Classification of the risk of internet gaming disorder by flow short scale and cardiovascular response

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Abstract— The American Psychiatric Association has identified Internet gaming disorder (IGD) as a potential psychiatric disorder. Questionnaires are the main method to classify high-risk IGD (HIGD) and low-risk IGD (LIGD). However, the results obtained using questionnaires might be affected due to several factors. Flow can measure a person's state of concentration and cardiovascular signals can reflect the autonomic responses of a person. We propose to observe the cardiovascular responses and flow scores from the flow short scale of the HIGD and LIGD groups to assist questionnaires in IGD risk assessment. The preliminary study recruited 18 gamers from colleges. Games with the easy and hard levels were set to arouse desire for playing. The result showed that the flow scores of five HIGD participants were significantly lower compared with that of 13 LIGD participants. The stroke volume (SV) of the LIGD group during baseline (67.06 ± 11.61) was significantly greater that of ($p < 0.05$) while playing the easy game (64.08 ± 10.37) and playing the hard game (63.70 ± 9.89). For the LIGD group, the cardiac output (CO) during baseline (5.28 ± 0.97) was significantly greater ($p < 0.01$) than that of recovery (5.03 ± 0.83), and while playing the easy game (5.34 ± 0.98) it was significantly more than that during recovery ($p < 0.05$). For the HIGD group, a significant difference in the heart rate, SV, and CO was not observed. The changes in cardiovascular responses of the LIGD group are greater than that of the HIGD group. Gamers with LIGD might have a higher susceptibility to the negative effect of playing video games, but gamers with HIGD might not. The finding of this study might help psychologists to estimate the IGD risk.

Clinical Relevance— This study investigated the differences in the score of flow short scale, self-assessment manikin, challenge/skill, emotional questionnaire, and the changes in the cardiovascular responses between the HIGD and LIGD groups.

I. INTRODUCTION

The National Purchase Diary Group reported in 2013 that 72% of Americans play online games [1]. Although online games are entertaining, a few users exhibit potential risks due to problematic use of video games. For example, users with problematic video game use get addicted to the game environment, which might harm their health and social life [2]. The American Psychiatric Association observed the situation and listed the diagnostic criteria for Internet gaming disorder (IGD) in the fifth edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-5) [3]. Gaming disorder

has also been added to the publication of International Classification of Diseases 11th Revision by the World Health Organization since 2018 [4]. A study conducted a questionnaire survey of 8110 students in Taiwan and demonstrated that the prevalence rate of IGD was 3.1% [6]. The negative effects caused due online gaming have attracted widespread attention and become an important research topic.

The psychological concept of flow was proposed by Mihaly Csíkszentmihalyi, and it is used to describe a person's state of concentration [7]. When a person's attention reaches to the most concentrated state, they completely grasp all the information presented to them and excel at the activity they perform, thereby attaining the greatest emotional happiness. A few scholars have found that gamers might play continuously when they have the best experience [8]. In terms of flow experience, research has found flow and immersion in games are related to addiction in cyber-game users [9], and flow is negatively correlated with the tendency of addiction [10]. According to the above studies, gamers diagnosed with low-risk IGD (LIGD) have a higher probability of entering into a state of flow than that of gamers diagnosed with high-risk IGD (HIGD). However, the relation among flow, emotional valence and arousal, and challenge and skill between LIGD and HIGD has not been extensively studied. Therefore, this study investigates the relationship between these factors using questionnaires.

Additionally, a few scholars have compared the physiological changes caused by HIGD and LIGD in gamers by measuring their physiological signals [11]. Cardiovascular signals can reflect the emotional response of a person [12]. Researchers have investigated the cardiovascular responses of gamers while they played video games. The research showed that the relationship between game challenge and successful performances was mediated by the heart rate (HR) [13]. Threat appraisal instructions increased negative emotion ratings and decreased HR variability [14]. It is crucial that a person has a suitable challenge to attain the state of flow. Studies have demonstrated that the cardiovascular responses and the flow score were significantly different when individuals played games with different levels [15]. Therefore, this study sets up different levels of games to create different levels of threat appraisal and negative emotion ratings. The

stroke volume (SV), cardiac output (CO), and HR were acquired from participants with HIGD and LIGD while they played online games with easy and hard game levels. The aim of this study is to investigate the differences in the flow state, emotional valence and arousal, game challenge and skill, HR, SV, and CO between the HIGD and LIGD groups.

