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Conscious distance monitoring and perceived exertion in light-deprived cycling time trial

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HIGHLIGHTS

- According to the internal clock model, the distance monitoring and RPE are crucial for pacing regulation.
- Light deprivation impaired the conscious distance monitoring in 20 km cycling time trial ($TT_{20\ km}$).
- Light deprivation further increased the actual distance-RPE ratio.
- Cyclists focused less on body sensations during deprived ambient lighting.

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ABSTRACT

The monitoring of distance is crucial to calculate the metabolic requirement and the ratings of perceived exertion (RPE) for a given exercise bout. Visual cues provide valuable information for distance estimation, navigation and orientation. The present study investigated if light deprivation may affect the conscious monitoring of distance, RPE and associative thoughts to exercise (ATE) during a 20-km cycling time trial ($TT_{20\ km}$). Eleven male, endurance cyclists performed two $TT_{20\ km}$ in illuminated-control and light-deprived laboratory. They were asked to self-report RPE and ATE when they perceived they had completed each 2 km. *Results:* The light deprivation resulted in elongated perceived distance at each actual 2 km, rather than in illuminated-control trial ($P < 0.05$). Although there was no difference in RPE when it was plotted as a function of the perceived distance, RPE was lowered in light-deprived environment when it was plotted as a function of the actual distance ($P < 0.05$). Additionally, ATE was lowered during $TT_{20\ km}$ in light deprivation ($P < 0.01$); however, pacing and performance were unaffected in light-deprived environment. *Conclusion:* Results suggest that pacing and performance were regulated through a system which was unaffected in light-deprived environment, despite the altered conscious distance monitoring and perceptive responses.

1. Introduction

According to the original pacing algorithm model, two aspects are crucial for the pacing regulation during exercise [1]. First, the monitoring of distance is important to set the algorithm of pacing, as the brain cannot calculate the metabolic requirement for the remaining period of exercise if the time that has passed or the distance that has been covered is unknown [1,2]. This model assumes that the brain uses a subconscious, scalar internal clock to monitor the passage of time, thereby enabling the individual to consciously judge the remainder exercise bout. Importantly, time and distance have been interpreted interchangeably in this model [1,3], although this relationship may be asymmetric in real world situations [4].

The second important aspect for the pacing algorithm is the conscious awareness of fatigue sensation, as the ratings of perceived exertion (RPE) would be incorporated in the brain's pacing algorithm [1]. Although the interpretation of the RPE's role in pacing regulation has differed slightly between studies [5,6], it has been proposed that RPE increases in a scalar fashion during exercise, reaching maximal values only at the exercise endpoint [7]. The scalar internal time clock would monitor the time during exercise to set a pacing algorithm according to the RPE's increase, thus matching maximal RPE scores with the exercise endpoint [1]. Hence, a robust pacing algorithm would be set due to both conscious and subconscious mechanisms; the pacing set at the first trial would be refined during successive trials due to a greater reliance on the conscious perceived distance and RPE [8–10].

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Although several studies have evidenced the effectiveness of the pacing algorithm model, since the deception of distance elapsed or the manipulation of visual and auditory inputs affected neither pacing nor performance [11–13], a setup depriving ambient lighting may challenge this model and provide some insightful information to this topic. It has been well documented that the intensity of light may alter the activity in reticular formation, thereby modifying the cortical arousal and perception of time [14,15]. Therefore, the light deprivation could elongate the conscious perception of distance during exercise, presumably due to the down-regulated cortical activity triggered by a reduced brainstem reticular formation [16]. As a result of the elongated conscious perceived distance there may be a distortion of the actual distance-RPE ratio [17, 18], thus challenging the effectiveness of a pacing algorithm [1].

In contrast to the original internal clock model, which based most of the pacing responses on subconscious factors [1,19], recent models have suggested that pacing is either consciously regulated (exclusively) according to the individual's RPE [20], or guided by an affordance-based control [21]. In this regards, variations in pacing may result from the conscious desire to maintain the exercise intensity while tolerating sensations of fatigue [20], or from the actions when perceiving available possibilities in the environment [21]. Thus, a setup depriving ambient lighting may further provide insights into these pacing models [20–22], as it could alter the conscious distance monitoring and RPE, as well as the perception of affordances.

Regardless of the pacing model, effects of light deprivation may be particularly interesting to individuals attending nighttime cycling training and competitions. The RPE is a practical tool for training purposes [23], so that the rate of increase in RPE is usually used as an anchor for pacing strategy in different exercise modes [3,5]. Therefore, a likely impairment of the individual's conscious distance monitoring through an elongated time perception in light-deprived setup may result in distortion of the actual distance-RPE ratio, thereby limiting the use of RPE during nighttime cycling.

