HOSTED BY

ELSEVIER

CrossMark

Available online at www.sciencedirect.com

ScienceDirect

Journal of Sport and Health Science 4 (2015) 56–63

www.jshs.org.cn

Original article

Where are the limits of the effects of exercise intensity on cognitive control?

Karen Davranche [a,*], Jeanick Brisswalter [b], Rémi Radel [b]

[a] Aix Marseille Université, CNRS, LPC UMR 7290, FR 3C FR 3512, 13331 Marseille Cedex 3, France
[b] Université de Nice Sophia Antipolis, UFR STAPS, LAMHESS EA 6309, 06205 Nice Cedex 3, France

Received 30 June 2014; revised 26 July 2014; accepted 16 August 2014
Available online 24 December 2014

Abstract

Purpose: This study aimed to investigate whether workload intensity modulates exercise-induced effect on reaction time (RT) performances, and more specifically to clarify whether cognitive control that plays a crucial role in rapid decision making is altered.
Methods: Fourteen participants performed a Simon Task while cycling 20 min at a light (first ventilatory threshold, $VT_1 - 20\%$), moderate (VT_1), or very hard ($VT_1 + 20\%$) level of exercise.
Results: After 15 min of cycling, RTs are faster than during the first 5 min of exercise. This benefit does not fluctuate with the intensity of exercise and enlarges as RT lengthens. Despite a numerical difference suggesting a greater facilitation during moderate exercise (−16 ms) than during a light exercise (−10 ms), the benefit is not statistically different. Interestingly, we did not observe any signs of worsening on RT or on accuracy during very hard exercise.
Conclusion: Cognitive control is extremely robust and appears not to be affected by the intensity of exercise. The selective inhibition and the between-trials adjustments are effective from the beginning to the end of exercise, regardless of the workload output.

Keywords: Between-trials adjustments; Intensity level; Reaction time distributional; Simon Task

1. Introduction

When cognitive performance is assessed while exercising, a beneficial influence of acute moderate exercise is generally reported.[1–3] However, recent studies suggest that above a certain intensity level, cognitive functioning could be disrupted during exercise and could particularly impair higher order cognitive processing also referred to as cognitive control or executive functions such as response inhibition, selective attention, and task flexibility[4–6] which are crucial elements in decision-making. According to the transient hypofrontality theory,[4,7] physical exercise generates a massive neural activation which contributes to the recruitment of motor units, sensory input integration, and regulation of the autonomic systems. Given a limited resource capacity, this huge request induces a competition for resources that would be expected to result in a diminution of the resources allocated to brain structures which are not directly involved in motor control (areas of the prefrontal cortex and, perhaps, the amygdala).

Nevertheless, to date, the accumulated evidence is equivocal and provides an unclear picture of the relationship between exercise intensity and cognitive control. Using a Simon Task, Davranche and McMorris[8] found that selective response inhibition was impaired by moderate acute exercise (20-min steady-state cycling at ventilatory threshold intensity corresponding to an average of 77% ± 4% of maximal heart rate (HR_{max}). The Simon Task[9] is a classic paradigm used to study how irrelevant spatial relationships between stimuli and responses affect human decisions. In the standard version of this task, participants have to choose between a left- and a right-hand key press according to a non-spatial attribute of a

* Corresponding author.
E-mail address: karen.davranche@univ-amu.fr (K. Davranche)
Peer review under responsibility of Shanghai University of Sport.