II. MATERIALS AND METHODS

A. Participants

18 participants (aged from 20 to 32 years; 16 males and 2 females) were selected from National Yang Ming Chiao Tung University and National Tsing Hua University, Hsinchu, Taiwan. Furthermore, a questionnaire was used to ensure that the participants did not have depression and history of cardiovascular diseases. To assess the risk of IGD, the nine-criteria from the IGD questionnaire (IGDQ) with the dichotomy of false (0) and true (1) was used [16]. The Chen Internet Addiction Scale (CIAS) with 26 items, scored on a 4-point Likert scale ranging from extreme disagreement (1) to extreme agreement (4) was used to assess the risk of Internet addiction [17]. The participants were divided into two groups: HIGD (IGDQ score ≥ 5 and CIAS ≥ 64) and LIGD (IGDQ score < 5 and CIAS < 64). In addition, a self-assessment manikin (SAM) with a 9-point Likert scale was used to estimate the emotional arousal and valence [18]. To measure the state of the flow, the 10 items of flow short scale with a 7-point Likert scale ranging from extreme disagreement (1) to extreme agreement (7) was used [19]. The game skill and challenge scale with a 5-point Likert scale ranging from challenge or skill too low (1) to challenge or skill too high (5) was used to assess the challenge and skill [20]. The 6 items of an emotional questionnaire with a 9-point Likert scale ranging from low (1) to high arousal (9) was used to assess the emotional state, including happiness, surprise, anger, sadness, disgust, and fear.

B. Physiological signal measurement

We adopted impedance cardiography (ICG; AESCULON, Osypka, Germany) with a sampling rate of 200 Hz to measure cardiovascular responses. The electrodes of ICG were attached to the surfaces of the left lumbar and left neck.

C. Experimental procedure

The participants signed an informed consent form, and they familiarized themselves with the experimental procedure before conducting the experiment. The physiological instruments were set up and the game CrazyRacing KartRider was explained to the participants. The experiment was divided into four stages: 1) The participants were requested to look at a gray screen (baseline, 6 minutes); 2) the difficulty level of the game ranged from 1 to 6. Initially, the participants played the game at a difficulty level of 2 (Easy game, 7 minutes); 3) Subsequently, the participants played the game at a difficulty level of 4 (Hard game, 7 minutes); 4) the participants were requested to look at the gray screen to recover from the stimulus (recovery, 6 minutes). The physiological signals of the participants were simultaneously measured during the experiment. Finally, the participants were asked to fill in a flow short scale, game challenge/skill scale, SAM, and emotional questionnaire (as a self-report, unlimited time). This study procedure was approved by the Research Ethics

Committees for Human Subject Protection of the National Chiao Tung University (number: NCTU-REC-108-114F).

D. Signal processing

The physiological signals of the participants were recorded in Waveform Explorer of ICG. Python program was used to automatically execute the screenshots of the Waveform Explorer, and LabVIEW (v.2020, National Instruments, America Austin Texas) was used to identify and read out the source data of the heart beats and SV from ICG. Then, the HR was calculated by the total number of beats per minute. The CO was calculated by accumulating the milliliter of the SV per minute. LabVIEW was also used for subsequent management and analysis.

E. Statistical analysis

The Wilcoxon signed-rank test was used to examine the statistically significant differences in the HR, SV, CO, flow score, valence and arousal score, challenge and skill score, and emotional scores between baseline and easy game, baseline and hard game, baseline and recovery, easy game and recovery, and hard game and recovery for the HIGD and LIGD groups. The Mann–Whitney U test was used to test the statistically significant differences between HIGD and LIGD groups during baseline, easy game, hard game, and recovery states. α was set to 0.05. The statistical analysis was performed using SPSS (V. 19).

TABLE I.   DEMOGRAPHIC DATA AND THE SCORE OF CIAS AND IGDQ

	LIGD	**HIGD**
Participant number	13	5
Gender	11 males, 2 females	5 males
Age	23.85 ± 2.99	21.40 ± 0.89[*]
CIAS	47.39 ± 10.19	75.00 ± 5.83[**]
IGDQ	1.46 ± 2.03	5.20 ± 0.45[**]

