wartberg & Lindenberg, 2020). Furthermore, significant gender differences have been observed in IGD. Research indicates that males are more likely to develop internet gaming disorder than females, possibly due to their preference for competitive and achievement-oriented games (Stavropoulos et al., 2019). In addition, studies have shown that individuals with IGD tend to have fewer years of formal education

compared to their non-IGD counterparts. This may be because excessive gaming negatively impacts academic tasks, reducing educational participation and academic achievement (Kim et al., 2017). IGD individuals often invest less effort in school, which further hinders their academic progress. Moreover, these inhibitory control defects are also reflected in individual behaviour characteristics. Young (1998) noted that IGD is associated with impulse control disorders. Mills and Allen (2020) did correlations showing that poorer self-control was associated with higher IGD and less adaptive video gaming motivations. Meanwhile, a significant positive correlation was found between trait impulsivity and internet gaming disorders, suggesting that prolonged gaming use may lead to a higher tendency towards impulsive behaviours (Li et al., 2018). In a prospective longitudinal design, Kräplin et al. (2021) found that lower general inhibitory control is predictively associated with more gaming behaviour one year later and that more impulsive decision-making is retrospectively associated with a higher IGD severity for a previous year. Moreover, individuals with internet gaming disorder (IGD) exhibit lower self-management abilities in their daily lives, struggling to control their intense need for internet gaming (Kuss, Pontes, & Griffiths, 2018). They may also engage in more risk-taking behaviours (Potenza et al., 2013) and demonstrate patterns of behaviour characterised by excessive reliance on gaming and difficulty with self-control (Gentile et al., 2011).

1.2.2   Cognitive Experiments

Deficiency in inhibitory control ability among individuals with internet gaming disorder is evidenced through cognitive behavioural experiments. Inhibitory control deficit has been suggested as a predictive marker for behavioural and drug addictions (Bartholdy et al., 2016). Littel et al. (2012) used the Go/NoGo behaviour inhibition task and found that excessive gamers exhibited deficits in response inhibitory,

demonstrating that IGD patients have higher levels of self-reported impulsivity and more impulsive responses. Patients with internet gaming disorder (IGD) often struggle to maintain attention in distracting environments. This is reflected in their tendency to be easily distracted by gaming-related stimuli when engaged in tasks that require focused attention. Metcalf and Pammer (2011) used the Stroop paradigm and found that people with Internet gaming disorders took significantly longer to respond to game-related words compared to healthy individuals. This indicates that the processing of game-related words interfered with their response to the colour naming of words, showing an attentional bias towards game-related words. Similar results were found by Jeromin et al. (2016) in their Stroop task study on Internet gaming disorders. Van Holst et al. (2012) applied a dot-probe task and found that people with Internet gaming disorders have an attentional bias towards game images. Some studies using cue-induced paradigms found that Internet-related words can induce strong cravings for online behaviour in Internet addicts (Niu et al., 2016). Nie et al. (2016) used a Stop-Signal Task to study Internet disorders and found that compared to non-internet-related cues, internet disorders were more likely to make mistakes when faced with Internet cues, indicating that their inhibitory control is weakened when faced with Internet-related words. More specifically, distractor interference inhibitory and prepotent response inhibitory are two critical components of inhibitory control, which differ in their methods of processing information and managing behaviour (Diamond, 2013; Aron, Robbins, & Poldrack, 2014). Distractor interference inhibitory tasks usually require individuals to ignore irrelevant or distracting stimuli while focusing on task-relevant information. For example, a study found that individuals with IGD have deficits in attention allocation and cognitive control during the Stroop task, suggesting difficulties in disregarding conflicting information (such as when the word for colour

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and the colour of the font do not match) (Kuss, Pontes, & Griffiths, 2018). Prepotent response inhibitory involves the capacity to inhibit automatic or habitual responses. For instance, Weinstein et al. (2016) reported that IGD patients may experience greater difficulty in stopping an already initiated response in Go/No-Go or Stop-Signal tasks, indicating deficits in response inhibitory.

