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Article

The effects of interactive fitness video games on stress and cognitive function

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Abstract
Exercise that stimulates perceptual and cognitive aspects and simultaneously enhances neuromuscular coordination has both cognitive and psychological effects. We examined the effects of an interactive fitness video game in 18 healthy participants (8 males and 10 females). The participants performed under 1) TETRIS, 2) Radio Gymnastics, or 3) FITRIS (interactive fitness video game) conditions on different days. In this experiment, first there was a 4-minute rest period during which the mean heart rate was measured, followed by a cognitive task. The heart rate was measured to confirm the intensity of the exercise. Then either the TETRIS, Radio Gymnastics, or FITRIS condition was initiated, while the mean heart rate was measured again. Then there was another cognitive task, followed by another 4 minute rest and mean heart rate measurement period. Saliva samples were collected after each period where the heart rate was measured. All of the participants completed evaluations of cognitive tasks (executive functions; inhibitory control and working memory) before and after each condition. The results showed that salivary cortisol decreased in all conditions, and both the FITRIS and Radio gymnastics conditions had a positive effect on executive function (inhibitory control and cognitive flexibility). In particular, it was shown that FITRIS had an increased effect on cognitive flexibility.

Keywords: Interactive fitness video games; salivary cortisol; stress; cognitive function; coordination exercises.

1. Introduction

Various studies have shown that transient exercise for the purpose of maintaining and improving health can also have a beneficial effect on mental health. In particular, many studies have shown that acute moderate-intensity exercise using treadmills, aerobics, or walking has a positive effect on mental health. For example, 30 minutes of exercise on a treadmill increases positive engagement and vigor, and the increase is greater than that of watching TV in a seated position (Bryan et al., 2007). Acute exercise using a bicycle ergometer or walking increased positive engagement and tranquility and decreased negative affect (Arai et al., 2003; Mitsuishi et al., 2010). All of these studies on moderate intensity exercise indicated that aerobic acute exercise has the potential to improve mental health through the mediation of emotional changes, and taken together with its ease of implementation, it can be considered that it is increasingly important to promote this type of exercise through public education programs.

In addition to the psychological effects of light intensity exercise, attention has recently been focused on its effect on cognitive functions. In particular, information-based training is a training method that stimulates the five senses, such as the eyes and ears, dramatically increases the speed of information processing in the brain related to the regulation and control of movement, and facilitates learning how to achieve optimal movement according to the situation at the time (Gundlach, 1968; Schreiner et al., 2002). In particular, coordination training (Hartmann & Minow, 2010; Schreiner et al., 2002) and rough life kinetic training (Horst, 2013; Horst, 2015) have attracted a great deal of attention in the German athlete training scene because they effectively stimulate the perceptual and cognitive aspects and

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enhance neuromuscular coordination through exercises using familiar tools such as juggling (otedama) and scarves. Although coordination training and life kinetic training are well known among sports practitioners, there are very few opportunities for other subjects to use them as exercise for the purpose of health maintenance and the promotion of mental health, even though they are readily available. Several studies have produced scientific evidence showing that coordination exercise may be expected to improve mental health (Draganski et al., 2004; Mitsuishi & Izuhara, 2018) and brain function (Nakahara et al., 2007). At present, coordination exercise is a form of training conducted mainly among athletes. However, if there is a possibility that these light intensity exercises can lead to the maintenance and promotion of physical and mental health by those who have little exercise habits, it is necessary to conduct more basic research in order to prepare promotion programs to ensure the spread of this type of inexpensive exercise that can be easily used in daily life.

