



Slowed response to peripheral visual stimuli during strenuous exercise

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HIGHLIGHTS

- We tested if strenuous exercise impairs peripheral visual perception.
- Manual responses to visual stimuli were examined at rest and during exercise.
- Response to central visual stimuli was not affected during strenuous exercise.
- Response to peripheral visual stimuli was slowed during strenuous exercise.
- Strenuous exercise impairs peripheral visual perception during strenuous exercise.

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ABSTRACT

Recently, we proposed that strenuous exercise impairs peripheral visual perception because visual responses to peripheral visual stimuli were slowed during strenuous exercise. However, this proposal was challenged because strenuous exercise is also likely to affect the brain network underlying motor responses. The purpose of the current study was to resolve this issue. Fourteen participants performed a visual reaction-time (RT) task at rest and while exercising at 50% (moderate) and 75% (strenuous) peak oxygen uptake. Visual stimuli were randomly presented at different distances from fixation in two task conditions: the Central condition (2° or 5° from fixation) and the Peripheral condition (30° or 50° from fixation). We defined premotor time as the time between stimulus onset and the motor response, as determined using electromyographic recordings. In the Central condition, premotor time did not change during moderate (167 ± 19 ms) and strenuous (168 ± 24 ms) exercise from that at rest (164 ± 17 ms). In the Peripheral condition, premotor time significantly increased during moderate (181 ± 18 ms, $P < 0.05$) and strenuous exercise (189 ± 23 ms, $P < 0.001$) from that at rest (173 ± 17 ms). These results suggest that increases in Premotor Time to the peripheral visual stimuli did not result from an impaired motor-response network, but rather from impaired peripheral visual perception. We conclude that slowed response to peripheral visual stimuli during strenuous exercise primarily results from impaired visual perception of the periphery.

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1. Introduction

Many sports require visual perceptual skills under physiological stress. Recently, we found that strenuous exercise impaired the speed of responses to peripheral visual stimuli, and based on these findings we proposed that strenuous exercise impairs peripheral visual perception [1]. However, this proposal was challenged because of the inherent

limitation in assessing visual perception with a reaction-time (RT) task in which a motor response is required [17]. Thus, as strenuous exercise is likely to affect the neuronal network required for motor responses, this could have been the source of the slower motor responses, rather than impaired perception [17].

In a series of studies that assessed peripheral visual perception during exercise, we calculated the premotor time as the amount of time needed by the central nervous system to process a visual stimulus, develop motor output, and conduct a motor command to the periphery [14]. Several cortical and subcortical brain areas are recruited for manual motor responses [18]. Furthermore, it has been shown that primary

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motor cortex (leg area) [9,12,19,20], supplementary motor area [9,12], cerebellum [9,12], and insular cortex [9,19,20] are involved in dynamic exercise. As suggested by Vaillancourt & Christou [17], given that metabolic resources are limited in the brain when multiple tasks are performed simultaneously, increased activation in brain areas involved in strenuous exercise might interfere with those that control the manual motor response used in reaction-time tasks similar to ours. However, to what extent this is the case remains to be clarified experimentally.

To address this issue, here we compare the effects of strenuous exercise on premotor time to centrally and peripherally presented visual stimuli. We hypothesized that if the slowed response to peripheral stimuli during strenuous exercise is caused by difficulties in peripheral perception, premotor time should only increase if stimuli are presented peripherally. Alternatively, if it is caused by a general impairment in motor output, premotor time during strenuous exercise should increase when stimuli are presented centrally as well as peripherally.

The purpose of this study was to examine whether the slowed response to peripheral visual stimuli during strenuous exercise results from impaired peripheral visual perception or from a general impairment in motor control. The present study will provide new insight into the effects of strenuous exercise on human visual perception.

2. Material and methods

2.1. Participants

Fourteen male participants (age = 23.4 ± 2.2 years; height = 1.70 ± 0.06 m; weight = 67.0 ± 6.5 kg; peak oxygen uptake [$\dot{V}O_2$]: 44.7 ± 5.0 ml/kg/min) gave written informed consent to participate in this study. Participants had normal or corrected-to-normal vision and no history of cardiovascular, cerebrovascular, or respiratory disease. All experimental procedures were approved by the local ethics

committee of Fukuoka University and were in accordance with the Declaration of Helsinki.

