



Original Article

The difference in attentional focus during exercise affects attention resources

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Abstract. [Purpose] The purpose of this study was to investigate the effect of the difference in attentional focus, including the external focus (EF) or internal focus (IF) during exercise on attention resources from the viewpoint of the brain activity. [Participants and Methods] The study included 20 healthy adult participants randomly assigned to two groups: the EF and IF groups. The participants in each group received different verbal instructions before performing a tennis ball task, in which they threw a tennis ball on the floor at a target with their non-dominant hands as accurately as possible while sitting on a chair. During the task, oxygenated hemoglobin (oxy-Hb) in the right dorsolateral prefrontal cortex was continuously measured using a near-infrared spectroscopy device. The accuracy of the task and the change of oxy-Hb were statistically analyzed. [Results] Although there were no statistically significant differences between the groups, both accuracy of the task and oxy-Hb in the EF group were found to be higher than those in the IF group. [Conclusion] Our results showed that although the accuracy of motor control in the EF was superior to that in the IF, there is a possibility of increased attention resources in the EF compared to those in the IF.

Key words: Attention resource, External focus, Internal focus

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INTRODUCTION

In rehabilitation, it is recommended that an exerciser pays attention to the outside of the body (external focus: EF) rather than the inside of the body (internal focus: IF) because the EF is beneficial for promoting motor performance and motor learning compared to the IF¹⁻⁴⁾. This can be explained by the “constrained action hypothesis”. According to the hypothesis^{1, 4)}, the EF promotes motor performance by encouraging the automatic control of movement, whereas the IF induces more deliberate and conscious control of movement. Thereby, the IF disrupts the so-called “normal” automatic control process. The constrained action hypothesis has been supported by previous studies on dual task costs^{1, 4)}. Moreover, these studies have hypothesized that attention resources required by the EF are less than those required by the IF. Nevertheless, the hypothesis has not been verified from the view point of brain science. Recently, brain activity in the prefrontal cortex, which plays an important role in attention function⁵⁾, has become relatively easy to measure using non-invasive techniques such as near-infrared spectroscopy (NIRS)⁶⁾.

Therefore, the purpose of this study was to investigate the effect of difference in attentional focus, that is, the EF or the IF, during exercise on attention resources from the viewpoint of brain activity reflected by cerebral blood flow measured using NIRS. We hypothesized that if attention resources required by the EF were less than that by the IF, then blood flow in the prefrontal cortex in the EF would also be decreased compared to that in the IF.

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PARTICIPANTS AND METHODS

Participants were 20 healthy adults (5 females and 15 males). The mean (\pm SD) age was 26.7 ± 4.2 years, the mean (\pm SD) weight was 62.3 ± 13.8 kg, and the mean (\pm SD) height was 168.7 ± 5.4 cm. They were randomly assigned to two groups: the EF group and the IF group.

In each group, after the participants attached a probe of a NIRS device (OEG-16, Spectratech, Tokyo, Japan) to the forehead, they rest on a chair with backrest for 3 minutes with their eyes closed for habituation. After the 3-minute habituation, the participants performed a tennis ball task⁷⁾, in which they threw a tennis ball (6.5 cm in diameter, 600 g in weight) at a target on the floor with their non-dominant hands as accurately as possible while sitting in the chair (Fig. 1). According to a previous study on the tennis ball task⁷⁾, the target was made to be 10 cm in radius and was placed on the floor 3 m in front of the chair where the participants sit. In addition, circles with a radius of 20 to 100 cm were drawn around the target at 10-cm intervals. The number of throws in the tennis ball task was 30 times/set, and the participants were required to perform a total of 6 sets of the tennis ball task. Incidentally, the 2nd to 6th-set tennis ball tasks were also carried out after the 3-minute habituation, similar to the 1st-set tennis ball task (Fig. 2). Before performing the tennis ball task, the participants in the EF group were instructed to “Throw the ball as accurately as possible while paying careful attention to the target”. The participants in the IF group, on the other hand, were instructed to “Throw the ball as accurately as possible while paying attention to your hand”. During the task, the area surrounding the target was monitored using a high-definition digital video camera (HC-V480MS, Panasonic, Osaka, Japan) with 2.2 million pixels to identify where the thrown tennis ball landed.