In regard to motivation, Sell et al. (2008) reported that experiential fitness games motivate increased physical activity compared to simply walking on a treadmill. Warburton et al. (2007) examined the effects of combining an interactive video game (combined with stationary cycling) and comparing it to traditional aerobic training (stationary cycling only) on health-related fitness and exercise persistence, and found that interactive video games increased participation in training and improved health-related fitness. The results of that study showed that interactive video games can increase training participation and improve health-related fitness. The children's study, on the other hand, examined whether children who received active video games (Nintendo wii video games) engaged in more spontaneous physical activity than those who received inactive video games (Baranowski et al., 2012). The results also reported that there was no evidence that children who were given active video games were more active than those who were given inactive video games. Thus, conventional research has not yielded consistent results across subject demographics and games.

Şimşek, & Çekok (2016) also investigated the effects of balance and upper limb shaking training using Nintendo Wii on activities related to daily living and the quality of life (hereafter, QOL) in subacute stroke patients. As a result, Nintendo Wii training was reported to have an effect on the daily functioning and QOL of subacute stroke patients, as well as an effect on the Bobath neurodevelopmental treatment group. Rosenberg et al. (2010), in a study on patients with subsyndromal symptomatic depression, also reported that exergame (a highly entertaining video game that combines gaming and exercise) was helpful in improving depressive symptoms. However, there are infinitely few studies that have evaluated psychological responses as an effect of interactive fitness video games, and even in studies aimed at clarifying the relationship between video games and gamers' psychological functioning, the reasons for conducting games and favorite game genres are differently related to psychological functioning, and distraction. It has been reported that playing games for distraction purposes or action games have a positive effect on psychological health. In addition, only a very limited number of studies have been conducted that used physiological indicators, such as autonomic nervous activity and stress hormones as evaluation indicators to verify the effects of interactive fitness video games.

On the other hand, in this study on cognitive function, we tested the potential cognitive benefits of exergame training based on physically simulated fitness in older adults. The results showed significant improvements in physical function and cognitive functions, such as executive control and processing speed, compared to the control group (Maillot et al., 2012). Stanmore et al. (2017) also conducted a systematic review and meta-analysis of the effects of exergame on overall cognitive function and specific cognitive domains in clinical and non-clinical populations. Their results showed that the effects of the game were observed in both healthy older adults and in a clinical population with diseases associated with neurocognitive impairment. In particular, domain-specific analyses revealed that games improve executive function, attentional processing, and visual abilities. Thus, there have been relatively many studies on interactive sports games for the elderly from the perspective of improving cognitive function, but the number of research reports for other generations is still small. Furthermore, although there have been studies focusing on psychological responses (subjective evaluations) and cognitive functions, as mentioned earlier, there have only been a few studies conducted using physiological indicators. In particular, subjective evaluations have disadvantages such as the possibility of giving false answers and the difficulty of deeply understanding the inner life of the individual, it is necessary to ensure greater objectivity. In addition, as reported in Stanmore's study (2017), many studies have examined the effectiveness of game implementation using game machines. If we consider the continuation of exercise as the first priority, light intensity fitness exercise is required that feature the following factors; 1) fewer environmental restrictions, 2) lower cost, 3) exercise possible for those with little exercise experience, and 4) lower mental and physical burdens. Therefore, in light of the increasing use of applications in efforts to maintain and improve health that have appeared along with the recent advent of iPhones and other smartphones, it will be necessary to verify the effectiveness of interactive sports or fitness video games using such smartphones.

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In this study, we employed an interactive fitness video game that included elements of coordination exercises requiring brain functions in order to examine the effects on stress and cognitive functions in young adults. Interactive fitness video game is the use of gamification concepts, technology for cardiovascular activities. The equipment and programs combined physical fitness and entertainment were bringing fun and measured results. It is often referred to as, e-games, exergames, exertainment.

2. Methods

2-1. Participants

There were 18 healthy participants in this study, 8 males and 10 females, between the ages of 19 and 24 (mean age 21.8 ± 0.9 years). We excluded participants from taking part in the study if they had an illness or were taking medication. The participants were encouraged to maintain their normal lifestyle as much as possible from the day before saliva collection until the final collection at 14:00-17:00. The Medical Research Ethics Review Committee at the Kyoto University of Advanced Science approved the study protocol. Verbal and written informed consent were obtained from each participant.

