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Effects of light deprivation in physical performance and psychophysiological responses to a time-to-exhaustion exercise test

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HIGHLIGHTS

- Studies had shown no effect of light deprivation in closed-loop exercise performance.
- The light deprivation decreased performance in open-loop, constant intensity exercise test (TE).
- Light deprivation decreased the subjective TE test tolerance by speeding up the RPE.
- Participants increased their focus on internal body sensations during the light-deprived TE test.
- There was greater psychophysiological disturbance during light-deprived TE test.

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ABSTRACT

Studies have shown that there is no effect of light deprivation in closed-loop exercise performance, however less is known about the open-loop exercise performance. Thus, we verified if light deprivation may affect performance and psychophysiological responses to a time-to-exhaustion (TE), constant intensity exercise test. Twelve men performed TE tests (at 80% W_{PEAK} of maximal incremental test) in control and light-deprived condition. Gaseous exchange (VE and VO_2), heart rate (HR) and vastus lateralis electromyography (EMG) were continuously assessed, ratings of perceived exertion (RPE) and associative thoughts to exercise (ATE) were obtained every 60 s. Responses at absolute time of exercise matched by the shortest time to exhaustion, and responses at exhaustion were compared between conditions ($P < 0.05$). Exhaustion was shortened (5.0 ± 1.6 min vs 6.4 ± 2.4 min) and RPE slope was elevated in light deprivation, when compared to control ($P < 0.05$). Responses of VE, VO_2 and RPE were greater at exhaustion in light deprivation TE test than at the equivalent, paired time in control test. However, responses were similar at exhaustion of both TE tests; the exception was the lower EMG when the light was deprived. The light deprivation shortened the exhaustion and increased RPE in TE test, until the attainment of similar maximal psychophysiological responses.

1. Introduction

Visual cue is an important stimulus to recognize the external environment, so motor performance during physical exertion is suggested to be affected by manipulations of visual cue [1,2]. Using a light deprivation approach with auditory cues, earlier study by Kriel et al. [3] had observed that, when compared to a control condition, neither performance nor psychophysiological responses such as ratings of perceived exertion (RPE) and heart rate (HR) were affected during a 40 km closed-loop cycling trial. The authors concluded that visual input was not required to perform this exercise mode. However, these results were counterintuitive, as the darkness is expected to negatively affect physical performance; individuals may feel lower alertness and subjective exercise tolerance in the absence of light [4]. From a mechanistic perspective, light deprivation may negatively affect physical performance due to a slowing of the motor cortices activation and arousal [5,6], perhaps as a result of the reduced connection between prefrontal cortex and hypothalamus, triggered by the retina of eyes in the absence of light [7–9,10]. Therefore, more studies are required to elucidate if light deprivation may affect physical performance and psychophysiological responses to exercise.

The absence of negative effects of darkness in that study [3] may be related to some aspects. First, the light-deprived condition was performed in a sequential order, after the illuminated-control condition.

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As highlighted by the authors, the lack of randomization between the light-deprived (2nd test) and illuminated-control exercise test (1st test) was a weakness of the study. Individuals could have improved physical performance in the second test due to the effects of order, thus reducing the negative effects of darkness on physical performance. Moreover, effects of darkness are apparent when brightness is very low, probably less than 5.5 lx [5,6]. Unfortunately, Kriel et al. [3] did not report the brightness used in that study.

Another aspect that should be pointed out is that the exercise tolerance (i.e., physical performance) and psychophysiological responses during exercise were obtained during a 40 km closed-loop cycling trial [3]. In closed-loop exercises individuals are free to pace themselves according to a known, pre-determined endpoint. It has been suggested that performance in this exercise mode is based on a RPE template model, so that the attainment of the exercise endpoint is programmed to match maximal RPE values (i.e. maximal subjective tolerance); pacing would be continuously adjusted to avoid that the maximal subjective exercise tolerance is reached before the exercise endpoint [11,12].

However, in laboratory tests such as a time-to-exhaustion (TE) cycling test, the exercise endpoint is unknown in anticipation. During a TE test individuals have to maintain a fixed power output throughout the test, so that they have no choice to pace themselves according to a RPE template [13,14]. Therefore, rather than closed-loop exercises, TE cycling tests seem to be highly dependent on the individuals' subjective tolerance to fatigue, as the time-to-exhaustion is related to the time of exercise until the attainment of maximal RPE values [12,15,16]. In this regard, some authors have suggested that the rate of increase in RPE fairly predicts the TE test performance, as the lowered subjective tolerance is related to a faster increase in RPE and reduced time-to-exhaustion [11,14]. However, it is still to be confirmed if light deprivation may reduce the subjective exercise tolerance in TE tests, thus elevating the rate of increase in RPE and decreasing performance.

Therefore, this study aimed to investigate the light deprivation effects on performance and RPE responses to a TE cycling test. We hypothesized that light deprivation may decrease the subjective exercise tolerance by shortening the attainment of maximal RPE values. As a result, the physical performance measured as the time-to-exhaustion would be reduced.

