Digital Life

Journal of Digital Life 2022,1,1

Secondary Publication

An attempt to verify the positive effects of esports : Focusing on concentration and cognitive skill

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Abstract
The purpose of this study was to clarify the relationship between cognitive skill and concentration, based on brain waves measured before and after esports activity. Participants were twenty male collegiate students belonging to an esports club (Mean Age ± 21.40, SD = 1.65). At first, participants were put on a simple electroencephalograph (EEG) and their psychological state at baseline was measured for two minutes. After that, Stroop Color Word Test (SCWT) was conducted to measure their cognitive skill (execution function) before the esports task. In addition, after the esports task, SCWT was conducted again. To examine the degree of concentration during esports task, this study adopted a simple band-type EEG that only measures the Fp1 point as defined by the international 10-20 systems. As a result, this study indicated that cognitive skill (executive function) might be improved before and after esports task, and concentration might appear during esports play.

Keywords: Digital Game, Sports, Brain Wave, Stroop Test.

1. Introduction

In recent years, esports has been gaining ground in the competitive sports industry due to the development of professional game leagues, its phenomenal drawing power as a spectator sport, and its increasing profitability year after year (Wagner, 2006).

By the way, it has been said that the physical and cognitive skills of elite players are one of the important factors in enhancing the entertainment value of spectator sports such as professional sports (Campbell et al., 2018). While traditional spectator sports such as professional baseball and soccer rely on the development of players' physical skills to create the appeal of the game, esports are said to rely on the development of players' cognitive skills to create the appeal of the game (Campbell et al., 2018; Himmelstein et al., 2017). In addition, Toth et al. (2019) showed the possibility of creating the appeal of esports by promoting research focusing on cognitive skills for further development of esports. However, most of the previous studies on digital games used in esports have examined the negative aspects of digital games, such as the relationship between games and aggression (Ferguston, 2007) and the problem of screen time (Swing et al., 2010). On the other hand, research on the positive effects of digital games has been conducted in recent years, and it has been reported that digital games in particular enhance various cognitive functions (Bediou et al., 2018).

Green and Bavelier (2003) randomly divided sixteen males between the ages of eighteen and twenty-four into two groups of eight and administered an attention test (flanker task) to the game-playing group, which played the action game at least four days a week for at least one hour a day, and the control group, which did not play the game. They demonstrated that participants who played the game tended to have a higher attentional skill than control participants. In addition, Anguera et al. (2013) examined the relationship between digital game playing and cognitive function in elderly people, and found that the power ratio of the theta wave band, which is considered to reflect unconscious attention and concentration, increased in the electroencephalograph (EEG) during digital game playing. Moreover,

Received: 13 August 2021, Accepted: 20 August 2021, Published: 1 September 2021
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Lim et al. Furthermore, Lim et al. (2019) measured the EEG of university students while playing League of Legend, a global esports title, and reported an increase in the power ratio of the beta wave band, which reflects selective concentration in the frontal lobe. In Japan, Hagiwara et al. (2019) examined the cognitive effects of soccer games on university students and found that the results of cognitive function tests were significantly better in the group that played soccer games for ten minutes than in the control group. In addition, they demonstrated that comparison of the concentration extracted from the EEG before and during the game showed that the power ratio of the beta wave band increased during the game, and the concentration level tended to be significantly higher. However, in Japan, there have been few studies dealing with esports in sports science research, and it is necessary to verify the effects of esports from the perspective of sports in a broad sense, although esports are not physical exercise. Therefore, the purpose of this study was to clarify the relationship between cognitive skills and concentration extracted from EEG before and after esports activities.

2. Methods

2.1. Participants

Participants were twenty male university students (mean age ±21.40, SD=1.65) who belonged to an esports club (tentative name). The average weekly activity time of the subjects was 17.55±7.41 hours. The subjects were fully informed of the contents of the experiment and the risks associated with the measurement, and the experiment was conducted with sufficient care and consideration for their physical condition after obtaining their written and oral consent.

