2021 43rd Annual International Conference of the
IEEE Engineering in Medicine & Biology Society (EMBC)
Oct 31 - Nov 4, 2021. Virtual Conference

Toward instantaneous frequency of respiration to investigate the risk of internet gaming disorder

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Abstract— **With the development of Internet, the number of people with symptoms of Internet gaming disorder (IGD) has increased. In the past, psychologists used retrospective questionnaires to diagnose IGD. However, it is difficult to diagnose IGD symptoms instantaneously using retrospective questionnaires due to the requirement of an Internet gaming experience of greater than 6 months and the limitations of retrospective memory. Observing the physiological regulation system might instantaneously diagnose IGD. However, observation of instantaneous physiological response is limited due to the lack of appropriate techniques. Our previous study successfully combined complimentary ensemble empirical mode decomposition and normalized direct quadrature to obtain respiratory instantaneous frequency (IF) to overcome this limitation. This study uses game-related films as stimulus materials to observe the difference in respiratory IF response per second of gamers with high-risk IGD (HIGD) and low-risk IGD (LIGD). The result showed that the respiratory IF of gamers with HIGD is lower than those of gamers with LIGD at the time of stimulation. In addition, the study also observes the dynamic change in respiratory IF per second (IF_{diff}). The results showed that the instant at which a significant difference is observed in IF_{diff} between HIGD and LIGD can be matched to the stimulation of the films. In summary, this study demonstrated that the IF_{diff} of gamers with HIGD and LIGD are different when stimulated. Therefore, this suggests that IF_{diff} might be used as a potential physiological marker to instantaneously distinguish and diagnosis the risk of IGD.**

Clinical Relevance— **This study investigates the dynamically psychophysiological response regulation by analyzing the respiratory IF of gamers diagnosed with IGD.**

I. INTRODUCTION

According to an estimate provided by the International Telecommunication Union, the number of Internet users was approximately 4 billion (51% of global people) at the end of 2019 [1]. For most Internet users, the benefits of the Internet outweigh the negative effects of overuse. However, excessive use of the Internet might lead to Internet addiction (IA). The most common symptom of IA is that the users cannot control the time spent on the Internet, which causes negative consequences in daily life such as ignoring sleep, sacrificing hobbies and social interactions, and escaping the stress of daily life [2]. The American Psychiatric Association (APA) has also noticed the problems with overuse of the Internet. The APA established a task force to review IA-related scientific literature and found that the most used Internet service by users diagnosed with IA was video games. Therefore, APA focused on the excessive use of the Internet games in response to IA-related problem. Based on the observation of the negative symptoms caused by excessively playing internet games, APA proposed internet gaming disorder (IGD). The APA listed the diagnostic criteria for IGD in the fifth edition of Diagnostic and Statistical Manual of Mental Disorders (DSM-5) for experts to discuss if IGD should be officially listed as a mental illness in the next edition [3].

People with IGD symptoms spend excessive time playing online games. They have a greater interest in playing online games instead of interacting with people and performing things in daily life. Therefore, this leads to interpersonal problems and a disconnect from society. In extreme cases, people with IGD ignore basic biological requirements such as diet, sleep, and personal hygiene while playing online games, which might cause physical and mental health problems [4]. Studies have shown that people with IGD are prone to psychiatric symptoms such as lack of attention, depression, and anxiety [5,6]. With the increase in Internet users, the probability of people suffering from IGD symptoms has increased. IGD has become an important issue that cannot be ignored. In 2018, the World Health Organization (WHO) declared that gaming disorder (GD) is a type of mental, behavioral or neurodevelopmental disorder. GD was included in the 11th edition of the International Classification of Diseases [7]. However, the impact of playing online games on health is still unclear. A few researchers consider that there is insufficient evidence to prove that IGD is a mental illness. Additionally, there is an absence of a clear definition for the diagnostic criteria of IGD.