2095-2546/$ - see front matter
http://dx.doi.org/10.1016/j.jshs.2014.08.004

stimulus which is presented on the left or on the right of a fixation point. Participants are required to respond, as quickly and accurately as possible, by selecting the relevant feature of the stimulus (e.g., the color) and inhibiting the irrelevant feature (the spatial location) of the same stimulus. The performance expressed both in terms of error rate and mean reaction time (RT) is better when the required response corresponds spatially to the irrelevant stimulus location (congruent association, CO) than when it does not correspond (incongruent association, IN). This phenomenon is known as the Simon effect (RT on incongruent trials minus RT on congruent trials) and is assigned to the emergence of a conflict between the activation of the incorrect response (associated with the irrelevant information) and the activation of the correct response (associated with the relevant information) which delays the response execution. Similar impairment have also been observed with elite white-water athletes[10] paddling at a moderate intensity (75% HR_{max}), suggesting that selective response inhibition was worse when the Simon Task was performed concurrently with a moderate paddling exercise compared with a light paddling exercise. In contrast, McMorris et al.[11] failed to observe any deteriorations of selective response inhibition despite very high physiological stress (i.e., 80% of maximal aerobic power, MAP). The intensity of exercise is probably a key variable in determining the presence or absence of a beneficial effect of exercise on cognitive control. The nature of the cognitive task is also critical. Cognitive processes appear to be differently altered by exercise-induced effects. Davranche and McMorris[8] suggested that the effect of exercise seems to be specific, rather than general, and can probably not be generalised across different cognitive functions even if these functions involve similar specific regions of the brain like prefrontal-dependent cognitive tasks. Future studies, using different prefrontal-dependent cognitive tasks in the same protocol, should be conducted while exercising to test this assumption.

RT distribution analyses have proved to be powerful for assessing the processes implemented during decision-making tasks and in the Simon Task in particular. According to dual-route models of information processing,[12–14] this finding results from a conflict between an automatic and rapid response impulse (triggered by the spatial location) and a slower, deliberately controlled response to the pertinent stimulus information (the color).

Using a Simon Task performed while cycling at light, moderate, and very hard level of exercises, the present study attempts to clarify past findings and to contribute to a better understanding of the interaction between exercise intensity and cognitive control processes. During light intensity exercise, we anticipate that cognitive performance will be facilitated (faster RT without change in accuracy) and cognitive control will continue to be fully efficient. If the intensity of exercise is a critical consideration for cognitive control, as the intensity of exercise increases to a moderate level and/or a very hard level of exercise, we should observe a decrease in cognitive performance (or at least a reduced benefit of exercise).

2. Methods

2.1. Participants

Fourteen undergraduate students were recruited in exchange for course credits through the research participation system of the Sport Sciences Department of the University. All of our participants were regularly involved in endurance activities at least once a week. They were regularly involved in sport activities and could be considered as moderately trained subjects. Written informed consent was obtained from all subjects prior to their participation. This study was approved by the local ethical committee. Anthropological and physiological characteristics of the participants are summarized in Table 1.

2.2. Procedure

The subjects were required to visit the laboratory during 4 different days. As the tests could be influenced by circadian rhythms, testing for each participant was carried out at the same time of day as their previous session. The lag-time between each visit ranged from 2 to 16 days. Participants were instructed to avoid doing any vigorous exercise during the last 24 h and to abstain from drinking coffee 2 h before each visit.

The first visit served to familiarize the participants with the cognitive task and to collect their anthropometrical and physiological characteristics. During the familiarization, subjects performed four blocks of 200 trials of the Simon Task. Additional blocks were performed, if necessary, until reaching the following learning criteria: a) RT intra-block variability below 5%, b) RT variability with the previous block below 5%, c) mean RT less than 600 ms, and d) response accuracy greater than 85%.

Five min after the Simon Task training, participants performed a maximal incremental exercise test to determine maximal oxygen consumption and power at the first ventilatory threshold (VT_1). The test was performed on an electronically braked cycle-ergometer adjusting the power to the pedal frequency (Brain-bike NeuroActive; recumbent bike, BE-7216, Taiwan, China). After a 4-min warm-up at light

Table 1
Anthropometric and physiological characteristics of the participants (mean ± SD).

Variables	All	Female	Male
n	14	3	11
Age (year)	21 ± 2	22 ± 1	21 ± 2
Weight (kg)	67 ± 12	50 ± 4	72 ± 8
Height (cm)	179 ± 10	166 ± 1	182 ± 8
Maximal HR (bpm)	183 ± 10	176 ± 13	185 ± 9
VO_{2max} (mL/kg/min)	47 ± 9	41 ± 3	49 ± 10
MAP (W)	287 ± 38	260 ± 26	294 ± 38
VT_1 (W)	169 ± 22	140 ± 10	177 ± 16
VT_1 − 20% (W)	134 ± 17	113 ± 15	140 ± 13
VT_1 + 20% (W)	211 ± 27	180 ± 23	219 ± 23

Abbtreviations: HR = heart rate; VO_{2max} = maximal oxygen consumption; MAP = maximal aerobic power; VT_1 = first ventilatory threshold.