1.2.3   Neurophysiological Studies

Moreover, neurophysiological studies pinpoint distinct neurological patterns in individuals with internet gaming disorder compared to normal healthy participants. Park et al. (2017) investigated the N100 and P300 event-related potentials (ERPs) in patients with IGD to compare them with those of healthy controls (HCs). Twenty-six patients with IGD and 29 HCs participated in this study. ERPs were acquired from young male adults during an auditory oddball task. Between-group differences in N100 and P300 were investigated separately using repeated-measures analysis of variance. Correlations between the ERP values and neurocognitive functioning of each group were examined. IGD groups showed reduced P300 amplitudes at the midline central and parietal area compared with the HCs. The IGD exhibited reduced N100 amplitudes at the midline frontal area compared with the HCs. The reduced P300 was correlated with a higher spatial span error rate in the IGD. The reduced N100 and P300 were not correlated with internet addiction severity scores in the IGD. Ko et al. (2014) aimed to identify the neural substrates of internet gaming disorders by evaluating brain areas associated with cue-induced gaming urges. They found that, compared to the control group, the addicted group showed activation in the right orbitofrontal cortex, right ventral striatum, bilateral anterior cingulate and medial frontal cortex, right dorsolateral prefrontal cortex, and right caudate nucleus during fMRI scans. Weinstein and Lejoyeux (2015) discovered that IGD also had decreased functional connectivity

of prefrontal cortex-striatal circuits, increased risk-taking choices, and impaired ability to control their impulses, similar to other impulse control disorders. Luijten et al. (2015) indicated significantly increased self-reported impulsivity levels and decreased inhibitory control in problem gamers, accompanied by reduced brain activation in the left inferior frontal gyrus (IFG) and right inferior parietal lobe (IPL) relative to controls. Kim et al. (2017) used Go/NoGo task and observed delayed NoGo-N2 latency in individuals with IGD, when compared to healthy control subjects, indicating that the elevated heightened impulsivity cognitive demand impaired inhibitory control. Fathi et al. (2022), through stop-signal experiments, noted that in stop trials, the video game addiction (VGA) group exhibited reduced N2 amplitude compared to the control group in proactive stop trials. Additionally, the VGA group demonstrated an increased P3 amplitude in the proactive stop trials. Overall, this evidence supports the proposition that there is a distinguishable EEG pattern between individuals with internet gaming disorder (IGD) and healthy controls (HC), which may serve as a neurophysiological marker of IGD. Therefore, it is necessary to explore the neurophysiological factors influencing internet gaming disorders through multiple methods.

Therefore, this study tends to combine questionnaire surveys, cognitive behavioural assessments, and Event-related potentials (ERPs) experiments to explore the neurophysiological characteristics of inhibitory control functions in individuals with IGD, with the independent variable being Internet Gaming Disorder (IGD) and the dependent variable being inhibitory control ability. The independent variable, IGD, refers to excessive and uncontrolled engagement in online gaming that significantly impacts an individual's personal, social, educational, or occupational functioning (American Psychiatric Association, 2013). IGD is characterised by symptoms such as preoccupation with gaming, withdrawal symptoms, and unsuccessful attempts to

reduce gaming. The dependent variable, inhibitory control ability, represents an individual's capacity to regulate and suppress inappropriate or impulsive responses, which is crucial for adaptive behaviour and self-control (Diamond, 2013). Inhibitory control deficits are often observed in individuals with IGD, potentially contributing to problematic gaming behaviours. The design of this study, which includes questionnaire surveys, cognitive behavioural assessments, and EEG experiments, aims to provide a comprehensive evaluation of inhibitory control abilities in individuals with IGD. The use of questionnaire surveys (e.g., IGD-20 and DSM-5) helps in diagnosing IGD and identifying sociodemographic and psychological factors associated with the disorder. Cognitive behavioural assessments allow for the evaluation of specific cognitive impairments related to inhibitory control, such as difficulties in resisting gaming-related cues (Verbruggen & Logan, 2008). The integration of EEG experiments is significant as it provides objective neurophysiological data regarding brain activity associated with inhibitory control. Event-related potentials (ERPs) are used to assess neural processes related to response inhibitory and attentional control (Luck, 2014). This multimethod approach enhances the reliability and validity of the findings by providing insights into both behavioural and neural aspects of inhibitory control, thereby offering a more complete understanding of how IGD affects cognitive functioning.