2-2. Procedures

Fig. 1 shows the experimental design in the present study. The experimental subjects (hereafter, participants) performed under three conditions, 1) TETRIS, 2) Radio Gymnastics, and 3) FITRIS (interactive fitness video game), on different days. In order to unify the duration with the Radio Gymnastics, the TETRIS and FITRIS conditions were performed for 4 minutes using the FITRIS smartphone application (FunLife Inc.). TETRIS was manipulated with the smartphone using only the fingers while seated in a chair; for FITRIS, being an interactive fitness video game, uses the entire body. FITRIS and TETRIS were performed for about 30 seconds, including confirmation of body movements (FITRIS) and buttons (TETRIS) before the starting the conditions.

TETRIS repeatedly lined up the falling blocks from the top of the screen with the bottom of the screen, rotating or moving them left and right. The rows disappeared when there was no gap between them in a horizontal line.

FITRIS was performed in a standing position. There are four movements in FITRIS, for example, the right elbow was extended forward from a bent position if the participants wanted to move the TETRIS block to the right. To move a block to the left, the participants extended their left elbow forward from a bent position. Squats were performed when rotating the TETRIS block, and jumping jacks were performed when dropping the TETRIS block in a straight line downward more quickly. Radio gymnastics was performed while watching NHK's Radio Gymnastics No. 1 (for 3 minutes and 16 seconds) distributed on Youtube. In all of the conditions, the participants used the same smartphone (HUWEI P30). The duration of the FITRIS conditions was set after confirming in a preliminary study that the heart rate and rating of perceived exertion (RPE: Onodera & Miyashita,1976), were almost the same as those seen when using Radio Gymnastics No. 1. In this experiment, first there was a 4-minute rest period during which the mean heart rate was measured, followed by a cognitive task. Then either the TETRIS, Radio Gymnastics, or FITRIS condition was initiated, and the mean heart rate was measured again during this period. Then there was another cognitive task, followed by another 4 minute rest period, during which the mean heart rate was measured again. Saliva samples were collected immediately after the first rest period, after the TETRIS, Radio Gymnastics, or FITRIS condition period, and after last rest period, that is, after each period where the heart rate data was acquired. The heart rate data was acquired to clarify the changes used a Polar H10 heart rate sensor during the each condition. Heart rate was measured at three points: HR-A (4 min before the start of the experiment), HR-B (during the FITRIS/TETRIS/RADIO condition after the measurement of the first cognitive task), and HR-C (during the 4 min rest period after the end of the second cognitive task). The mean values were used in the analysis. This data was transmitted via Bluetooth® to an iPhone app (Heart Rate Variability Logger) (Altini & Amft, 2016; Yoghourdjian et al., 2020).

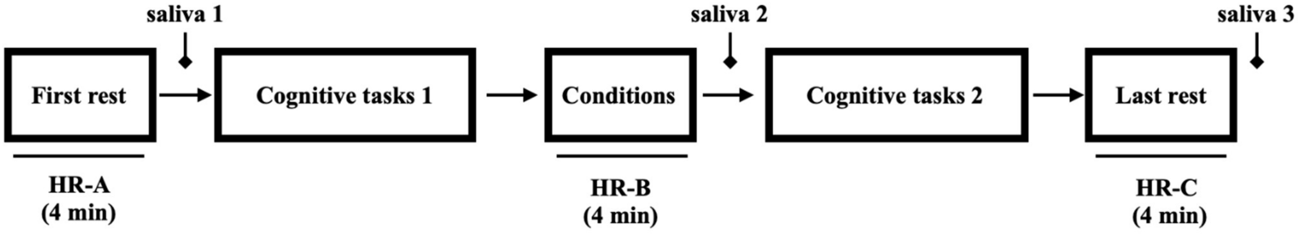

Fig. 1. Experimental design in the present study

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2-3. SOMA Cube Reader Collection and Analysis