2.2. Measuring and evaluating cognitive skills

The Stroop test was used to measure cognitive skills. The Stroop test generally consists of two tasks: a congruent task in which the participants are required to answer the color indicated by the letter for the four colors (red, blue, green, and yellow) as accurately and quickly as possible, and a incongruent task in which the participants are required to answer the ink color of a letter whose meaning is incongruent with the color of the letter as accurately and quickly as possible (Watanabe, 2009; Fukuhara et al., 2013). In particular, the incongruent task is used as an index to measure the executive function to control behavior, which is one of the cognitive skills, because responses to the ink color of letters whose color and letter meanings are incongruent are inhibited by information about the letters (linguistic information) as well as the color names (sensory information) (Fukuhara et al., 2013). Omori (2017) examined the relationship between the Stroop test performance and low-intensity exercise in ten male university students, and compared executive functions by measuring the reaction time (in seconds) to perform a ten-question task using a discrepancy task. In addition, Wakisaka and Hashimoto (2012) reported that the reaction time obtained from the Stroop test task has high reliability and stability in measuring executive function, which is one of the cognitive skills. In this study, we asked twenty questions each of congruent and incongruent tasks of the Stroop test. In addition, Kageyama (2017) reviewed previous studies on cognitive function tests using tablet terminals and reported that tablet terminals are useful as a new research method for psychological studies when examining cognitive and executive functions, so we adopted the Stroop test using tablet terminals. In this study, we used the Hakaro Series Stroop Test (Digital Standard, Inc., Osaka, Japan). This application can be used to perform the Stroop task (congruent and incongruent tasks) easily using a tablet device, and we judged that it would be less burdensome for the subjects. The test consists of twenty questions each for congruent and incongruent tasks, and the questions start three seconds after the subject presses the start button, and each question is set to switch to the next question after the subject answers it. Each question is set to switch to the next question after the subject answers it, and each task is set to randomly switch questions. The Stroop test was conducted on an Apple iPad mini tablet device (Apple Inc., California, USA).

2.3. Measuring and evaluating concentration in esports activities

We adopted electroencephalography (EEG) to measure the level of concentration in esports activities. EEG is an electrical signal generated by the brain and can measure human psychological state in real time (Hotta & Kohata, 2017). It is also easier to measure in daily life environment than other brain activity measurements (Mitsukura, 2016a). Therefore, we adopted EEG measurement in this study. In addition, conventional EEG measurement requires a large measuring device with a large number of electrodes to measure EEG from multiple locations. Therefore, in recent years, except for precise verification research at the medical level, the mainstream of psychological state estimation research has been conducted using a simple EEG (Ohkubo et al., 2018; Mitsukura, 2016b; Yoshida et al., 2013). In this study, we will also use a simple EEG to measure the level of concentration. Since Fp1 is located in the left frontal lobe, there is no need to be concerned about the noise caused by the hair on the head, and the EEG obtained from Fp1 has been shown to be appropriate for obtaining the psychological state of human beings (Mitsukura, 2016b; Fukai et al., 2013). In this study, we use a band-type simple EEG that uses a chip for acquiring EEG signals (NeuroSky, Inc., California, USA) and the Sports KANSEI (Littlesoftware Inc., Tokyo, Japan) that records the acquired data on a smartphone and outputs the data as sensitivity values. In this study, two frequency bands, the frequency band of beta-waves and the frequency band of SMR waves, are adopted to evaluate the degree of concentration. The beta wave is a frequency band of brain waves extracted during concentration with eyes open (Hagiwara et al., 2019; Friel, 2007; Heinrich et al., 2007) and it appears when processing information that is selectively received (Connor, 1997). On the other hand, the SMR wave (sensory motor rhythm) is a frequency band of brain waves that appears during a relaxed yet focused psychological state (Heinrich et al., 2007; Omura, 2010).