In order to evaluate the accuracy of the tennis ball task, scores were set according to the position where the tennis ball landed by checking the recorded data of the video camera. The details of the scores according to the landing position of the tennis ball were as follows: 10 points if inside the target, 9 points if outside the target and within the circle with a radius of 20 cm, 8 points if between the circle with a radius of 20 cm and that with a radius of 30 cm, 7 points if between the circle with a radius of 30 cm and that with a radius of 40 cm, 6 points if between the circle with a radius of 40 cm and that with a radius of 50 cm, 5 points if between the circle with a radius of 50 cm and that with a radius of 60 cm, 4 points if between the circle with a radius of 60 cm and that with a radius of 70 cm, 3 points if between the circle with a radius of 70 cm and that with a radius of 80 cm, 2 points if between the circle with a radius of 80 cm and that with a radius of 90 cm, 1 point if between the circle with a radius of 90 cm and that with a radius of 100 cm, 0 point if outside the circle with a radius of 100 cm. Total scores in each set of the tennis ball task were calculated and used for subsequent statistical analysis.

Blood flow in the prefrontal cortex was evaluated using oxygenated hemoglobin (oxy-Hb) measured by the NIRS device. In this study, oxy-Hb in the dorsolateral prefrontal cortex (DLPFC) was measured because the area controls “visuospatial working memory”⁸⁾ that is likely to influence the performance of the tennis ball task adopted in this study. The conditions for oxy-Hb data acquisition were sampling at 1.54 Hz and low-pass filtering below 0.05 Hz. oxy-Hb was continuously measured from the start of the 1st 3-minute habituation to the end of the 6th tennis ball task. Thereafter, the differences between the mean value of oxy-Hb during each set of the tennis ball task and that during the corresponding 3-minute habituation (Δ oxy-Hb) were calculated and used for subsequent statistical analysis.

Both the total scores in each set of the tennis ball task and Δ oxy-Hbs were statistically analyzed using two-way repeated measure analysis of variance (ANOVA) with the groups and time course as factors, followed by Shaffer’s multiple comparison test. All statistical analyses were performed in R version 2.8.1.

To ensure its ethicality, the study was based on the Declaration of Helsinki. The personal information of the participants was carefully protected, the study was explained to all participants, and each participant provided their informed consent to participate in the study. The study was approved by the Ethics Committee of Hirosaki University’s Graduate School of Health Sciences (Approval No. 2019-006).

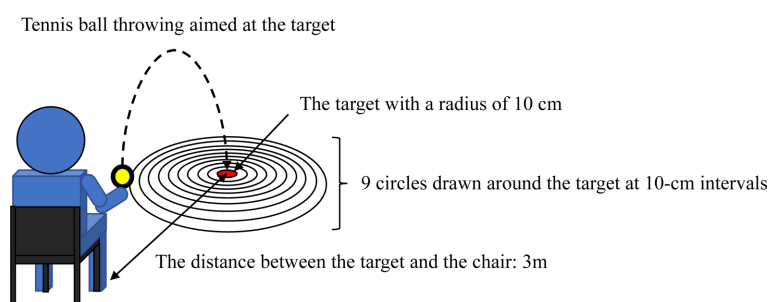


Fig. 1. Illustration of the tennis ball task.