The OFC swab containing the absorbed saliva was placed into a 3-ml buffer solution for analysis using a Cube Reader (SOMA Bioscience Ltd) at each of the specified time points and mixed for 2 minutes. The saliva/buffer mix samples were analyzed immediately after collection in the laboratory using an OFC swab. Two drops of the saliva/buffer mix from the OFC swab were added to the sample test window of the cortisol LFD. In this procedure, the liquid runs the length of the test strip via lateral flow, creating control and test lines visible in the test window. The test line intensity was inversely proportional to the cortisol concentration in the sample giving a quantitative value on the reader. This method of saliva analysis has previously been validated using ELISA analysis (Fisher et al., 2015; Mitsuishi et al., 2021).

2-4. Cognitive tasks

The executive function, one of the cognitive functions, is a higher-order cognitive function that controls (inhibitory control), switches (cognitive flexibility), and updates (working memory) inappropriate behavior in order to achieve a goal (Miyake et al., 2000), and it is considered to be one of the cognitive functions involved in sociality. In this study, we assessed executive function by having the participants perform 3 tasks; the 1) Stroop task, 2) the Number-Letter task, and 3) the Block recall task. All programs for the cognitive tasks were created using E-Prime3 software for cognitive experiments and implemented on a Surface2 notebook, running Windows 8. The time required was about 15 minutes for all cognitive task.

Inhibitory Control - Stroop Task

The Stroop task is a matching test consisting of the following three sub-tasks, each of which uses four different color name words (blue, yellow, red, and green) written in hiragana and their corresponding four colors patches. The contents of each task and the usual implementation method are as follows. For each task, a fixation point was presented in the center of the screen for one second after the start of the task, and then the target stimulus was displayed for five seconds. The colors and letters of the choices were four types (blue, yellow, red, and green), the letters were hiragana, and the letters were painted in the same color as the letter, so that they were the same in all tasks. The target stimuli in the congruent task consisted of four types of hiragana letters (blue, yellow, red, and green), and were presented in colors that matched the letters. The standard stimuli in the incongruent task were displayed in such a way that the colors applied to the four types of letters representing colors (blue, yellow, red, and green), were incongruent. For example, in the congruent task, when the word "red" was displayed in red in the center, the participants selected the same letter "red" from the choices of "blue" "yellow" "red" and "green" below. In the incongruent task, when the word "red" was displayed in green in the center, they chose "green" from the choices of "blue" "yellow" "red" and "green" below. Four sets of ten trials were performed for the matching task, and four sets of ten trials were performed for the incongruent task. The evaluation was based on the percentage of correct responses and the average reaction time (msec) in the incongruent task. The participants performed one trial of both congruent and incongruent tasks as practice before starting the task. In addition, the first trial of the incongruent task was excluded as a practice task in the analysis.

Switching - Number-Letter Task

The cognitive flexibility test (Rogers & Monsell, 1995) was a computerized task. Visual stimulus pairs consisting of a letter and a digit were presented. The letter was either a consonant (sampled randomly from the set G, K, M, and R) or a vowel (sampled randomly from the set A, E, I, and U). The digit was either even (sampled randomly from the set 2, 4, 6, and 8) or odd (sampled randomly from the set 3, 5, 7, and 9) in the stimulus pairs. The letter and the digit, as well as the order of both in the stimulus pair, were randomly selected. Trials were administered in the form of a three-block design. The letter task (Block 1) was presented only in the upper block (4 trials), and the digit task (Block 2) was presented only in the lower block (4 trials). In the letter task, participants pressed a left key when a consonant was presented and a right key when a vowel was presented in the stimulus pairs. In the digit task, participants pressed a left key when an even digit was presented and a right key when an odd digit was presented. All of the participants responded using the index fingers of their dominant hand. Additionally, the clockwise task (Block 3) was a presentation of the first stimulus pair in each block starting in the upper left box and the trial-to-trial presentation moved clockwise to the subsequent box (8 trials). When the letter and the digit was placed in the upper block, the participants answered using the number task method. On the other hand, when the letter and the digit was placed the lower block, the participants answered using the letter task method. The evaluation was based on the percentage of correct responses and the average reaction time (msec) for trials 3, 5, 7, and 9, in which the pattern switched in each set of clockwise tasks. The subjects performed one trial of the letter task, the digital task, and the clockwise task as practice before starting the task. as practice before starting the task. In addition, the first trial of the clockwise task was excluded as a practice task in the analysis.

