



Altered cardiorespiratory coupling in young male adults with excessive online gaming



Jae Seung Chang^{a,1}, Eun Young Kim^{b,1}, Dooyoung Jung^c, Seong Hoon Jeong^d, Yeni Kim^e, Myoung-Sun Roh^f, Yong Min Ahn^{c,g}, Bong-Jin Hahm^{c,g,*}

^a Department of Psychiatry and Institute of Clinical Psychopharmacology, Dongguk University Ilsan Medical Center, 27 Dongguk-Ro, Ilsandong-Gu, Goyang, Gyeonggi 410-773, Republic of Korea

^b Mental Health Clinic, National Cancer Center, 323 Ilsan-Ro, Ilsandong-Gu, Goyang, Gyeonggi 410-769, Republic of Korea

^c Department of Psychiatry, Seoul National University Hospital, 101 Daehak-Ro, Jongno-Gu, Seoul 110-744, Republic of Korea

^d Department of Psychiatry, Eulji University Hospital, 1306 Seo-Gu, Dunsan-Dong, Daejeon 302-799, Republic of Korea

^e Department of Adolescent Psychiatry, National Center for Child and Adolescent Psychiatry, Seoul National Hospital, 398 Neungdong-Ro, Gwangjin-Gu, Seoul 143-711, Republic of Korea

^f Department of Medicine, Seoul National University College of Medicine, 103 Daehak-Ro, Jongno-Gu, Seoul 110-799, Republic of Korea

^g Department of Psychiatry and Behavioral Science, Seoul National University College of Medicine, 101 Daehak-Ro, Jongno-Gu, Seoul 110-744, Republic of Korea

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ABSTRACT

Introduction: This study aimed to investigate changes in heart rate variability and cardiorespiratory coupling in male college students with problematic Internet use (PIU) excessive gaming type during action video game play to assess the relationship between PIU tendency and central autonomic regulation.

Method: Electrocardiograms and respiration were simultaneously recorded from 22 male participants with excessive online gaming and 22 controls during action video game play. Sample entropy (SampEn) was computed to assess autonomic regularity, and cross-SampEn was calculated to quantify autonomic coordination.

Results: During video game play, reduced cardiorespiratory coupling (CRC) was observed in individuals with PIU excessive gaming type compared with controls, implicating central autonomic dysregulation. The PIU tendency was associated with the severity of autonomic dysregulation.

Conclusion: These findings indicate impaired CRC in PIU excessive gaming type, which may reflect alterations of central inhibitory control over autonomic responses to pleasurable online stimuli.

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1. Introduction

The Internet is currently one of the most important academic communication tools available, especially for adolescents and young adults (Derbyshire et al., 2013; Park, Hong, Park, Ha, & Yoo, 2013). In developed countries, the rapid increase in broadband connections allows youths to have easy access to information through the Internet. However, a loss of control over Internet use may lead to negative impacts on daily life, social relationships, and mental health (Lu, Wang, & Huang, 2010). A recent study

based on a sample of American college students reported that 5.3% were experiencing significant problems in their life derived from non-essential Internet use, such as online games, shopping, and social networking (Derbyshire et al., 2013). Especially, excessive and prolonged Internet gaming results in poor academic performance and impaired peer relationship (Kuss, 2013). In a sample of Korean high-school students, 38.0% were classified as excessive Internet users, and among these excessive Internet users, male students primarily use the Internet for gaming (Kim et al., 2006). Although it is still open to debate whether excessive Internet use is an independent psychiatric disorder, previous studies have suggested that problematic Internet use (PIU) for online gaming in adolescents and young adults often co-occurs with mood disorders, dissociative disorders, impulse control disorders, and suicidal ideation (Bernardi & Pallanti, 2009; Park et al., 2013; Shapira, Goldsmith, Keck, Khosla, & McElroy, 2000).

* Corresponding author at: Department of Psychiatry, Seoul National University Hospital, 101 Daehak-Ro, Jongno-Gu, Seoul 110-744, Republic of Korea. Fax: +82 2 744 7241.

E-mail address: hahm@snu.ac.kr (B.-J. Hahm).

¹ These two authors contributed equally to this work.

Although the pathophysiological mechanisms of excessive online gaming are not fully understood, recent studies suggest a relationship between cardiac autonomic regulation and video gaming (Ivarsson, Anderson, Akerstedt, & Lindblad, 2009; Ivarsson, Anderson, Akerstedt, & Lindblad, 2013). During video game play, increased heart rate was observed in male adolescents regardless of violent content (Ivarsson et al., 2013). Clinical manifestations such as arousal dysregulation, irritability, aggression, and behavioral disinhibition also support autonomic dysregulation in individuals with excessive online gaming (Desai, Krishnan-Sarin, Cavallo, & Potenza, 2010). While parasympathetic inputs facilitate humans to respond flexibly to stressors, sympathetic dominance is associated with maladaptive behaviors (Cyranowski, Hofkens, Swartz, Salomon, & Gianaros, 2011). For instance, blunted vagal reactivity may predict the ability to resist smoking in abstinent smokers (Ashare et al., 2012). Thus, quantifying autonomic function may provide valuable information about the pathophysiology of excessive online gaming.