RESULTS

In the EF group, mean values (\pm SD) of the total scores in the tennis ball task from the 1st to 6th sets were as follows in the order from the 1st to 6th sets: 239 (\pm 22.5) points, 257 (\pm 11.5) points, 253 (\pm 10.2) points, 258 (\pm 11.5) points, 258 (\pm 13.9) points, and 264 (\pm 11.8) points. In the IF group, on the other hand, those were as follows in the order from the 1st to 6th sets: 224 (\pm 20.8) points, 242 (\pm 10.1) points, 243 (\pm 8.5) points, 246 (\pm 6.8) points, 254 (\pm 7.4) points, and 255 (\pm 9.1) points. The two-way repeated measure ANOVA revealed main effects of the two factors, and no significant interaction between the two factors. Although the mean values of the total scores in the tennis ball task from the 1st to 6th sets in the EF group were constantly higher than those in the IF group, the post hoc multiple comparison test showed no statistically significant differences (Table 1).

In the EF group, mean values (\pm SD) of the Δ oxy-Hbs in the tennis ball task from the 1st to 6th sets were as follows in the order from the 1st to 6th sets: 0.08 (\pm 0.09) mmol/mm, 0.03 (\pm 0.07) mmol/mm, 0.04 (\pm 0.07) mmol/mm, 0.03 (\pm 0.08) mmol/mm, 0.06 (\pm 0.09) mmol/mm, and -0.01 (\pm 0.05) mmol/mm. In the IF group, on the other hand, those were as follows in the order from the 1st to 6th sets: 0.01 (\pm 0.04) mmol/mm, -0.02 (\pm 0.07) mmol/mm, -0.04 (\pm 0.08) mmol/mm, -0.02 (\pm 0.05) mmol/mm, -0.01 (\pm 0.04) mmol/mm, and -0.02 (\pm 0.09) mmol/mm. The two-way repeated measure ANOVA revealed main effects of the two factors, and no significant interaction between the two factors. Although the mean values of the Δ oxy-Hbs in the tennis ball task from the 1st to 6th sets in the EF group were constantly higher than those in the IF group, the post hoc multiple comparison test showed no statistically significant differences (Table 2).

DISCUSSION

In this study, the total scores in the tennis ball task from the 1st to 6th sets in the EF group tended to be constantly higher than those in the IF group. The result suggests that motor control in the EF group might be more accurate from the onset of the 1st set of the tennis ball task compared with the IF group. On the other hand, the Δ oxy-Hbs in the tennis ball task from the 1st

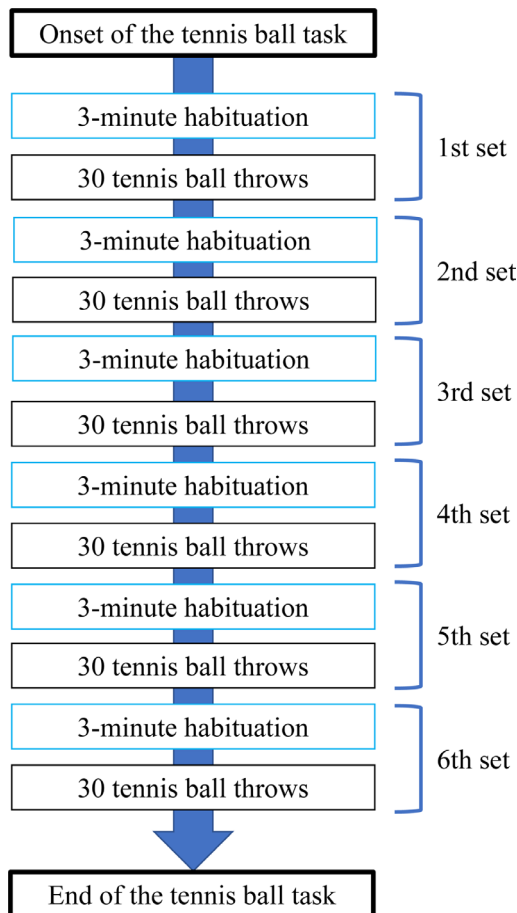


Table 1. The total scores in the tennis ball task in the EF and IF groups

Set	EF group	IF group
1st	239.1 \pm 22.5	223.9 \pm 20.8
2nd	256.6 \pm 11.5	241.6 \pm 10.1
3rd	253.3 \pm 10.2	242.9 \pm 8.5
4th	257.6 \pm 11.5	246.4 \pm 6.8
5th	257.6 \pm 13.9	254.3 \pm 7.4
6th	263.5 \pm 11.8	255.1 \pm 9.1

Mean \pm standard deviation.