2. Materials and methods

2.1. Participants and experimental design

Twelve physically active males (25.1 ± 4.9 years, 175.7 ± 5.7 cm, 77.8 ± 5.7 kg, and 11.4 ± 4.5% of body fat), unhabituated with dark environments volunteered to participate in this study. The participants were free from visual and cognitive disorder as well as from neuromuscular and cardiopulmonary disease; they were informed about the experimental procedures, risks, and benefits before signing a written consent form. This study conformed to the Declaration of Helsinki, and was previously approved by the local Research Ethics Committee.

The experimental design consisted of three sessions. In the first session, participants completed a physical activity readiness questionnaire (PARQ), were familiarized with the cycle ergometer and psychophysiological measures, and performed a maximal incremental test. During sessions two and three, participants who were already familiarized with TE tests, performed a TE cycling test set at 80% of the peak power output (W_{PEAK}) achieved in the preliminary maximal incremental test, either exposed to (control condition) or deprived of light (light-deprived condition). These TE tests were performed in a counterbalanced fashion, in laboratory (~20 °C) environment at the same time of the day. Thus, psychophysiological responses were obtained while participants cycled in illuminated-control and light-deprived environments. Psychological variables were RPE and associative thoughts to exercise (ATE), as previous study suggested that higher RPE during physical task in the absence of visual stimuli (individuals blindfolded with a sleeping mask) was related to a greater ATE [17]. On the other hand, traditional laboratorial variables such as cardiopulmonary and electromyography (EMG) responses were the physiological variables.

All the tests were performed on a bicycle (Giant®, USA) adapted with comfortable saddle and pedals, coupled with a cycle-simulator (CompuTrainer™ RacerMate 8000, EUA), calibrated before the tests according to the manufacturer's instructions.

2.2. Preliminary session

After PARQ's completion, participants were evaluated for anthropometric variables, thus body mass, height, and chest, abdomen, and thigh skinfolds were obtained. To get acquainted to instruments and scales, participants cycled for 10 min while using a mask for gaseous exchange measures. Thereafter, they were familiarized with psychological scales. The RPE was obtained according to the 15-point Borg's scale [18]. The participants were oriented to consider breathlessness, cardiopulmonary work, body temperature and overall discomfort to rate their perceived exertion. On the other hand, ATE was obtained through a 10 cm bipolar line ranging from 0 (dissociative thoughts) to 10 (associative thoughts), as suggested elsewhere [17]. Briefly, participants were oriented to rate their thoughts according to internal (sensations derived from the body) and external cues (unrelated body sensations such as daily tasks, environment, etc), scoring 0 to 4 as dissociative and 6 to 10 as associative thoughts. The number 5 would score a shift from dissociative to associative thoughts. Participants were fully aware about the distinction between associative and dissociative thoughts, however only the associative thoughts to exercise (ATE) were reported. Evidences of ATE scale's validity have been provided [17].

After familiarization with instruments and scale, participants were positioned on the bicycle for a 3 min baseline period, which was followed by a 5 min self-paced warm-up period. Immediately after the warm-up, they began a traditional maximal incremental test, with initial workload set at 100 W and pedal cadence at ~80 rpm. The workload was increased 25 $W \cdot min^{-1}$, until exhaustion. They were strongly encouraged to push themselves for as long as they could, while exhaustion was identified as the incapacity to maintain the pedal cadence at ~80 rpm (despite three strong verbal encouragements). Throughout the preliminary incremental test, participants wore a mask (Hans Rudolph, USA) connected to an open-system gas analyzer for breath-by-breath measurements of the gaseous exchange (Quark CPET, Cosmed, Italy). The gas analyzer was calibrated according to manufacturer's recommendation before each test. In addition, the HR was assessed by a cardio belt (Suunto, Finland) at a 2-Hz frequency. The oxygen uptake (VO_2) data were smoothed to 10 s intervals and the VO_2 peak (VO_{2PEAK}) was determined as the average of the three highest VO_2 values obtained during the last 60 s of the test [19]. The W_{PEAK} was defined as the maximal power output achieved during the test.

2.3. Open-loop exercise procedures

After the preliminary session (~7 days), participants performed TE cycling tests in the illuminated-control and light-deprived environment, following a washout interval of 3 to 7 days between them. In order to manipulate the laboratory's brightness, we sealed the laboratory's door and windows with thick black plastic, and a 1.1 m^2 area was further isolated with black thick curtains to separate the bicycle from the electronic devices and experimenter. Furthermore, the lights of the electronic devices were covered with black fabric to block other light sources. In the illuminated-control condition the laboratory's lights were switched on to provide a set-up environment with a normal, constant light intensity of ≈224 lx and 10^{01} W/m^2 [9]. In contrast, the room's lights were switched off in the light-deprived condition, and a dark environment with ≈2 lx and 0^{01} W/m^2 was created. The overall perception was of complete darkness in the testing room, in the light-deprivation conditions.