1.3   Problem Statement

Firstly, studies on the neurophysiological characteristics of internet gaming disorder, especially its inhibitory control capabilities, vary significantly, and research findings lack consistency. Different research methods and paradigms can impact the outcomes of studies, leading to variations in the results. Among existing systematic reviews,

some studies have explored the prevalence and characteristics of individuals with gaming disorder (Long et al., 2018; Kim et al., 2022), yet none have empirically examined the neurophysiological features of individuals with internet gaming disorder (IGD) using ERP experiments. Others have reviewed the neurophysiological traits of gaming disorder (Kuss & Griffiths, 2012; Legault et al., 2021) but have not investigated EEG amplitude characteristics in ERP experiments or considered EEG amplitude as an empirical indicator for assessing the relationship between IGD and inhibitory control. Additionally, while certain studies have explored the behavioural characteristics of IGD, such as impulsivity and compulsivity (Şalvarlı & Griffiths, 2019; Lee et al., 2019), they have not systematically reviewed the inhibitory control-related behavioural characteristics associated with IGD. Therefore, there is a lack of systematic research analysing internet gaming disorder and its inhibitory control capabilities to identify the EEG amplitude characteristics of impaired inhibitory control functions in individuals with internet gaming disorders. From the empirical perspective, this study aims to reveal the neurophysiological characteristics of inhibitory control in IGD from behavioural, cognitive, and neural perspectives to fill this critical gap in existing research.

Secondly, from a theoretical perspective, although research on internet addiction has matured, studies specifically focussing on internet gaming disorder (IGD) are relatively lacking (Kuss & Griffiths, 2012). The extensive literature on internet addiction and gaming addiction suggests that, while a considerable amount of research has been conducted on general online behaviours, there remains a notable gap in understanding the specific characteristics and underlying mechanisms of IGD (Király et al., 2020). This gap points to the need for more targeted studies that delve into the unique aspects of IGD. Inhibitory control, a key issue in IGD, involves multiple

dimensions, including cognitive, behavioural, and neural mechanisms (Brand et al., 2016). Current research often relies heavily on self-reported questionnaires to assess IGD symptoms, which may not fully capture the complex nature of inhibitory control deficits. Some behavioural tasks, such as the Go/No-Go task and the Stop-Signal task, have been employed to study inhibitory control, but their findings in IGD research have been inconsistent (Smith et al., 2010). These inconsistencies may be attributed to differences in study design, participant characteristics, and variations in the paradigms used to measure inhibitory control. Therefore, there is a need for more rigorous, standardised approaches to investigating inhibitory control in IGD. Furthermore, the neurophysiological aspects of IGD, particularly concerning inhibitory control, remain underexplored. Current studies often lack depth in examining how neural mechanisms contribute to inhibitory control deficits in IGD. A more thorough exploration of the neurophysiological characteristics, such as using event-related potentials (ERPs), could provide insights into the neural basis of these deficits and help establish biomarkers for IGD (Dong & Potenza, 2014). This would be instrumental in developing more effective diagnostic tools and interventions. Therefore, there is currently a lack of established methods to effectively explore the factors influencing inhibitory control abilities in IGD.