In the last two decades, IGD-related research and diagnosis have been investigated through questionnaires. These questionnaires are retrospective self-reports, which might have inherent bias due to the current emotional state and memory of a person [8]. Furthermore, it is difficult to immediately observe and evaluate the risk of IGD while playing games using retrospective questionnaires. However, the physiological regulation in this study shows different responses while playing games compared with that during the normal state. Researchers combined questionnaires with physiological signals and used stimuli to observe the psychophysiological responses of people with different IGD

* Research was fully supported by the Taiwan Ministry of Science and Technology.

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risks. Among several physiological responses, respiration is a physiological system that can be controlled autonomously. Respiratory response affects the regulation of emotional state and autonomic nervous system (ANS) [9]. Our previous study demonstrated that respiratory training is a potential method to slow down changes in the emotional state and ANS activity of people with IGD symptoms [10]. In the follow-up, we overcome the problem that the analysis of instantaneous psychophysiological responses is limited by appropriate algorithms. We proposed to combine complimentary ensemble empirical mode decomposition (CEEMD) and normalized direct quadrature (NDQ) to obtain instantaneous frequency (IF) to overcome the limitation. This study observes the distribution of IF in people with IGD symptoms and postulates that the distribution of IF can be used as a respiratory physiological index of IGD risk [11].

Although our previous study demonstrated that when people with high-risk IGD (HIGD) watch negative game films, the instantaneous phase delay of HIGD people is significantly lower than that of low-risk IGD (LIGD) people [10]. We have investigated the distribution of respiratory IF under different experimental stages [11]. However, we observed the IF distribution for a short period in the previous study, and we did not further analyze the instantaneous respiratory IF changes under stimulation. We postulate that observing the difference of instantaneous physiological responses through different stimuli can provide an insight about the physiological mechanism of IGD. Therefore, further investigation is required for respiratory IF. The purpose of this study is to 1) observe the difference in the instantaneous respiratory physiological response between HIGD and LIGD groups while they are stimulated by the negative game film, and 2) investigate their dynamic changes of IF of gamers with HIGD and LIGD. The study hypothesizes that the respiratory IF of gamers with HIGD will differ from the respiratory IF of gamers with LIGD under stimulation and investigates the feasibility of respiratory IF as a potential physiological marker to distinguish IGD.

II. MATERIALS AND METHODS

A. Participants

Fifty healthy participants were recruited from National Chiao Tung University, Hsinchu, Taiwan. None of these subjects had a history of cardiovascular diseases and depression. This experiment was approved by the Research Ethics Committee for Human Subject Protection, National Chiao Tung University (NCTU-REC-102-009-e). To assess the IGD risk of each participant, the IGD questionnaire (IGDQ) was adopted [3]. IGDQ consists of 9 items, and each item is answered by a dichotomy, where 0 means that the item description does not fulfill the participant's experience; Conversely, 1 means that the item description fulfills the participant's experience. Additionally, this study uses the Chen Internet Addiction Scale (CIAS) to evaluate the IA risk of each participant, which is a reliable screening tool for assessing IA in Chinese people [12]. The CIAS contains 26 items with a 4-point Likert scale, ranging from extreme disagreement (1) to extreme agreement (4). According to the CIAS and IGDQ scores, the participants are divided into 2 groups: low-risk IA with non-IGD (CIAS < 64 and IGDQ score < 5) and high-risk IA with IGD (CIAS ≥ 64 and IGDQ score ≥ 5). Excluding the data of 10 participants, due to the results of the questionnaire, they were high-risk IA with non-IGD (CIAS ≥ 64 and IGDQ score < 5) and low-risk IA with IGD (CIAS < 64 and IGDQ score ≥ 5). Additionally, this study employed a self-assessment manikin (SAM) with a 9-point Likert scale to evaluate the emotions such as valance and arousal of a participant [13].

B. Physiological signal measurement

The respiratory inductive plethysmography (RIP; RIPmateTM Inductance Belts, Ambu Inc., Denmark) sensor belt was placed around the abdomen at the level of the umbilicus to obtain a respiration signal. The cardiac electrical activity of a participant was measured by lead II electrocardiography (Best-C-04084, BioSenseTek, Taiwan). The physiological signals of participants were measured at a sampling rate of 1000 Hz throughout the experiment.

