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The behavior of an opponent alters pacing decisions in 4-km cycling time trials

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HIGHLIGHTS

- The opponent's behavior alters an athlete's pacing in lab-controlled conditions.
- A faster starting opponent evokes a faster start compared to a slower starting one.
- The opponent is an important, but often overlooked determinant for pacing decisions.

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ABSTRACT

Introduction: The present study aimed to explore how athletes respond to different behaviors of their opponents.
Methods: Twelve moderately to highly physically active participants with at least two years of cycling experience completed four 4-km time trials on a Velotron cycle ergometer. After a familiarization time trial (FAM), participants performed three experimental time trials in randomized order with no opponent (NO), a virtual opponent who started slower and finished faster compared to FAM (OP-SLOWFAST), or a virtual opponent who started faster and finished slower compared to FAM (OP-FASTSLOW). Repeated-measures ANOVAs ($P < 0.05$) were used to examine differences in pacing and performance related to power output, velocity and RPE.
Results: OP-SLOWFAST and OP-FASTSLOW were completed faster compared to NO (385.5 ± 27.5, 385.0 ± 28.6, and 390.6 ± 29.3 s, respectively). An interaction effect for condition × distance ($F = 3.944$, $P < 0.001$) indicated differences in pacing profiles between conditions. Post-hoc analysis revealed that a less aggressive starting strategy was adopted in NO compared to OP-FASTSLOW and OP-SLOWFAST during the initial 1000 m. Finally, a faster starting opponent evokes higher power outputs by the participants in the initial 750 m compared to a slower starting opponent.
Conclusion: The present study is the first to show that the behavior of an opponent affects pacing-related decisions in laboratory-controlled conditions. Our findings support the recently proposed interdependence of perception and action, and emphasize the interaction with the environment as an important determinant for an athlete's pacing decisions, especially during the initial stages of a race.

1. Introduction

Pacing has been defined as the goal-directed regulation of exercise intensity over an exercise bout [1], in which athletes need to decide how and when to invest their energy [2]. Recent theoretical frameworks from both heuristic [3] and ecological [2] perspectives emphasized that pacing is a decision-making process in which interaction with the environment is a crucial determinant for the regulation of the exercise intensity. That is, in addition to internal characteristics such as perceived fatigue, athletes may decide to alter their pacing behavior based on environmental characteristics [2] such as drafting possibilities or expectations or actions of the opponents' behaviors affecting winning chances.

Even though some form of interpersonal competition is indispensable in every (elite) sport, research about the exact influence of different opponents on pacing behavior, tactics, decision-making and performance of athletes is still limited. A better understanding of how athletes respond to their opponents could assist coaches and athletes to optimally prepare themselves for the tactical decision-making involved in athletic competitions [2,3]. The relatively controlled and simplified situation of cycling a time trial against a competing opponent while monitoring pacing behavior can provide new insights in how exercisers regulate their exercise intensity, supporting the suggestion that not only internal, but also external information is incorporated in the decision at what intensity to exercise [2]. A better understanding of the decision-

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making process involved in pacing behavior could even contribute to our general understanding of the way people pace their activities in daily life or how exercise intensity is regulated when achieving demanding goals in a rehabilitation context [4].

Previous research has explored the effect of an opponent on pacing and performance, and reported a positive effect of the presence of a direct opponent on performance [5–11]. In addition, the performance enhancement when an opponent is present appeared to be independent of the performance of the opponent [11]. On the other hand, it is still unclear if every competitor evokes a similar behavioral response or whether different behavior of the opponents might alter the decisions of the competing athlete. By manipulating the pacing strategy of a virtual opponent, the present study explored how exercisers responded to different opponents in a well-controlled, experimental setting. It is hypothesized that exercisers adapt their pacing behavior and decision-making regarding the regulation of exercise intensity over the race based on the strategy employed by the opponent. We expect that a faster or slower starting opponent will invite exercisers to adopt a respectively faster or slower starting pacing strategy, mirroring the behavior of the opponent. This will provide support for the notion that there is an interdependence of perception and action when regulating exercise intensities in competitive situations, which will emphasize the interaction with the environment as a crucial, but often overlooked determinant for an athlete's decisions regarding the regulation of exercise intensity.

2. Materials and methods

2.1. Participants

Twelve participants with at least two years of cycling experience (age: 25.8 ± 9.5 years; body mass: 74.2 ± 10.8 kg; height: 176.2 ± 6.4 cm) participated in this study. All participants were moderate to highly physically active (two or more moderate to high-intensity training sessions per week), familiar to pacing their exercise, and were able to complete a 4-km cycling time-trial within seven minutes. Before participating all participants gave written informed consent and completed a health screening questionnaire (Physical Activity Readiness Questionnaire; [12]. The study was approved by the university's local ethical committee in accordance to the Declaration of Helsinki.