Table 2. The Δ oxy-Hbs in the tennis ball task in the EF and IF groups

Set	EF group	IF group
1st	0.08 \pm 0.09	0.01 \pm 0.04
2nd	0.03 \pm 0.07	-0.02 \pm 0.07
3rd	0.04 \pm 0.07	-0.04 \pm 0.08
4th	0.03 \pm 0.08	-0.02 \pm 0.05
5th	0.06 \pm 0.09	-0.01 \pm 0.04
6th	-0.01 \pm 0.05	-0.02 \pm 0.09

Mean \pm standard deviation.

Fig. 2. Flow of the tennis ball task.

to 6th sets in the EF group tended to be constantly higher than those in the IF group. The result was contrary to our hypothesis, and suggests that the EF might require more attention resources compared to the IF. One of the crucial functions of the right DLPFC, which was the target of oxy-Hb measurement in the study, is visuospatial working memory⁷⁻⁹). Visuospatial working memory has two functional roles. One is the static role of storing information only temporarily, and the other is the dynamic role of actively selecting information to achieve objectives according to the task^{7, 8, 10}). Select information processing in the attention function serves to not only focus attention on necessary sensory information but also suppress attention on sensory information that is generally unnecessary or no longer necessary^{7, 8, 10}). In the tennis ball task adopted in this study, it is extremely important for the participants to focus on the spatial position information, that is, the position of the target. For this reason, it is likely that the above-mentioned dynamic role of visuospatial working memory worked more strongly in the participants in the EF group compared to those in the IF group. Consequently, we speculate that Δ oxy-Hbs during the tennis ball task in the EF group tended to be constantly higher than those in the IF group because the right DLPFC in the EF group was more activated compared to that in the IF group.

When the human exercises, it is necessary to retain spatial position information, and compare it with body position information. At that time, spatial position information must be temporarily retained in visuospatial working memory¹¹). Therefore, in the tennis ball task adopted in this study, the exercise performance is likely to change depending on whether or not the spatial position information of the target can be accurately retained¹¹). In order to accurately retain the spatial position information of the target, it is necessary to pay attention to the target space¹¹). On the contrary, it has been reported that the ability to retain spatial position information is impaired when attention is not paid to the target space¹²). In this study, it is likely that the participants in the EF group improved their exercise performance compared to those in the IF group because the former were able to retain the spatial position information of the target more accurately compared to the latter.

There are some limitations in this study that include relatively small sample size, the difficulty in confirming whether the participants were paying attention as instructed while performing the tennis ball task, the condition of having lost activities of the cerebral cortices other than the right DLPFC due to the characteristics of the NIRS device used in this study and the lack of kinematic data while performing the tennis ball task due to unused a three-dimensional motion analysis method. There is a highly possibility that these limitations affected not only the results of this study but also the interpretation of the results of this study. Future research should be conducted more minutely in consideration of the above-mentioned matters. In addition, the future outlook from a clinical perspective is to examine the effectiveness of the EF in the rehabilitation of hemiplegic patients after stroke. Some hemiplegic patients after stroke have a body image disturbance. In such patients, it is likely to be more important to know body position information, important for the IF, rather than spatial position information, important for the EF. The effectiveness of the EF and the IF in the rehabilitation of hemiplegic patients after stroke is still controversial³), and additional research will be needed to confirm this.

Conflict of interest

None.

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