C. Experimental procedure

The participants were requested to sign an informed consent form before conducting the experiment. Subsequently, the participants were asked to fill out the CIAS questionnaire and the instruments were set up to record physiological signals. The experiment was divided into three stages: 1) Participants were requested to look at a gray screen (baseline, 2 min), look at a game-related film (stimulus, 2 min), fill out the SAM (self-report, unlimited time), and recovery from the stimulus (recovery, 2 min); 2) participants were requested to perform abdominal wall movement for 10 minutes at a breathing rate of six cycles/minute while holding their breath； and 3) the procedure in the first stage was repeated. Finally, the participants filled out the IGDQ. The stimulus film used in first and third stages was a first-person shooter game (FPSG) films called Resident Evil. We extracted the Resident Evil film into two films (film 1 and film 2) for the participants to watch.

D. Processing and Analytical procedure

The respiratory signals in this study were acquired, processed, and analyzed using LabVIEW software (v.2020, NI Corp., Austin, TX, USA). This study focuses on exploring the respiration instant response of people with IGD symptoms while they are stimulated by game-related films. Previous studies have suggested that the thoracic or abdominal muscles of people with high-risk IA stimulated by negative films have stronger contractions than that of the contractions observed while watching positive films [18]. Therefore, this study only analyzes the respiratory signal of the abdominal wall movement. To accelerate the computing performance of CEEMD, we reduced the sampling rate of the original respiratory data from 1000 Hz to 50 Hz. After down-sampling, we used CEEMD and NDQ to calculate IF (Fig. 1) [11], which contains 6,000 data points, with a time length of 2 min and a sampling rate of 50 Hz.

This study aims to observe the instantaneous dynamic changes in respiration per second. The IF signal per second was calculated based on the average of 50 IF data points.

TABLE I. POSSIBLE STIMULUS TIMES IN TWO FILMS

Film	Times (s)							
Film 1	17	21	41	54	61	92		
Film 2	18	25	31	34	41	79	84	105

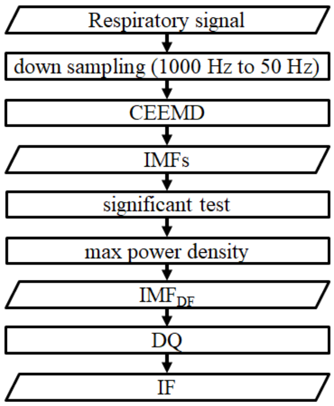

Figure 1. Signal processing to obtain IF.

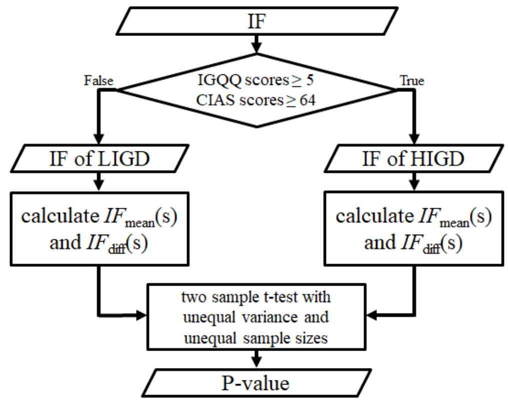

Figure 2. Steps of the statistical procedure.

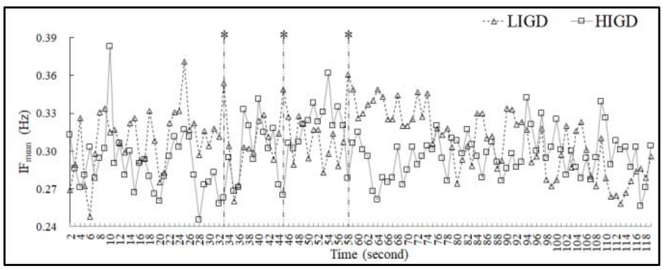

Figure 3. IF_{mean} for two groups per second watching film 1. *: significant difference between HIGD and LIGD. (p-value < 0.05)