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Working Memory - Block recall task

Working memory was assessed using a block recall task based on Pickering and Gathercole's method (Pickering & Gathercole, 2001). In the block recall task, nine squares of the same color and shape (35 x 35 mm, gray) were presented irregularly on a touch panel. The participants were instructed to memorize seven blocks out of the nine squares (blocks) presented on the screen that glowed blue in turn every second, and then asked to play the blocks in sequence while the nine blocks were presented again for 15 seconds. Three trials were conducted with this process as one trial unit. The presentation position of the target blocks and the order in which they glowed blue were randomly determined for each trial. For evaluation, the percentage of correct responses to 21 target blocks (7 target blocks x 3 trials) was calculated. The participants performed one trial as practice before starting the task.

2-5. Statistical Analysis

In this study, 18 participants were included in the analyses. Heart rate was calculated for each condition by averaging the values for 4 minutes (HR-A, HR-B and HR-C). The heart rate for each condition was calculated by subtracting each time point (During = HR-B minus HR-A; After = HR-C minus HR-A). To confirm that the exercise intensity is low, %Intensity was calculated based on these heart rates using the Karvonen formula [%HRR Intensity = [(HR-B minus HR-A) / (max HR minus HR-A) × 100] (American college of sports medicine, Brubaker, Otto, Armstrong, 2006). As we cannot be measured the maximum heart rate (max HR) directly, it can be roughly estimated using the traditional formula 220 minus age.

We Averages were calculated for the salivary cortisol levels at each time point. The salivary cortisol levels during each condition were calculated by subtraction using values obtained before and after each condition (Immediately = the value obtained immediately upon starting the condition minus that value obtained before starting the condition; After = values obtained after the experiment minus the values obtained before the experiment). The accuracy (all tasks) and reaction time (Stroop and Number-Letter tasks) for each condition were calculated by subtracting values obtained before each condition from those obtained after the condition (= after minus before).

We conducted a two-way analysis of variance (ANOVA) with the average cortisol levels as the dependent variable [within-subjects design: Condition types (FITRIS / Radio Gymnastics / TETRIS) × Time point (Immediately / After)]. Additionally, we conducted a one-way analysis of variance (ANOVA) with the difference in the accuracy rate (all tasks) and the reaction time (Stroop and Number-Letter tasks) for each condition as dependent variables [within-subjects design: Condition types (FITRIS / Radio Gymnastics / TETRIS)]. SPSS21.0J (IBM SPSS, Japan) was used for data analysis. Regarding the results of statistical analysis, a risk ratio of 5% or less was determined as a significant difference.

3. Results

3-1. Exercise intensity

The exercise intensity was 17.5 ± 7.9 for FITRIS and 9.6 ± 6.6 for Radio Gymnastics.

3-2. Salivary Cortisol

Table 1 shows the salivary cortisol levels for all of the time points. The two-way ANOVA showed no significant differences were Condition Types × Time point interaction [F (2, 34) = 0.35, *ns*, η^2 = 0.020]. Additionally, a significant main effect related to the Time point [F (1, 17) = 5.78, p <.05, η^2 = 0.254]. Multiple comparisons found that the salivary cortisol levels were significantly lower after each experiment, compared with immediately after the condition. No significant differences were shown for the main effects of Condition Types [F (2, 34) = 0.26, *ns*, η^2 = 0.015].