Next, I will explain the basic concept of the Sport KANSEI, which calculates the power ratio of the frequency band of beta-waves and SMR waves. The potential difference obtained from the electrodes on the forehead and earlobe of the left frontal lobe (Fp1) was amplified by the circuit in the measuring instrument, digitized at 512 samples/second, processed by HANNING window, and then analyzed by fast Fourier transform to obtain the power spectrum. The power spectrum was analyzed by Fast Fourier Transform. From the obtained power spectrum, the sum of the power of each frequency band was calculated, and the percentage of the total power is shown as a relative value. Since the amplitude of each frequency band is different (Maeda et al., 2012), the sum of the power of each frequency band cannot be used, so the average of the power of each band is taken and this value is used as the representative value for each frequency band. The calculation method used the following Formula as a standard for analysis.

$$P_x = \sum_{f=F_{\min}^x}^{F_{\max}^x} V_f / (F_{\max}^x - F_{\min}^x + 1) \qquad (1)$$

$$P_{sum} = P_\delta + P_\theta + P_\alpha + P_\beta \qquad (2)$$

$$R_x = P_x / P_{sum} \qquad (3)$$

The average Px of the x-wave power was calculated by Formula (1), where Vf is the power of the EEG at the frequency f [Hz]. Since this study concerns the SMR-wave band (10Hz to 11.75Hz), the beta wave band (13 Hz to 29.75 Hz), when x = beta, it becomes (13, 29.75) [Hz], and the numerical value is applied to ($Fxmax - Fxmin$) in Formula (1). Next, the sum of the power averages ($Psum$) in each frequency band is calculated by Formula (2). The ratio (Rx) included in the total power of the beta wave band was calculated in Formula (3).

Based on the above calculation method, the Sports KANSEI (Littlesoftware Inc., Tokyo, Japan) normalized the power ratio that can be taken in the SMR and the beta band to the value of 0-100.

2.4. Experimental procedure

The experimental procedure was based on previous studies (Fukuhara et al., 2013) using the Stroop test, and the following steps were taken.

1. Explain the experiment to the participants and obtain informed consent
2. Practicing the car racing-type esports task and wearing the EEG
3. Measurement of the baseline concentrate state in a seated position with eyes open (two minutes)
4. Stroop test (first time)
5. Car racing-type esports tasks (three trials) **Note*
6. Stroop test (second time)
7. Remove the EEG
8. Finish

In this study, in order to compare the level of concentration during the baseline state and the level of concentration during the esports task, the average of the level of concentration during the two-minute baseline measurement was used as the baseline state, and the average of the level of concentration during the three trials was used as the level of concentration during the esports task. In addition, referring to Green and Bavelierm (2003), the participants were asked to perform car racing-type esports at least four days a week for at least one hour a day for six months. For the esports task, we used the Nintendo Switch and MARIOKART Deluxe 8 (Nintendo Co., Ltd., Kyoto, Japan). In addition, the course used for the task was Mario Kart Stadium, and the mode was set to the Time Attack, in which one player makes three laps around the course. The participants were given a choice of characters and machines to use.