Diverse HRV indices can be used to assess the central autonomic modulation of the cardiovascular system (Thayer and Lane, 2009) and have been widely applied to a broad range of psychiatric disorders as psychophysiological measures. Although diminished HRV is generally regarded as parasympathetic hypoactivity and autonomic dysregulation (Lampert, Ickovics, Viscoli, Horwitz, & Lee, 2003), the influence of respiratory rate and tidal volume on R–R interval power spectra needs to be considered in the relationship between vagal regulation and psychological changes (Brown, Beightol, Koh, & Eckberg, 1993; Grossman and Taylor, 2007). Respiratory sinus arrhythmia is HRV in synchrony with respiration and an effective index of cardiac vagal tone. For example, normalized respiratory sinus arrhythmia for mean R–R interval can reduce the influence of basal levels of cardiac sympathetic tone (Grossman and Taylor, 2007). Recently, to evaluate the interactions between HRV and respiration, nonlinear measures of the coordination between heart rate and respiration (cardiorespiratory coupling, CRC) have been introduced to psychiatry field (Peupelmann et al., 2009). Weak interactions between two self-sustained oscillators (i.e., cardiovascular and respiratory systems) are known to follow nonlinear dynamics (Rosenblum et al., 1998). The CRC measures quantify the strength of the association between the two physiological systems (i.e., the cardiac and respiratory systems) under the central autonomic control (Dick and Morris, 2004), and thus the resting level of CRC is largely associated with overall output of central autonomic network (CAN) (Peupelmann et al., 2009). In a recent study on the relationship between pharmacodynamics properties and CRC level, the changes in the CRC level was closely associated with the dose of central norepinephrine enhancer (Chang et al., 2012). By combining HRV with the respiratory rhythm, CRC can enhance the signal-to-noise ratio and be used to evaluate the intrinsic interactions among higher regulatory centers (Lalley, 2008; Peupelmann et al., 2009). Peak-valley or respiration controlled HRV measures, such as the transfer function from respiratory activity to heart rate, are well-established and useful in investigating time- and frequency-domain CRC characteristics (Grossman, Karemaker, & Wieling, 1991; Saul et al., 1989). However, HRV demonstrates a fractal-like complexity pattern and a noise-like variability, especially in relation to respiration (Francesco et al., 2012). Nonlinear measures such as approximate entropy (ApEn) or sample entropy (SampEn) can provide useful information about the regularity and complexity of HRV and respiratory rhythm (Richman and Moorman, 2000). Similar to R–R interval, the respiration time series extracted from timing component of breathing can be quantified by the entropy indices. In addition to the described influence of amygdala activity on the respiratory pattern (Masaoka, Hirasawa, Yamane, Hori, & Homma, 2003), the relationship between central autonomic dysfunction and cardiorespiratory decoupling was suggested in unmedicated

Table 1

Demographic and clinical characteristics of the study sample.

	PIU (n = 22)	Control (n = 22)	p ^a
Age, years, mean (SD)	22.91 (2.35)	23.55 (2.46)	0.39
BMI, kg/m ² , mean (SD)	22.92 (1.98)	22.74 (3.14)	0.82
Smoker/non-smoker, No. of subjects	5/17	3/19	0.70
≤10 cigarettes/day	1	1	
10–15 cigarettes/day	4	2	
YIAT total score, mean (SD)	71.14 (11.61)	31.09 (7.34)	<0.001
KIAS total score, mean (SD)	43.55 (10.01)	21.73 (2.87)	<0.001
MADRS total score, mean (SD)	4.95 (4.45)	1.50 (2.45)	0.003

PIU, problematic Internet use; BMI, body mass index; YIAT, Young's Internet Addiction Test; KIAS, Korea Internet Addiction Scale; MADRS, Montgomery–Åsberg Depression Rating Scale.

^a p Values were obtained from an independent t test or Fisher's exact test.

patients with schizophrenia (Peupelmann et al., 2009). Given the relationship between excessive online gaming and autonomic dysregulation, it is valuable to examine whether the measures of HRV and CRC can be used as electrophysiological markers of PIU.

In the current study, we investigated an integrative pattern of HRV and CRC in male college students with excessive online gaming compared with matched controls during action video game play. We hypothesized that HRV and CRC would differ between the groups and that the individuals with excessive online gaming would show cardiorespiratory dysregulation and cardiorespiratory decoupling in comparison to matched controls, leading to maladaptive preoccupation with Internet use.

2. Methods and materials

2.1. Participants

The study was conducted among male college students aged 19–29 years from two universities located in Seoul, Republic of Korea. All the participants were recruited through postings on college bulletin boards, advertisement in college publication, or campus email. A total of 60 students were screened for this study, of which 44 were enrolled into the study. Monetary reward of approximately 50 US dollars was given to the participants for their time and efforts. None of the participants were identified as majoring in sports or a related field. Twenty-two male individuals with PIU excessive gaming type and 22 healthy controls matched for sex, age, and body mass index (BMI) were included. Conceptually, PIU mainly consists of three subtypes (excessive gaming, sexual preoccupations, and social networking) and we focused on the excessive gaming type. Based on the operational criteria (Shapira et al., 2003), we defined PIU excessive gaming type as follows: (1) a maladaptive preoccupation with online and/or offline computer gaming, experienced as irresistible use for periods of time longer than intended; (2) significant distress or impairment resulting from computer gaming; (3) Young's Internet Addiction Test (YIAT) scores over 50 (Young and Rodgers, 1998); (4) at least 4 h daily of computer gaming; and (5) absence of another Axis I psychiatric disorder that might lead to excessive computer usage, such as mania, hypomania, or substance-related disorders (Aboujaoude, 2010; Derbyshire et al., 2013). Table 1 depicts the demographic and clinical characteristics of the two groups. None of the participants suffered from any diseases known to affect autonomic cardiac function, such as cardiovascular, neurological, or endocrinological diseases. Medical and neurological histories of the participants were examined through medical records. The participating universities in this study provide annual medical check-up at the health service centers. We also screened the participants for sleep distur-

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