3-3. Executive Function

We carried out repeated-measures one-way ANOVAs on the differences between the accuracy rate (for all of the cognitive tasks) and the reaction time (for the Stroop and Number-Letter tasks) for each condition as dependent variables. The reaction time employed showed a significant main effect related to the Condition Type for the Stroop task [F (2, 34) = 4.94, p <.05, η^2 = 0.225] and the Number-Letter task [F (2, 34) = 3.99, p <.05, η^2 = 0.190]. The results of multiple comparisons in the Stroop task showed the highest values for the TETRIS condition with significantly lower scores for the FITRIS condition (p <.05) and the Radio Gymnastics condition (p <.05). Additionally, the results of multiple comparisons in the Number-Letter task showed significantly lower scores for the FITRIS condition (p <.01), compared with the TETRIS and Radio Gymnastics conditions (Table 2). The accuracy rate employed did not show any significant main effect related to the Condition Type when comparing the

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Stroop task [*F* (2, 34) = 0.28, *ns*, η^2 = 0.002], the Number-Letter task [*F* (2, 34) = 2.85, *ns*, η^2 = 0.144] or the block recall task [*F* (2, 34) = 0.99, *ns*, η^2 = 0.055].

Table 1. Differences in the salivary cortisol levels for each condition at each time point

	Mean (SD) N=18		*F* (df, error)		
	Immediately (μ g/L)	After (μ g/L)	Main Effect of Condition Types	Main Effect of Time point	Condition Types × Time point interaction
FITRIS	-0.99 (3.84)	-1.75 (4.03)	[*F*(2,34) = 0.26, *ns*, η^2 = 0.015]	[*F*(1,17) = 5.78, *p*<.05, η^2 = 0.254]	[*F*(2,34) = 0.35, *ns*, η^2 = 0.020]
Radio Gymnastics	-0.47 (2.43)	-0.85 (2.54)			
TETRIS	-0.17 (3.86)	-1.27 (3.46)			

Note. SD = Standard Deviation; η^2 = Effect Size. All p values smaller than *p* = .05 remain significant after Bonferroni correction.

Table 2. Differences in the reaction time for the conditions in the cognitive tasks

Task		Mean (SD) N=18			*F* (df, error)
		FITRIS	Radio Gymnastics	TETRIS	Main Effect of Condition Types
Stroop	accuracy rate (%)	1.620 (4.348)	1.774 (7.536)	1.343 (6.487)	[*F*(2,34) = 0.28, *ns*, *η2* = 0.002]
	Reaction Time (msec)	-85.593 ‡ (102.056)	-96.056 ‡ (117.828)	2.723 (72.576)	[*F*(2,34) = 4.94, *p*<.05, *η2* = 0.225]
Number Letter	accuracy rate (%)	2.243 (5.928)	2.469 (5.114)	-1.620 (6.216)	[*F*(2,34) = 2.85, *ns*, *η2* = 0.144]
	Reaction Time (msec)	-125.400 (135.681)	-29.846 * (74.845)	-4.771 * (166.715)	[*F*(2,34) = 3.99, *p*<.05, *η2* = 0.190]
Block recall	accuracy rate (%)	7.672 (20.474)	5.291 (15.571)	0.265 (12.701)	[*F*(2,34) = 0.99, *ns*, *η2* = 0.055]

Note. SD = Standard Deviation; η^2 = Effect Size. All *p* values smaller than *p* = .05 remain significant after Bonferroni correction. * *p*<.05 vs FITRIS, ‡*p*<.05 vs TETRIS

4. Discussion

In this study, we examined the effects of interactive fitness video games, which include elements of coordination exercises that use cognitive functions while performing physical and motor activities, on stress and cognitive functions in young adults. The results showed that salivary cortisol decreased in all conditions, and the FITRIS and Radio gymnastics conditions had a positive effect on executive function (inhibitory control and cognitive flexibility). In particular, it was shown that the FITRIS condition increased the effect on cognitive flexibility. The following is a discussion of the effects of the interactive fitness video game on salivary cortisol and executive function.