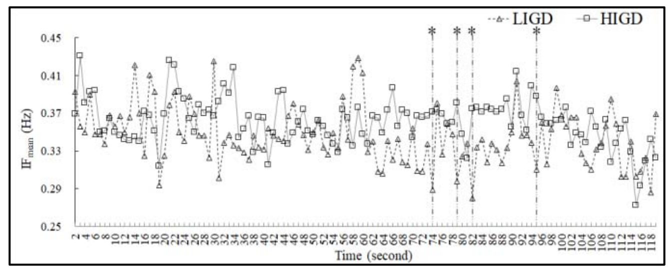

Figure 4. IF_{mean} for two groups per second watching film 2. *: significant difference between HIGD and LIGD. (p-value < 0.05)

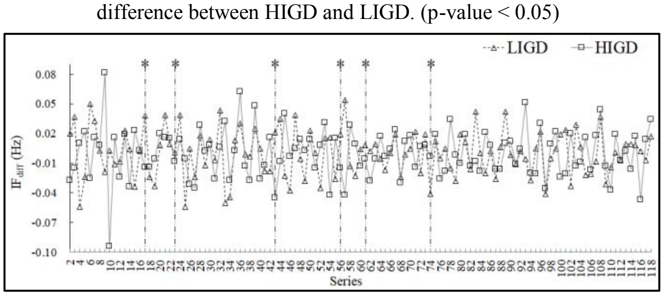

Figure 5. IF_{diff} for every two consecutive seconds for film 1. *: significant difference between HIGD and LIGD. (p-value < 0.05)

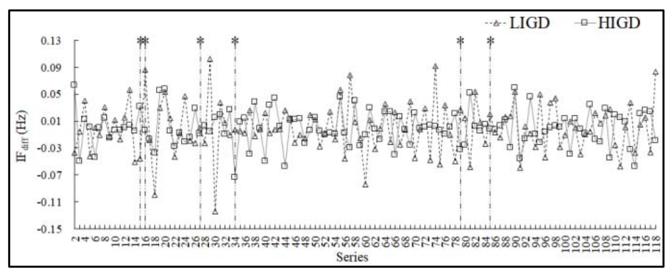

Figure 6. IF_{diff} for every two consecutive seconds for film 2. *: significant difference between HIGD and LIGD. (p-value < 0.05)

$$IF_{\text{mean}}(s) = \frac{\sum_{i=s\times50-49}^{i+49} IF(i)}{50} \quad (1)$$

$$IF_{\text{diff}}(n) = IF_{\text{mean}}(s) - IF_{\text{mean}}(s\text{-}1) \quad (2)$$

As shown in (1), where i represents the data point of IF and counts from 1, s represents the number of seconds and counts from 1, and $IF_{\text{mean}}(s)$ represents the average IF of the second. To further observe the changes in respiratory regulation between the two groups, the difference in IF per second was compared with that of the previous second (current IF minus the previous second IF, also called IF_{diff}) was calculated as shown in (2). Both sets of data were subjected to a two-sample t-test with unequal variance and unequal sample sizes (Fig. 2)

III. Result

According to the IGDQ and CIAS scores, there were 21 participants with LIGD (aged 23 ± 2 years; 12 males) and 19 participants with HIGD (aged 24 ± 5 years; 15 males). This study analyzed the instantaneous respiratory physiological responses of participants while they were watching Resident Evil (FPSG type) film. We invited 5 authorized gamers to determine the possible stimulus times of the film. Table 1 lists the possible stimulus times for the two films.

Since the 1st second and 120th second of the calculated IF_{mean} might be affected by the boundary effect of the CEEMD, they were regarded as outliers.

Therefore, Fig. 3 and Fig. 4 demonstrate the values from the 2nd second to the 119th second.