Thirdly, the review indicates that inhibitory control encompasses two distinct types: distraction interference inhibitory and prepotent response inhibitory. Distractor interference inhibitory refers to the ability to resist distraction from irrelevant stimuli, while prepotent response inhibitory involves the suppression of automatic or habitual responses (Diamond, 2013). Despite the importance of both types of inhibitory control in understanding behavioural regulation, there is currently a lack of studies comparing these two forms of inhibition specifically in individuals with Internet Gaming Disorder

(IGD) and examining whether they exhibit unique neurophysiological characteristics (Smith et al., 2020). Inhibitory control has different classifications, each reflecting unique cognitive demands and mechanisms. The use of different research paradigms, such as the Go/No-Go task for prepotent response inhibition and the Flanker task for distractor interference inhibition, may influence study outcomes and lead to variations in the results across studies (Verbruggen & Logan, 2008). These differences highlight the complexity of inhibitory control and the need for standardised methods to ensure comparability of findings across studies. Moreover, how these distinct inhibitory control functions manifest in the neurophysiological activity of individuals with IGD is yet to be elucidated (Dong & Potenza, 2016). Addressing this gap is crucial for developing a more comprehensive understanding of the cognitive and neural basis of IGD, which could inform targeted interventions aimed at improving inhibitory control in affected individuals. Identifying EEG amplitude characteristics indicative of impaired inhibitory control in individuals with IGD can provide objective biomarkers for diagnosis, enabling more accurate differentiation from other disorders and guiding targeted interventions (Kuss & Griffiths, 2012). Additionally, from a practical perspective, finding EEG markers can be used for personalised therapy and early intervention (Legault, Liu, & Balodis, 2021). The analysis of neurophysiological characteristics may not only provide a better understanding of the brain activity of gaming disorders but also offer invaluable input to inform healthcare professionals in the diagnosis and targeted treatment of patients. The research mainly focuses on the characteristics of inhibitory control related to internet gaming disorder. The study employed three methods: questionnaire surveys, behavioural experiments, and EEG (Event-Related Potentials) experiments to measure the inhibitory control abilities of individuals with internet gaming disorder. These approaches allowed for the

characterisation of inhibitory behaviours in individuals with internet gaming disorder from both behavioural and neurocognitive psychology perspectives. Furthermore, this study also investigated the differences in inhibitory control functions (interference inhibitory and prepotent response inhibitory) among individuals with internet gaming disorder. It elucidated the behavioural and neurocognitive characteristics of individuals with internet gaming disorder in different types of inhibitory control functions, aiming to explore the mechanisms behind the differential inhibitory control abilities within the population of internet gaming disorder. The outcome of the study may potentially inform distinguishable patterns of IGD, allowing an effective screening and monitoring strategy as well as a better design treatment plan for this population.

1.4 Research Objectives

1.4.1 General Objective

To explore behavioural, cognitive and neuropsychological characteristics associated with inhibitory control ability of internet gaming disorders among university students.

1.4.2 Specific Objective

i) To compare the differences in sociodemographic and behavioural characteristics of university students in the internet gaming disorder group to those in the healthy control group.

ii) To investigate the differences in cognitive performance between the internet gaming disorder group and the healthy control group, specifically in terms of distraction interference inhibitory control and prepotent response inhibitory control.

iii) To examine the differences in ERP (Event-Related Potential) characteristics between the internet gaming disorder group and the healthy control group, focusing on distraction interference inhibitory control and prepotent response inhibitory.

1.5   Research Questions

1. How do the sociodemographic and behavioural characteristics of inhibitory control functions in the internet gaming disorder group differ from those of the healthy control group?

2. What are the differences in the cognitive characteristics between individuals with internet gaming disorder and healthy control groups in terms of their performance on interference inhibitory control and dominant response inhibitory control functions?

3. How do the neurophysiological features of individuals with internet gaming disorder and healthy controls differ in terms of their performance in distractor interference inhibitory control and prepotent response inhibitory control functions?

1.6   Scope of the Study

The scope of this study encompasses the exploration of inhibitory control deficits in individuals with Internet Gaming Disorder (IGD) using multiple methodologies, including questionnaire surveys, cognitive behavioural tasks, and electroencephalogram (EEG) experiments. Not included are other research methods. The study focuses on both behavioural and neurophysiological aspects of inhibitory control in IGD, aiming to provide a comprehensive understanding of how internet gaming disorder behaviour affects cognitive functioning.