Comparing with HIGD and LIGD. *p<0.05, **p<0.01

TABLE II.   THE SCORE OF FLOW SHORT SCALE

	Easy game		**Hard game**	
Flow short scale	LIGD	HIGD	LIGD	HIGD
Q1: I felt just the right amount of challenge.	4.69 ± 0.95	4.20 ± 0.45	4.46 ± 1.45	3.00 ± 1.41
Q2: My thoughts ran fluidly and smoothly.	4.31 ± 1.31	3.40 ± 1.67	3.85 ± 1.52	3.20 ± 0.84
Q3: I didn't notice time passing.	5.00 ± 1.29	5.80 ± 1.10	5.23 ± 1.48	5.40 ± 1.14
Q4: I had no difficulty concentrating.	5.77 ± 0.83	6.00 ± 0.70	5.69 ± 0.94	5.80 ± 0.84
Q5: My mind was completely clear.	5.62 ± 0.87	5.00 ± 0.71	5.15 ± 1.21	4.60 ± 0.89
Q6: I am totally absorbed in what I was doing.	5.85 ± 1.21	5.40 ± 1.14	5.53 ± 1.20	5.60 ± 0.89
Q7: The right thoughts occur of their own accord.	4.31 ± 1.38	3.40 ± 1.52	4.38 ± 1.50	2.80 ± 1.30[*]
Q8: I knew what I have to do each step of the way.	4.23 ± 1.74	3.20 ± 2.28	4.62 ± 1.45	2.40 ± 1.14[*]
Q9: I felt that I have everything under control.	3.08 ± 1.19	1.40 ± 0.55[*]	2.92 ± 1.44	1.60 ± 0.54
Q10: I was completely lost in thought.	4.62 ± 1.12	5.00 ± 1.41	5.38 ± 0.76	5.00 ± 1.58
Total flow score	47.46 ± 7.71	42.80 ± 6.06	47.23 ± 10.08	39.4 ± 3.21

Comparing with HIGD and LIGD. *p<0.05

Self-report	Easy game		Hard game	
	LIGD	**HIGD**	**LIGD**	**HIGD**
Challenge	3.23 ± 0.60	$4.20 \pm 0.45^*$	4.15 ± 0.80	4.60 ± 0.89
Skill	2.54 ± 1.05	2.60 ± 1.82	2.31 ± 1.32	1.40 ± 0.55
Valence	6.39 ± 1.56	5.40 ± 2.88	6.54 ± 2.07	$4.00 \pm 2.12^*$
Arousal	6.39 ± 1.39	6.80 ± 1.92	6.77 ± 1.64	7.60 ± 1.67
Happiness	6.08 ± 1.93	4.40 ± 2.30	6.08 ± 2.06	$3.20 \pm 1.79^*$
Anger	2.62 ± 2.02	5.20 ± 3.03	2.77 ± 2.09	5.00 ± 3.54
Sadness	2.85 ± 2.51	3.80 ± 2.39	3.31 ± 2.93	4.00 ± 2.74
Disgust	1.62 ± 1.66	1.00 ± 0.00	1.77 ± 2.20	1.00 ± 0.00
Surprise	3.62 ± 2.22	3.20 ± 2.29	3.54 ± 2.47	3.60 ± 3.44
Fear	1.85 ± 1.46	1.60 ± 1.34	1.62 ± 1.20	1.40 ± 0.55

Comparing with HIGD and LIGD. $^*p < 0.05$

TABLE IV. STROKE VOLUME (SV), HEART RATE (HR), AND CARDIAC OUTPUT (CO) DURING EACH STAGE

	Baseline	Easy game	Hard game	Recovery
SV (ml)				
HIGD	66.32 ± 9.14	66.78 ± 13.74	63.77 ± 10.99	63.70 ± 8.93
LIGD	67.06 ± 11.61	$64.08 \pm 10.37^*$	$63.70 \pm 9.89^{**}$	65.05 ± 8.88
HR (BPM)				
HIGD	78.17 ± 7.26	80.4 ± 6.07	81.2 ± 4.10	79.6 ± 5.67
LIGD	79.30 ± 11.25	82.56 ± 14.50	81.46 ± 12.92	77.23 ± 10.76
CO (L)				
HIGD	5.17 ± 0.74	5.51 ± 1.06	5.29 ± 1.02	5.05 ± 0.49
LIGD	$5.28 \pm 0.97^{\#\#}$	$5.34 \pm 0.98^{\#}$	5.20 ± 0.89	5.03 ± 0.83

Comparing with baseline, $^*p < 0.05$, $^{**}p < 0.01$

Comparing with recovery, $^{\#}p < 0.05$, $^{\#\#}p < 0.01$

III. PRELIMINARY RESULTS

According to their IGDQ and CIAS responses, 13 participants were classified as LIGD (24 ± 3 years old; 11 males and 2 females) and 5 participants were classified as HIGD (21 ± 1 years old; 5 men). Table I shows the age, gender, and CIAS and IGDQ scores of these two groups.