Since the variance and sample size of the HIGD and LIGD groups were unequal, the statistics of the results used two-sample t-test with unequal variance and unequal sample sizes. Fig. 3 shows the IF_{mean} per second of the two groups while watching film 1 to observe which seconds between the two groups have significant differences. The results show that the IF_{mean} at 33 s, 45 s, and 58 s have significant differences.
Fig. 4 shows the IF_{mean} per second of the two groups under film 2 to observe which seconds between the two groups have significant differences. The results show that the IF_{mean} at 74 s, 79 s, 82 s, and 95 s have significant differences.
Fig. 5 shows the IF_{diff} per second of the two groups under film 1 to observe which seconds between the two groups have significant differences. The results show that there are significant differences in IF_{diff} at the 17th (17–18 s), 23rd (22–23 s), 43rd (43–44 s), 56th (56–57 s), and 61th (61–62 s), and 74th (74–75 s).

Fig. 6 shows the IF_{diff} per second of the two groups under film 2 to observe which seconds between the two groups have significant differences. The results show that there are significant differences in IF_{diff} at 15th (15–16 s), 16th (16–17 s), 27th (27–28 s), 34th (34–35 s), 79th (79–80 s), 85th (85–86 s), and 109th (109–110 s).

IV. Discussion

We compared the results with possible stimulus time of both films in Table I. The study observed the first stimulus of the two films (film 1: 17 s; film 2: 25 s). We believe that at the first stimulus time, the participants had not produced the expected response to the negative stimulus of the film, which could be presented physiological responses more realistically. The results showed that the IF_{mean} of HIGD at the first stimulus time point of the two films were lower than that of the IF_{mean} of LIGD. The result indicated that when stimulated, the breathing rate of gamers with HIGD was comparatively stable than that of gamers with LIGD. However, at the first stimulation instant, a statistically significant difference between the IF_{mean} of participants with HIGD and LIGD was absent. Therefore, we further investigated the dynamic changes of IF_{mean} between participants with HIGD and LIGD, which is IF_{diff}. The results demonstrated that the instants (film 1: 17th, 23rd, 43rd, and 56th; film 2: 27th, 34th, 79th, and 85th) at which the HIGD and LIGD were significantly different and these points can correspond to the possible stimulus time shown in Table I. The IF of participants with HIGD at these instants tended to be negative and the absolute value was smaller than those of participants with LIGD, indicating that the breathing of participants with HIGD tended to be stable and the change in the breathing rate was smaller than those of participants with LIGD under stimulation. Previous studies mentioned that the fast modulation of psychophysiological response might help patients with HIGD to remain online for gaming for a long duration [11]. HIGD had a more stable trend in respiratory regulation [10]. Additionally, the previous study has demonstrated that under long-term negative emotional stimulation, the breathing control of participants with HIGD is better than those of participants with LIGD [14]. From this study, we observed the instantaneous respiratory IF change under stimulation, and observed a similar phenomenon as that of above studies. The results also proved that the instantaneous respiratory response of participants with HIGD and LIGD under stimulation was different. The study suggests that respiratory IF can be used as a potential marker for diagnosing and distinguishing HIGD from LIGD.

There are a few limitations in this study. First, the small sample size might lead to insufficient power for statistical test. Therefore, require additional participants for further verification. Second, this study only investigated the difference in IF dynamic changes between HIGD and LIGD in a single type of film. Further research should use different types of game films to investigate self-regulation of HIGD.

V. Conclusion

This study investigated the instantaneous respiratory physiological response of IGD when stimulated by game-related films and observed the dynamic changes of respiratory IF. The results demonstrated that the IF of participants with HIGD is lower than that of participants LIGD under stimulation. The dynamic changes in IF were observed and it was found that the instant of significant difference can correspond to the instant of the possibility stimulus in two films. The results show that the dynamic change of IF (IF_{diff}) of HIGD at the time of stimulation is smaller than that of LIGD and tends to be negative. In summary, when a participant with HIGD was stimulated by a negative film, their breathing rate was comparatively stable than that of the participant with LIGD. Significant differences between HIGD and LIGD at the moment of stimulation can be observed through IF_{diff}. Therefore, this study suggests that IF_{diff} might be used as a potential physiological marker to instantaneously distinguish and diagnosis the risk of IGD.

Acknowledgment

This work was fully supported by the Taiwan Ministry of Science and Technology (MOST 109-2811-E-009-522-MY3).

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