The study scope in university students diagnosed with IGD, as determined by the DSM-5 criteria and IGD-20 questionnaire scores (Pontes & Griffiths, 2014). These participants are selected from young adult populations, as this age group is particularly vulnerable to developing IGD due to their high engagement in gaming activities (Wartberg & Lindenberg, 2020). Participants of other ages were not included.

The scope is limited to individuals meeting the criteria for IGD, and the study does not include participants with other forms of behavioural addiction or psychiatric conditions. The findings are intended to contribute to the theoretical understanding of inhibitory control in IGD and have practical implications for diagnosis, treatment, and intervention strategies aimed at improving cognitive and behavioural regulation in affected individuals. By integrating behavioural and neurophysiological assessments, the study aims to offer a well-rounded evaluation of inhibitory control in IGD, ultimately enhancing the precision of diagnosis and effectiveness of treatment (Dong et al., 2012).

1.7 Significance of Study

1.7.1 Theoretical Significance

The present study on characterising inhibitory control deficits in individuals with Internet Gaming Disorder (IGD) has significant theoretical importance, as it contributes to our understanding of the underlying cognitive and neural mechanisms involved in IGD. By employing behavioural, cognitive, and event-related potential (ERP) studies, the research provides a deeper insight into how inhibitory control deficits manifest in individuals with IGD, addressing a critical gap in the literature. This deeper understanding adds to the theoretical frameworks surrounding addiction, particularly behavioural addictions, and highlights the cognitive and

neurophysiological dimensions of IGD that differentiate it from other forms of addiction.

The study also advances the theoretical understanding of inhibitory control by exploring its various components, including distractor interference and precursor response inhibitory. These two forms of inhibitory control are often studied separately, but this study compares them directly, providing a comprehensive picture of how different types of inhibitory processes may be impaired in IGD. This comparative approach enriches our knowledge of inhibitory control mechanisms, enhancing theories about how different cognitive processes contribute to behavioural addictions such as IGD.

Furthermore, the study's findings contribute to the refinement of theoretical models of addiction, such as the I-PACE (Interaction of Person-Affect-Cognition-Execution) model. By providing empirical data on the role of inhibitory control in IGD, the research helps to elucidate the interplay between individual characteristics, cognitive functions, and emotional regulation in the development and maintenance of gaming addiction. This theoretical contribution is crucial in moving towards a more nuanced and integrative understanding of IGD, thereby providing a foundation for future studies on behavioural addictions.

1.7.2   Practical Significance

The practical significance of this study lies in its potential to develop more effective screening strategies for IGD. By identifying specific inhibitory control deficits and characterising their behavioural and neurophysiological markers, the study provides valuable information that can be used to improve diagnostic tools for IGD. The findings from this research can be used to inform public health strategies and

preventive measures aimed at reducing the incidence of IGD. Clinicians can use these insights to better identify individuals at risk for developing IGD and distinguish them from those with other forms of addiction or mental health issues, thereby improving early detection.

The study also has practical implications for treatment planning and intervention. Understanding the specific nature of inhibitory control deficits in IGD allows for the development of targeted therapeutic approaches that specifically address these deficits. For instance, by distinguishing the characteristics of distractor interference inhibitory and prepotent response inhibitory, targeted interventions can be developed based on the specific features of each type of inhibitory control, enabling precise treatment and more effectively alleviating the symptoms of IGD. Such tailored interventions are likely to result in more favourable outcomes for individuals struggling with IGD.

In addition, the study's use of ERP techniques provides a non-invasive method to monitor individuals with IGD. By characterising the cognitive and neural markers associated with IGD, the study provides evidence that can be used to design educational programs and campaigns that promote healthier gaming behaviours. By using EEG to measure changes in brain activity related to inhibitory control, clinicians can assess the effectiveness of interventions in real time, allowing for treatment plans based on neurophysiological data. This approach provides a more holistic way to diagnose IGD, incorporating both behavioural and neural outcomes.