Additionally, a recent study showed that light-deprived setup speeded-up the RPE during a time-to-exhaustion exercise, due to an increased perception of body sensations in the darkness [24]. It was suggested that the increased emotional disturbance in light deprivation may have mediated reinvestments in the conscious control of movement, by increasing the focus on internal body sensations during exercise [24–26]. Given the relationship between focus on body sensations and RPE [1,27], the increased associative thoughts to exercise (ATE) in the darkness probably affected the rate of increase in RPE. However, if a light-deprived setup would also increase ATE and momentary RPE [24,27] in a self-paced cycling time trial still needs verification, as this light deprivation study used a controlled-pace exercise. A previous study [12] had investigated the darkness effects on pacing strategy and performance during a self-paced cycling time trial, however no measure of the conscious distance monitoring was addressed.

Therefore, the present study investigated if the conscious monitoring of distance and RPE would be altered when performing a cycling time trial in a light-deprived environment. We hypothesized that individuals would report elongated conscious distance, with a greater ATE and RPE when cycling in the light-deprived setup. As a result, we expected that pacing and performance were changed.

2. Materials and methods

2.1. Participants

Eleven male, experienced endurance cyclists (34.9 ± 5.1 years, 178.9 ± 5.3 cm, 76.3 ± 8.8 kg, VO_{2PEAK} of 56.2 ± 8.0 $mL \cdot kg^{-1} \cdot min^{-1}$ and W_{PEAK} of 366.5 ± 26.1 W), familiarized with 20-km cycling time trials ($TT_{20\ km}$), but unaccustomed to cycling in the dark environments, volunteered to take part in this study. They were informed about the experimental procedures, risks, and benefits before providing their written informed consent. This study, which conformed to the Declaration of Helsinki, was approved by our institutional Research Ethics Committee.

2.2. Design

During the first visit, cyclists completed a Physical Activity Readiness Questionnaire (PAR-Q), and were familiarized with procedures, equipment and scales. During the second visit cyclists performed a familiarization with the $TT_{20\ km}$, and during visits 3 and 4 they performed the $TT_{20\ km}$ in illuminated and light-deprived setups. Sessions 2, 3 and 4 were conducted after a washout interval between 3 and 7 days, and sessions 3 and 4 were performed in a counterbalanced order, after random allocation of participants. The cyclists were asked to refrain from consuming alcohol and caffeine during the 24 h before the procedures, and to avoid intense exercise for the 48 h before the procedures. All the $TT_{20\ km}$ were performed in a laboratory environment (~20 °C), at the same time of the day, on a bicycle (Giant®, USA) coupled with a cycle-simulator (CompuTrainer™ RacerMate® 8000, USA) calibrated before each test, according to manufacturer's instructions.

2.3. Familiarization with the $TT_{20\ km}$

Cyclists were accommodated on the bicycle and performed a standard 7-min warm-up, which consisted of a 5-min self-paced exercise (gear and cadence freely adjusted) and a 2-min controlled-pace exercise (fixed gear, power output at 100 W and cadence at 80 rpm). At the end of the warm-up period, when they were still cycling at 80 rpm, they began the $TT_{20\ km}$. Feedback of time and distance was available on the computer's monitor. Cyclists were instructed to pace themselves throughout the exercise bout, in order to finish the trial within the shortest possible time. Moreover, they were asked to self-report their RPE and ATE every 2 km. The familiarization session were conducted in a conventional laboratory illuminated with artificial light (≈225 lx and 10^{01} W/m^2).

2.4. Illuminated-control and light-deprived setups

The brightness was manipulated in order to set a complete darkness in the light-deprived condition, in contrast to the illuminated-control condition. The laboratory's door and windows were sealed with a thick black plastic, and the lights of the electronic devices were covered with black fabric to block any light sources. In addition, a 4 m^2 area was used to separate the participant from the electronic devices and experimenter, and this area was further isolated with black thick curtains. We obtained a dark environment with ≈2 lx and 0^{01} W/m^2 when the room's lights were switched off in the light-deprived condition. In contrast, the laboratory's lights were switched on in the illuminated-control condition, creating a setup with normal, constant light intensity of ≈225 lx and 10^{01} W/m^2 [28]. Although the brightness of ≈2 lx and 0^{01} W/m^2, the overall perception was of complete darkness in the testing room in the light-deprived setup, in contrast to a typical laboratory environment in the control setup. Importantly, we used a testing room with a ≈2 lx and 0^{01} W/m^2 brightness in order to potentiate the effects of light deprivation, agreeing with previous studies [12,24].

After being accommodated on the bicycle, a 2-min habituation period was performed with the room's lights switched on in the control, and with lights switched off in the light deprivation. Then, cyclists warmed-up for 7 min, as performed in the familiarization session, and then they immediately started the $TT_{20\ km}$. Before the trials, cyclists were encouraged to complete the $TT_{20\ km}$ as fast as possible in both the environments, but no verbal encouragement was provided during the trials. No recommendation to maintain the pacing strategy used in the familiarization $TT_{20\ km}$ was given, so that they were free to pace themselves throughout the trials. No distance feedback, time cues or information about performance was provided in these conditions, but the participants knew that all trials would finish at the actual 20th km. Cyclists