First, %HRR lower than 30% is considered to be very light intensity exercise (Garber et al., 2011). %HRR of both FITRIS and Radio Gymnastics in this study was lower than 20%. Therefore, it was suggested that the exercise intensity was very light.

In regard to the salivary cortisol, there was a main effect related to the Time point, as the values obtained prior to the initiation of a condition decreased significantly immediately after the implementation of the condition, regardless of the condition content. Salivary cortisol is widely known as an indicator of stress in the hypothalamic-pituitary-adrenocortical (HPA) system, and its secretion is increased in response to mental stress. In the case of saliva samples, their usefulness has been noted in the field of sports science, due to the non-invasive method employed, and it has also been shown that the decrease in cortisol after light intensity exercise compared to before exercise reflects the relaxation of mental stress (Sugano & Nomura, 2000; Guseman et al., 2021). Therefore, the decrease in cortisol associated with the Radio Gymnastics and FITRIS conditions represents a reduction in the mental stress due to the

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light intensity exercise. We also consider that the decrease in cortisol occurred because the TETRIS condition has the effect of reinforcing positive emotions and alleviating negative emotions (Rankin et al., 2019). However, in this study, no significant difference was found between either the Radio Gymnastics condition or the FITRIS condition, compared with the TETRIS condition. We believe this was due to the short duration of the exercise (4 minutes) compared with previous studies where exercise was performed for 30 or 90 minutes.

Next, we must discuss the executive function. In the Stroop task, which was used to assess inhibitory control, there was no significant difference in the accuracy rate across all of the conditions. On the other hand, the reaction times shown for the Radio Gymnastics and the FITRIS conditions were significantly faster than that shown in the TETRIS condition. Byun et al. (2014) reported that 10 minutes of bicycle pedaling at an intensity of 30% VO2 max improved performance reflected in Stroop interference as measured by reaction time and enhanced task-related subregional prefrontal functions. They reported that it enhanced cortical activation. Yanagisawa et al. (2010) also showed that 10 minutes of bicycle pedaling exercise at 50% VO2 max intensity improved the performance of the Stroop interference as measured by reaction time than when no exercise was performed. These results indicate that approximately 4 minutes of Radio Gymnastics and FITRIS can have the same effect on inhibitory control as the study with 10 minutes of exercise. It has been reported that moderate aerobic exercise such as running and walking can temporarily enhance the ability of cognitive flexibility (Bae et al., 2019; Netz et al., 2007). Furthermore, it is known that cognitive improvements during exercise are also seen at light intensities (Chang et al., 2012). In the present study, the reaction time shown in the FITRIS condition was significantly faster than that shown in the Radio Gymnastics and TETRIS conditions. This suggests that the FITRIS condition is more cognitively flexible than the Radio Gymnastics condition. Game experiences that emphasize the maintenance of multiple sources of information and rapid manipulation have been reported to coordinate distributed brain networks that support cognitive flexibility (Glass et al., 2013). We assumed that the FITRIS condition was very similar to a coordination exercise that effectively stimulates the perceptual and cognitive aspects and simultaneously enhances neuromuscular coordination, because it has a physical fitness component in addition to the thinking and judgment component of placing blocks while considering their positions. In addition, in light of the fact that acute stress reduces cognitive flexibility (Shields et al., 2016) and that cognitive flexibility is facilitated by positive emotions (Dreisbach & Goschke, 2004), the implementation of interactive fitness video games such as FITRIS, in which participants think and make decisions while connecting with their bodies, has the potential to work as an interactive fitness game that contributes to the maintenance and promotion of physical and mental health by widely evaluating and verifying the influence of positive psychological aspects on individuals. The exercise intensity in this study was lower than that of previous studies (including Byun et al., 2014; Yanagisawa et al., 2010). There have been several studies that have shown significant differences in reaction times for the Stroop (Byun et al., 2014) and Number Letter (Steinberg & Doppelmayr, 2017) tasks before and after exercise, but no differences in error rates. Incongruent (Stroop task) and Switching (Number Letter task) reaction times were decreased without statistically significant changes in accuracy rates, which suggests that the participant's cognitive system speeded and held accuracy constant. However, by increasing the number of conditions and samples and examining the relationship between reaction time and accuracy rate, it is necessary to further clarify the indicators that lead to the improvement of the executive function.