2.2. Experimental procedures

Participants completed four 4-km cycling time trials. They were allowed to perform a 5-min self-paced warm-up of low to moderate intensity, followed by a 5-min inactive recovery period before starting the time trials. To control for warm-up intensity, participants were asked to exercise at an intensity similar to previous visits. The first time trial was always a familiarization trial (FAM). Hereafter, participants completed one time trial without opponent (NO) and two time trials with an opponent (OP-FASTSLOW and OP-SLOWFAST) in a random order.

Two opponents (OP-SLOWFAST and OP-FASTSLOW, respectively) were constructed for each participant using different pacing profiles compared to the participant in his FAM in order to explore how athletes respond to different opponents. OP-FASTSLOW adopted a faster pace (+3% compared to FAM) between 250 m–2000 m, followed by a slower pace (−1% compared to FAM) between 2000 m–3750 m. In contrast, OP-SLOWFAST adopted a slower pace (−1% compared to FAM) between 250 m–2000 m, followed by a faster pace (+3% compared to FAM) between 2000 m–3750 m. Both opponents adopted a velocity in the first and last 250 m that was 1% faster compared to the participants' FAM in order to match the start and end spurt of the participants. This was done to increase the participant's perception of the opponent as a realistic competitor of a level of performance within reach of the participant. Based on an expected performance improvement of 1% after FAM [8,13], the pacing profiles of the both opponents were constructed to a finishing time 1% faster compared to FAM. Although the pacing strategies differed between the opponent conditions, the finishing time of the opponent was for both opponent conditions exactly the same. Accuracy of the "constructed opponents" compared to the "calculated opponent" has been determined. If an error of more than 1 s was found, the trial was repeated until an acceptable error was achieved. The mean error was 0.39 ± 0.18 s, with a maximal error of 0.76 s.

Before every time trial, participants were instructed to perform optimally and give maximal effort. No verbal coaching or motivation was given to the participants during any of the trials. In order to simulate real competitive situations, participants were shown a leader board before the start of the virtual opponent trials on which they could compare their ranked previous performances to other (anonymous) participants. A "ghost" rider was added to the first and last positions on the chart, so that also the fastest and slowest rider believed that there was respectively a rider ranked closely ahead or behind them, who would be competitive for him as opponent [14]. In addition, participants were told that their opponent would be of similar level of performance in order to stimulate the participant to perceive the virtual opponent as a realistic and competitive one.

Time-trials were completed at the same time of the day (±2 h), and the same day of the week to minimize circadian variation [15,16]. Participants were asked to maintain normal activity and sleep pattern throughout the testing period. In addition, participants were asked to refrain from any strenuous exercise and alcohol consumption in the preceding 24 h, and from caffeine and food consumption respectively, 4 and 2 h before the start of the test. Participants were informed that the study was examining the influence of external factors on performance during cycling time trials. To prevent any pre-meditated influence on preparation or pre-exercise state, the specific feedback presented for each trial was only revealed immediately before the start of the time trial. All trials were conducted in ambient temperatures between 18 and 21 °C.

2.3. Apparatus

Time trials were performed on acycle ergometer (Velotron Dynafit, Racermate, Seattle, USA) that has been shown to be a reliable and valid tool to measure cycling performance and pacing behavior [17–19]. Using the Velotron 3D software, a straight and flat 4-km time trial course with no wind was programmed and projected onto a screen for all trials. During the time trials only relative distance feedback was provided. In the opponent conditions, a virtual opponent was projected. Participants started every trial in the same gear, but were free to change their gear ratio throughout the time trial. Power output, velocity, distance, cadence, and gearing were monitored continuously during each trial (sample frequency = 4 Hz). Rate of perceived exertion (RPE) on a Borg-scale of 6–20 [20] was asked after the warm-up, before the start of the time trial, at three random points during the time trial, and directly after passing the finish line.

2.4. Data analysis

Mean power output, velocity, cadence, and finish time were calculated in order to examine performance. Differences in performance between conditions were assessed using a repeated-measures ANOVA. During each time trial, RPE was asked at three random moments. Before statistical analyses on RPE were performed, we calculated whether these moments were, on average, asked at similar points during the race for every condition using a One-Way ANOVA. To assess differences in pacing behavior between the conditions, average power output, cadence, and split times for each 250 m segment were calculated, and differences were tested using a two-way repeated-measures ANOVA (conditions × distance). Post-hoc tests with Bonferroni correction were performed when significant results were found. All analyses