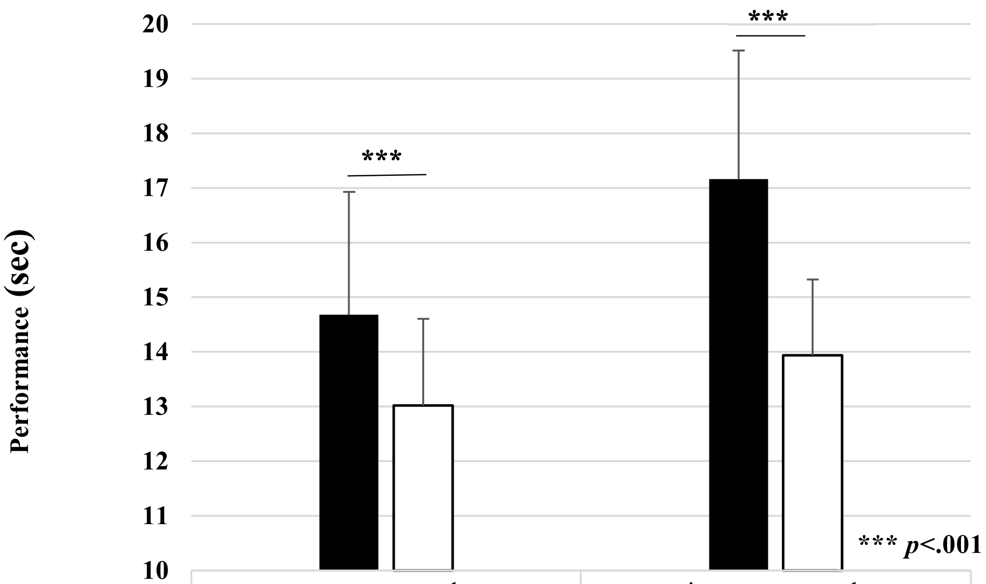
2.4. Analysis

In order to compare the changes in executive function, which is one of the cognitive skills, the reaction time (seconds) in the Stroop test before and after the esports task was examined using a corresponding t-test. In addition, to compare the changes in concentration, the mean of concentration during the baseline state and during the esports task was examined using a corresponding t-test. SPSS 25.0 （IBM, Inc., New York, USA) was used for the analysis.

3. Results

3.1. Comparison of cognitive skills before and after the esports task

In order to compare the changes in cognitive skills (executive function) before and after the esports task, the reaction time in the Stroop test was tested using a paired t-test. The results showed that there were significant differences in both congruent and incongruent tasks (congruent task: t=5.24, p<.001; incongruent task: t=7.01, p<.001). As a result, significant differences were found between the congruent and incongruent tasks (congruent task: t=5.24, p<.001; incongruent task: t=7.01, p<.001), and the reaction time was significantly faster before and after the esports task (congruent task: before task; M=14.68±2.25 sec, after task; M=13.02±1.59 sec, incongruent task: before task; M=17.16±2.36 sec, after task; M=13.94±1.39 sec) (Figure 1).

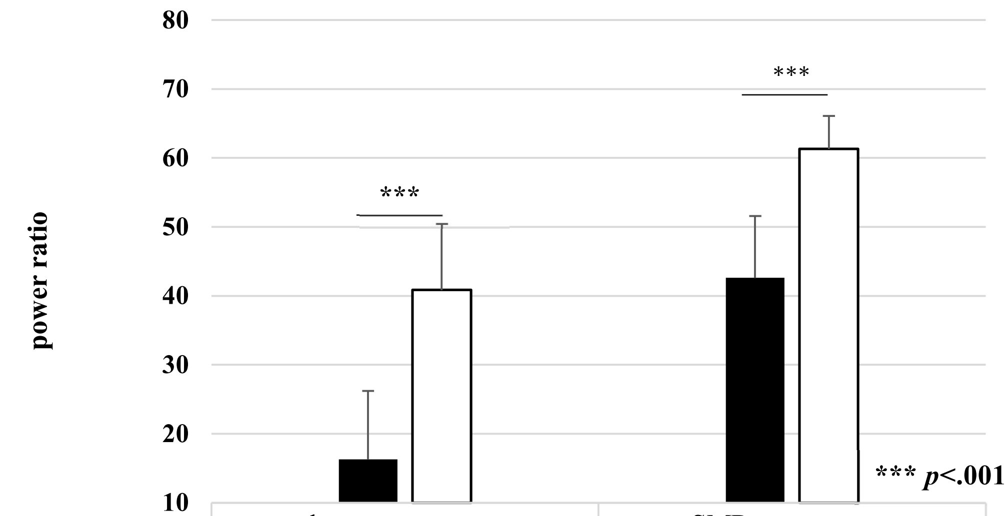


	congruent task	incongruent task
■ before esports task	14.68	17.16
□ after esports task	13.02	13.94

Figure 1. Results of comparison in cognitive skills before and after the esports task