Table II displays the mean $\pm$ standard deviation score of each item of the flow short-scale and total flow score. The average flow score of the HIGD group after playing the easy and hard games was lower than that of the LIGD group. The LIGD group exhibited three items of the flow short-scale which were significantly higher than that of the LIGD groups ($p < 0.05$). These items were Q7, Q8, and Q9. Table III shows the results of the SAM scale and emotional questionnaire. While playing the easy game, the HIGD group showed that their game challenge was significantly higher than that of the LIGD group. While playing the hard game, the valence score and happiness score of the HIGD group were significantly lower than that of the LIGD group.

Table IV shows the SV, HR, and CO for HIGD and LIGD groups during baseline, easy game, hard game, and recovery stages. The SV of the LIGD group during baseline was significantly greater than that of while playing the easy game ($p < 0.05$) and hard game ($p < 0.01$). For the SV of the HIGD group, significant differences during each stage were not observed. The CO of the LIGD group during baseline was significantly greater than that during recovery ($p < 0.01$), and the CO during recovery was significantly lesser than that while playing the easy game ($p < 0.05$). Significant differences at each stage for the CO of the HIGD group were not observed.

IV. DISCUSSION

The aim of this study was to investigate the differences in the score of flow short scale, SAM, game challenge/skill scale, emotional questionnaire, and the changes in the cardiovascular responses between the HIGD and LIGD groups. In the previous literature, the overall flow score of the HIGD group was lower compared with that of the LIGD group [6]. The results of this study are similar that that of the previous studies, particularly, after playing the hard game. In the items of flow short scale, the scores of Q9 when playing the easy game, Q7 and Q8 when playing the hard game for the HIGD participants were significantly lower than those of the LIGD participants. These results confirmed the hypothesis that the flow score of the HIGD group is lower than that of the LIGD group. We infer that the gamers with HIGD might have felt underconfident while playing the hard game. The results of previous studies showed that Internet game addiction might lead to various negative consequences [21], such as low psychosocial well-being, loneliness [22], stress [23], and decreased academic achievement [24]. In this study, we found similar results to that of the previous research. The result showed that the emotional valence and happiness scores of the HIGD group were significantly lower compared with that of the LIGD group while playing the hard game. These findings suggest that compared with that of the LIGD group, the HIGD group exhibited greater frustration and unhappiness while playing hard games, particularly, while facing the hard game. For the game challenge and skill, we found that the challenge score of the HIGD group was significantly higher than that of the LIGD group while playing the easy game. This finding suggests that the HIGD group might encounter greater challenges while playing online games than that of the LIGD group.

The cardiovascular responses can effectively reflect emotional changes in a person [15]. The results showed that the value of HR, SV, and CO for the HIGD group from baseline to recovery stages did not have a significant difference. However, the SV of LIGD exhibited a significant decrease from baseline to playing easy ($p < 0.05$) or hard games ($p < 0.01$). These results are likely to be related to that LIGD may very susceptible when playing online games, playing the hard games in particular. The gamers with HIGD might be adaptable to the game environment, and they feel calm while playing hard games. The result showed an absence of a significant difference in HR for the LIGD group and showed a significant increase in CO from baseline to playing the easy game. There are two possible causes for the differences between HIGD and LIGD. The emotional changes in the LIGD group after playing games might be relatively greater compared with that of the HIGD group. In the previous study, the average HR of the players increased when

they faced challenges and threats [25]. Although there was no statistically significant difference in HR, both HIGD and LIGD groups showed that the HR while playing the easy game and hard game increase compared with that of during baseline. The change in HR of the HIGD group while playing was slightly less than that of the LIGD group. According to these results, we might infer that the HIGD group has a better physiological regulation ability in the game environment. These results were consistent with the hypothesis that the changes in cardiovascular response in the LIGD group were different from that of the HIGD group. The changes in cardiovascular response in the LIGD group might be larger than that of the HIGD group, and the LIGD group might have a higher susceptibility to the negative effects of video games.

A few potential biases were present in this study. First, the participants in the HIGD group were fewer than that of the LIGD group. Secondly, the laboratory environment might have been different from the actual gaming situation, which might have affected the gaming performance of the participants.

V. CONCLUSION

This study investigated the differences in flow score, emotional valence and arousal, game challenge and skill, emotional questionnaire, and cardiovascular responses between participants with HIGD and LIGD while they played the easy game and the hard game. The overall flow scores of the HIGD group were lower compared with that of the LIGD group. The SV of the LIGD group during baseline was significantly greater than that while playing the easy and hard games. The CO of the LIGD group during recovery was significantly lower than that during baseline and playing the easy game. Significant differences were not observed for the HR, SV, and CO of the HIGD group at each stage. These results might provide scholars to explore the flow state and cardiovascular responses during different online game levels. Additional participants should be recruited to validate this result for further work.

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