1.8   Definition of Study

1.8.1   Conceptual Definitions

1. Internet Gaming Disorder (IGD)

Conceptually, Internet Gaming Disorder (IGD) refers to a behavioural addiction involving excessive and compulsive engagement in online gaming activities, which leads to significant disruption in an individual's daily functioning, relationships, and overall quality of life. IGD is characterised by a persistent inability to control gaming behaviour, resulting in negative consequences such as emotional distress, impaired social interactions, and diminished academic or occupational performance. It reflects the pathological use of online games that prioritise gaming over essential life activities and well-being, which can escalate into dependency-like behaviour similar to other addictions.

2. Inhibitory Control

Conceptually, inhibitory control refers to the cognitive process that allows an individual to regulate their actions, impulses, and responses in order to achieve a desired outcome or conform to social norms. It involves the ability to suppress automatic, impulsive, or habitual responses when they are inappropriate or counterproductive. Inhibitory control is essential for goal-directed behaviour, self-regulation, and adaptive functioning, as it enables individuals to resist distractions, delay gratification, and make thoughtful decisions in complex environments. It encompasses two dimensions, including interference inhibitory (resisting distracting stimuli) and response inhibitory (withholding prepotent responses), both of which are crucial for maintaining attention and managing behaviours effectively.

3. Event-Related Potentials (ERP/ERPs)

Conceptually, event-related potentials (ERPs) represent the brain's electrical responses that are specifically linked to the processing of particular events or stimuli. ERPs reflect the brain's dynamic and real-time neural activities involved in cognitive functions such as perception, attention, and motor responses. They provide a non-

invasive measure of how the brain processes information in response to sensory, cognitive, or emotional stimuli, enabling researchers to examine underlying neural mechanisms associated with specific mental processes. In the context of psychological research, ERPs are used to gain insights into how cognitive functions are modulated by various factors, thereby offering a valuable perspective on the functional dynamics of the brain.

1.8.2   Operational Definition

1. Internet Gaming Disorder (IGD)

Internet Gaming Disorder (IGD) is operationally defined as a pattern of excessive and compulsive gaming behaviour that causes significant impairment in personal, social, academic, or occupational areas. This disorder is identified based on criteria outlined in the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-V), which include symptoms like preoccupation with gaming, withdrawal symptoms, tolerance, and unsuccessful attempts to reduce gaming (American Psychiatric Association, 2013). The IGD-20 questionnaire is used as a standardized assessment tool to measure the severity of IGD symptoms, focusing on factors such as psychological dependence, escapism, and impaired control over gaming behaviour (Pontes et al., 2014). These instruments help operationally define IGD by evaluating specific behaviours and their impact on daily functioning.

2. Inhibitory Control

Inhibitory control is defined as the ability to suppress automatic or dominant responses in order to perform a more goal-appropriate action. This cognitive ability is often assessed through tasks such as the Flanker task, which measures distractor interference inhibitory control by assessing an individual's capacity to ignore conflicting stimuli, and the Go/No-Go task, which measures prepotent response inhibitory control by

evaluating the ability to withhold a dominant response when instructed (Eriksen & Eriksen, 1974; Verbruggen & Logan, 2008). Through these paradigms, inhibitory control is operationalised by quantifying an individual's accuracy and reaction time in suppressing responses under different conditions.