3.2. Comparison of concentration levels extracted from EEG

In order to compare the differences in concentration extracted from the EEG, the corresponding t-tests were performed on the mean values of the EEG in baseline conditions and during the esports task. The results indicated that there were significant differences in the beta wave and the SMR wave band power ratio (t=8.38, p<.001, and t=9.69, p<.001, respectively). The beta wave band power ratio during esports task (M=40.85, SD=9.67) was significantly higher than in baseline conditions (M=16.29, SD=9.95). In addition, the SMR wave band power ratio during play esports (M=61.33, SD=4.77) was significantly higher than in baseline conditions (M=42.62, SD=8.96) (Figure 2).



	beta wave power	SMR wave power
■ before esports task	16.29	42.62
□ during esports task	40.85	61.33

Figure 2. Results of comparison in concentration extracted from EEG before and during the esports task

4. Discussion

The purpose of this study was to clarify the relationship between cognitive skills and concentration extracted from EEG before and after the activity using car racing-type esports.

Green and Bavelier (2003) examined the effects of action games on adolescents, and found that playing fast-paced games resulted in faster information processing. The results of this study also indicated that the reaction time of the participants to the task performance became faster, indicating that racing-type esports may also contribute to the improvement of executive function, which is one of the cognitive skills. In addition, a previous study (Toth et al., 2019) conducted on esports-athletes demonstrated that the reaction time to the Stroop task was significantly faster for higher level players, indicating that those who continuously perform esports have higher cognitive skills. In addition, Anguera et al. (2013) examined the effects of digital games on the elderly, found that the performance of cognitive functional tests improved after digital games, and further development of esports research in Japan is expected by conducting future studies on the elderly.

Lim et al. (2019) examined the EEG of thirty-three esports players in South Korea, and found that the power ratio of the beta and SMR wave bands obtained from Fp1 increased during the esports activity compared to the resting state. In other words, esports activities may lead to selective concentration and concentration during complete immersion in an gaming activity. On the other hand, Anguera et al. (2013) reported that the power ratio of the theta wave band, which is considered to reflect unconscious attention and concentration, increased in the EEG of elderly people during game play. In the future, it may be necessary to focus on indices other than selective concentration.

In this study, we attempted to examine the relationship between car racing-type esports activities, cognitive skills (executive function), and concentration, and presented some findings, but there are limitations and issues to be addressed. In this study, the reaction time of the Stroop test using a tablet device was determined to verify the executive function, which is one of the cognitive skills, but there is a possibility of measurement error depending on the tablet device used in the verification. Sharts et al. (2015) examined the time required for stimulus presentation, tapping, and response on four types of tablet devices, and found that measurement errors may occur depending on the type of tablet device used. In addition, the verification tests using tablet devices may include game elements, which may affect the results. Therefore, it is necessary to consider measurement methods other than tablet terminals in the future.

This study found that the relationship between cognitive skills and concentration extracted from EEG before and after the activity using car racing-type esports. However, research on esports is still in the accumulation stage in Japan, and it will be necessary to promote further research on esports.

Author Contributions

Conceptualization, G.H.; methodology, G.H.; software, I.K; validation, G.H., I.K. and S.K.; formal analysis, G.H.; investigation, S.K.; resources, I.K.; data curation, S.K.; writing—original draft preparation, G.H.; writing—review and editing, G.H.; visualization, G.H.; supervision, G.H.; project administration, G.H.; funding acquisition, I.K.

Funding

This research received no external funding.

Institutional Review Board Statement

The study was conducted according to the Declaration of Helsinki, and approved by the Institutional Review Board of the National Institute of Fitness and Sports in Kanoya.

Informed Consent Statement

Informed consent was obtained from all participants involved in the study.

Conflicts of Interest

The authors declare no conflict of interest.

Acknowledgments

This paper is a translation into English of the following research paper, which has already been published in Japanese.

Hagiwara, G., Kawahara, I., & Kihara, S. (2020). An attempt to verify the positive effects of esports: Focusing on concentration and cognitive skill. *Journal of Japan Society of Sports Industry, 30*(3), 239-246. https://doi.org/10.5997/sposun.30.3_239

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