2.2. Experimental procedure

The experiment was performed over three non-consecutive days. In the laboratory, the ambient temperature was between 21 and 23 °C, and the relative humidity was <50%. Before the main experiments, participants performed a maximal exercise test until exhaustion on a cycle ergometer (75XLI, COMBI Wellness, Tokyo, Japan). The maximal exercise test was terminated when participants were unable to maintain a pedaling rate of 50 rpm. Ventilatory parameters were measured using a gas analysis system (ARCO-2000, ARCO System, Chiba, Japan). Peak $\dot{V}O_2$ was determined as the highest oxygen uptake attained during the maximal exercise test. A few days before the main experiments, participants performed practice trials. They completed practice at least two blocks (120 trials) sitting on the cycle ergometer and while cycling until they were familiar with the task. We expect that these practice blocks minimize the possibility that learning affects the results.

On experimental days, participants performed RT tasks after they had adapted to a dark environment. We used two visual conditions (Central and Peripheral) that differed in how far away the visual stimuli were from fixation (central or peripheral visual fields). These visual conditions were blocked, and each one was tested on two different days, separated by at least 3 days. The condition order was counterbalanced across participants. Fig. 1A shows the experimental protocol. At the beginning of the experiment, RT was measured for 3 min while participants rested on the cycle ergometer (baseline, or at-rest measurement). One minute following the at-rest measurement, participants gradually cycled the ergometer up to 50% (moderate: 114.2 ± 14.1 W) and then 75% peak $\dot{V}O_2$ (strenuous: 178.5 ± 20.3 W). Pedaling rate was freely chosen by each participant, and the duration of each workload was

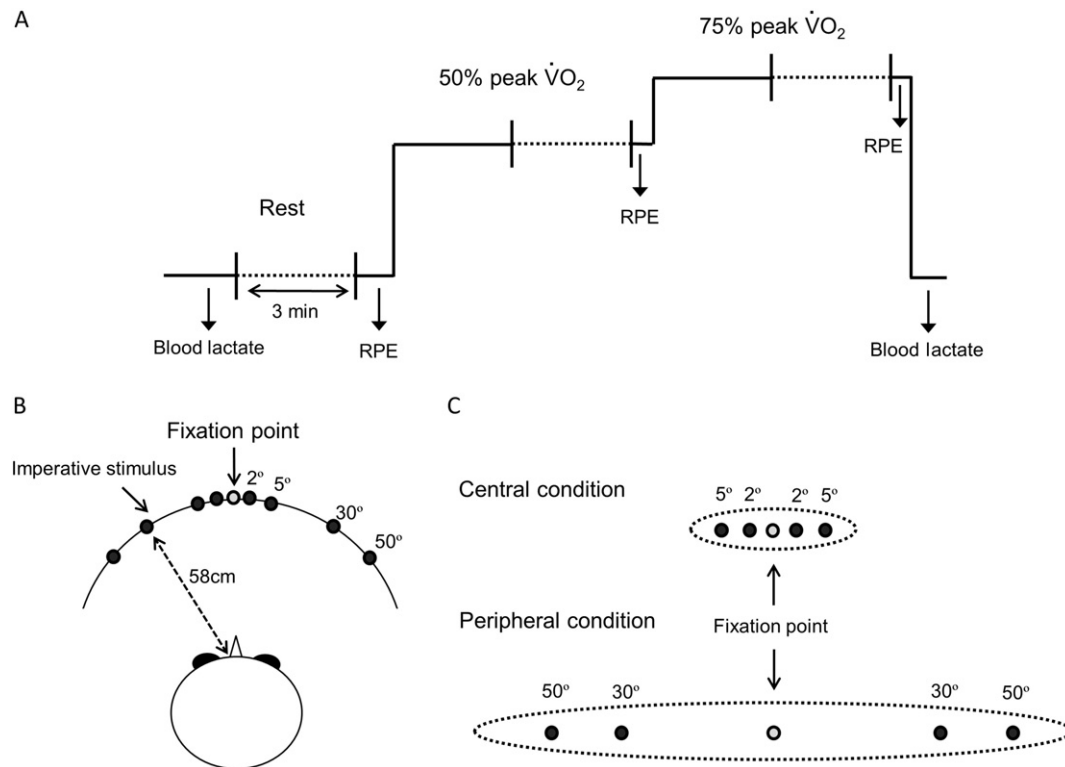


Fig. 1. (A) Illustration of the experimental protocol. Dashed lines show the duration of the RT measurements (3 min). Downward arrows indicate the timing of each measurement. (B) Location of the fixation point and visual stimuli (top view). Visual stimuli were positioned horizontally at 2°, 5°, 30°, and 50° either to the right or left of the midpoint between the eyes with an equidistance of 58 cm. (C) Simplified horizontal views from the participants. Dashed ovals indicate areas of visual attention to which the participants were presumably oriented in each condition. Note that shape, size, and angle of the stimuli were different from the actual ones for clarification.

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