3. Event-related Potentials (ERP/ERPs)

Event-related potentials (ERP/ERPs) refer to the brain's electrical activity that occurs in response to specific sensory, cognitive, or motor events. ERPs are measured using electroencephalography (EEG) and reflect the neural processes underlying sensory perception, cognitive processing, and motor responses (Luck, 2014). In the context of inhibitory control, ERPs provide insight into the brain's real-time response to tasks that require suppression of irrelevant or automatic actions. The N2 component is associated with conflict detection and response inhibition, whereas the P3 component is linked to attentional resource allocation and decision-making (Luck, 2014). These components provide a quantifiable measure of the underlying neurophysiological processes involved in inhibitory control and cognitive regulation. These neural markers help identify the specific areas of cognitive dysfunction, offering a deeper understanding of how excessive gaming affects brain function.

1.9 Summary

This chapter discusses the introduction, background of the study, problem statement, research objectives, research questions, research hypotheses, the significance of the study, the gap of the study, and operational definitions. Firstly, a cross-sectional questionnaire will be used to assess the participants' internet game history, degree of internet gaming disorder, and behavioural characteristics related to inhibitory control. The questionnaire survey will investigate the association and characteristics of

inhibitory control behaviours in relation to internet gaming disorder. It will also compare the inhibitory control features of university students in the internet gaming disorder group with those in the healthy control group. Secondly, the cognitive study adopted a case-control study design and cognitive behaviour experiment to investigate the characteristics of the inhibitory control ability of internet gaming disorders and compare the inhibitory control characteristics between internet gaming disorders and healthy control groups. Furthermore, this study compares the differences in inhibitory control characteristics between the internet gaming disorder group and the healthy control group in the domains of interference inhibitory control and prepotent response inhibitory control. Thirdly, the ERP study employs a case-control research design and electroencephalogram (ERP) experiments to compare the neurocognitive characteristics of individuals with internet gaming disorder and those in the healthy control group in the domains of interference inhibitory control and prepotent response inhibitory control.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this chapter, theoretical and empirical discussions are conducted based on crucial concepts mentioned in the text, such as internet gaming disorder (IGD), inhibitory control functions, and Event-Related Potentials (ERP/ERPs). For internet gaming disorder, the concept, characteristics, and measurement methods of IGD are introduced. For the inhibitory control functions, the chapter primarily covers the concept, categorisation, and research paradigms of inhibitory control. Moreover, Event-Related Potentials (ERP/ERPs) technology is elaborated upon, detailing its applications, functions, and inhibitory control deficits in individuals with internet gaming disorder. Critical issues and the theoretical framework of the study are then raised in this chapter. This chapter lays the groundwork for subsequent research.

2.2 Internet Gaming Disorder

2.2.1 The Concept of Internet Gaming Disorders

In recent years, psychological problems associated with Internet gaming have been increasingly recognised as a global problem (Wang & Cheng, 2022; Brailovskaia et al., 2022; Yuan et al., 2022; Yao et al., 2022). Internet gaming disorder (IGD) is a specific manifestation of internet addiction, which is characterised by losing control over games and becoming increasingly addicted to games so that other interests and daily activities must give way to games. Even if there are negative consequences, game behaviour will continue or continue to escalate (World Health Organisation, 2019). Internet gaming

disorder (IGD), also known as pathological Internet use (PIU), problematic Internet game use (PIU), Internet game dependence (IGD), or internet gaming disorder (IGD), refers to the continuous and repeated use of the network by internet gaming disorders to participate in the game (Young, 1998). Currently, the clinical diagnosis of IGD mainly refers to the corresponding standards proposed by the American Psychiatric Association (APA) and the World Health Organisation (WHO). In May 2013, the 5th edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-5) issued by the American Psychiatric Association included IGD as a "clinical phenomenon requiring further research" in the appendix of DSM-5. DSM-5 revision experts believe that IGD will hurt patients' personal and social lives (American Psychiatric Association, 2013). In mid-2018, the World Health Organisation (WHO) adopted the eleventh revision of the international classification of diseases (ICD-11) at the 72nd World Health Assembly. Gaming disorder, with its online and offline variants, has been included in the 11th edition of the International Classification of Diseases (ICD-11) as a clinically recognisable and clinically significant syndrome when the pattern of gaming behaviour is of such a nature and intensity that it results in marked distress or significant impairment in personal, family, social, educational, or occupational functioning (World Health Organisation, 2018).