In previous studies, it has been reported that aerobic exercise may increase working memory capacity. For example, Li et al. (2014) found that 20 minutes of moderate intensity exercise improved performance on the N-back task, and Pontifex et al. (2009). reported that 30 minutes of moderate-intensity exercise resulted in shorter reaction times for the Recognition task (a modified Sternberg task), compared with resistance training. The block replay task used to assess working memory in this study increased the percentage of memory available, but there was no statistical difference. The duration of the exercise in this study was 4 minutes. Ishihara evaluated working memory using the n-back task and indicated that a longer duration of coordination training can be associated with better working memory. These results suggest that significant improvement in working memory may require exercise longer than the time set employed in this study, even if it is a coordination exercise. Additionally, the block replay task in this study was to memorize only seven blocks, considering the number of cognitive tasks and the implementation time. In previous studies, the method has been to perform the task in stages from three to nine (Berch &Krikorian, 1998). Further consideration will be needed to yield about the possibility that the number of blocks to be memorized (difficulty level) affects the correct response rate, and to examine the method of presenting the task.

In regard to the limitations of the present study, there was a lack of sufficient statistical substance due to the small sample size taken from a limited population of young adults. For these reasons, future studies will be required to clarify the results we obtained in this study and especially, more detailed studies should be conducted in order to take additional confounding factors into consideration, such as Games and fitness preferences, screen time, gender, and physical activity. Larger participant samples would also be beneficial, with expanded age ranges and occupations,

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including workers. In the present study, no difference in the stress-relieving effects of the Radio gymnastics condition and the FITRIS condition could be confirmed from salivary cortisol after the completion of the conditions. The FITRIS condition combined the anxiety-reducing elements of TETRIS with light intensity exercise, which may have the effect of enhancing positive emotions and alleviating negative emotions. On the other hand, in terms of exercise implementation time and exercise intensity, it is predicted that the longer the FITRIS implementation time, the greater the exercise intensity and the greater the psychological stress. Therefore, in order to clarify the psychological and physiological effects of FITRIS, it is necessary to take exercise duration into account and simultaneously collect data on time series changes in salivary cortisol levels and subjective indices under FITRIS conditions.

5. Conclusions

We examined the effects of interactive fitness video games on stress and cognitive functions in young adults. The data obtained in the present study showed a decrease in the salivary cortisol in all of the conditions (FITRIS, Radio Gymnastics, and TETRIS), and that the FITRIS condition, as well as the Radio gymnastics condition had the effect of shortening the reaction time on inhibitory control and cognitive flexibility. In particular, FITRIS was shown to increase the effect of cognitive flexibility.

Author Contributions

Conceptualization, H.M. and T.O.; methodology, H.M.; software, T.O.; validation, H.M.; formal analysis, H.M.; investigation, H.M.; resources, H.M., T.O.; data curation, H.M.; writing—original draft preparation, H.M.; writing—review and editing, H.M.; visualization, H.M.; supervision, H.M.; project administration, H.M.; funding acquisition, H.M, T.O. All of the authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement

This study was conducted according to the guidelines of the Declaration of Helsinki, and approved by the Institutional Review Board (Ethics Committee) of Kyoto University of Advanced Science (protocol code; 21-525, date of approval; 19 November 2021).

Informed Consent Statement

Informed consent was obtained from all of the participants involved in the study prior to the commencement of the study.

Data Availability Statement

The datasets generated in this study are available on request to the corresponding author.

Conflicts of Interest

The authors hereby declare no conflict of interest.

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