Internet gaming disorder has the characteristics of anonymity and virtuality. In internet games, players typically use pseudonyms to communicate and compete, so it simultaneously has technical and social anonymity characteristics. In the process of internet gaming disorders, players have high information security, and rules or laws will not constrain their antisocial behaviour in the virtual environment, nor will they have any reputation-related impact on individuals. Antisocial behaviour has been proven to be related to the lack of inhibitory control (Catalano & Hawkins, 1996). internet gaming

disorders can realise many wishes that cannot be fulfilled in real life or behaviours restricted by laws or rules in reality. Therefore, during the game, players will be satisfied and further promote their desire for the game (Whang & Chang, 2004). The virtuality of the online game platform can vent the pressure from daily life. At present, most internet gaming disorders are full of violent elements. For example, in role-playing games, game participants can easily destroy buildings or kill enemies, making it easy for individuals who have long participated in internet games and are immersed in a virtual environment to show high aggression (Griffiths, 2000). This feature may also strengthen individuals' interest in internet games and increase their satisfaction with the game (Madran & Cakilci, 2014). The virtual environment provided by internet gaming disorders also meets the needs of communication between players, challenging personal abilities, or commanding others (Billieux et al., 2013; Pawlikowski & Brand, 2011). The virtual environment can enable players to escape from life pressure for a short time and improve their emotions (Xu, Turel, & Yuan, 2012). To a certain extent, internet gaming disorders meet the wishes that players can't meet in real life. This process brings players a sense of satisfaction beyond real-life achievements.

2.2.2   Measurement of Internet Gaming Disorders

In the early research, the diagnostic criteria of internet gaming disorder are often used to test internet game addiction. Young (1998) first made an analogy between internet addiction and pathological gambling. An internet addiction questionnaire with eight diagnostic items was proposed by drawing lessons from the diagnostic criteria of pathological gambling in DSM-4 (Young Diagnostic Questionnaire, YDQ). If an individual meets five of them, he will be diagnosed with internet addiction. Based on Young's diagnostic criteria, some researchers have also developed a diagnostic scale that meets their research needs and cultural characteristics according to their needs and

regional differences. Chen Shuhui, a Taiwanese scholar, has developed a Chinese Internet Addiction Scale (CIAS) based on Young's diagnostic scale and expanded the diagnostic items to measure internet addiction symptoms and the impact of internet addiction on life. The symptoms of addiction include three parts: compulsive Internet use, withdrawal reaction, tolerance change, and the effect on life, which includes interpersonal relationships and health problems, totalling 26 questions. CIAS is widely used in the research on internet addiction and internet gaming disorder in East Asia (Chen et al., 2003).

Additionally, according to research needs, many scholars have developed or adapted new addiction diagnosis methods, including some diagnostic scales for internet gaming disorder. Demetrovics et al. found that the current research on internet gaming disorder only focuses on role-playing games. Therefore, it has developed a more adaptable problem-based online game questionnaire (POGU) and provided a clear diagnostic limit: individuals with a questionnaire score higher than 65 will be diagnosed with internet gaming disorder (Demetrovics et al., 2012). The game addiction scale (GAS) further enriches Young's diagnostic questionnaire. By referring to the diagnostic methods of pathological gambling in DSM-IV, Lemmens et al. (2009) expanded the seven diagnostic criteria of pathological gambling to GAS, which is highly correlated with factors such as loneliness, life satisfaction, and game time (Lemmens, Valkenburg, & Peter, 2009). Charlton et al. analysed the characteristics of large-scale multiplayer online role-playing games, summarized the diagnostic research on internet gaming disorder, improved the existing diagnostic scale, and determined the role of behavioural traits such as behaviour prominence, tolerance, and withdrawal disorder in internet game diagnosis. This study combined various types of addiction questionnaires to develop an internet game addiction questionnaire (Charlton & Danforth, 2007).