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Effect of Unaware Clock Manipulation on Pacing Strategy and Performance in Recreational Athletes

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Featured Application: This is the first study to perform different analyses on runners in a closed-loop exercise to understand and clarify time manipulation on performance and pacing strategy in runners. Gaining knowledge of time manipulation relative to running environment is important for applied practitioners, particularly when attempting to understand pacing strategies and optimize performance. In this context, our study has reported that time manipulation might create different time perfections affecting performance and pacing strategy. For instance, applying time manipulation (modified chronometer) during training sessions could possibly convince athletes to train for longer periods than expected. In addition, the use of this manipulation could generate different time perceptions, in which athletes during time manipulation exercises would start to feel the exercise is "easier" or "harder" than expected. Thus, our study provided some indications on how time manipulation could be applied in training settings, showing different perspectives of the modified chronometer. Future research identifying the energy expenditure and analyzing the neuromuscular system in time manipulation methods will help to understand how fatigue could affect performance and pacing strategy in runners.

Abstract: It is unclear how athletes regulate their performance prior and during exercise when deceptive methods are applied. Therefore, the aim of this study was to test if time manipulation can influence pacing strategy and running performance. Ten recreationally active subjects were informed they would complete four 60-min time trials only with time feedback. The first session was a familiarization trial (60-min), and in the following three sessions, the time feedback was modified: normal chronometer (NC—60 min.), 10% faster (Faster chronometer—FC—54 min.), and 10% slower (slower chronometer—SC—66 min.). Total distance was different between conditions, while average of total speed, Heart Rate, oxygen consumption, and Rate of Perceived Exertion were similar ($p > 0.05$). A slow start pacing strategy was adopted in all conditions and did not differ between conditions when averaged across the session; however, when analyzing the first and final 10 min of the session, differences were found between conditions. Finally, the observed time was an important determinant of the regulation of exercise intensity, because, although the pacing strategy adopted in all conditions was regulated according to previous exercise information, adjustments were made in the initial (NC) and final (FC) phases of the trials.

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1. Introduction

It has been proposed that athletes set their pacing strategy in an anticipatory manner but continue to make adjustments during exercise so as to achieve their best performances [1]. This self-regulation is hypothesized to be based on information about the exercise, which is then used to prevent severe disturbances to homeostasis and to achieve an optimal performance [2–6]. Related to this is the concept of teleoanticipation, which states that athletes combine multiple sources of information about the exercise (e.g., endpoint, previous experience, external environmental conditions, energetic reserves, and metabolic conditions) to calculate how much energy they need to finish the exercise without harming the physiological systems and to devise an exercise strategy that will optimize performance [2,3,5–9].

Studies manipulating the information athletes receive about the exercise they are performing have been conducted to better understand how pacing and performance are regulated [1,10]. Among the many deception methods, exercise endpoint and time manipulation have been observed to influence physiological responses, performance, and pacing strategy [7,11–18]. When false endpoint expectations are given, studies reported that physiological responses, average power, and pacing strategy were similar between trials, while performance (total time) was different [15,16]. These authors stated that participants selected their pacing strategy based on the perceived distance of a trial rather than the actual distance. Using a similar methodology, one study found that the performance is downregulated when the perceived distance does not meet the actual distance [19], while another study demonstrated that the participants selected their pacing strategy according to their perceived effort [17]. Moreover, when the information about activity is not given during the exercise, the performance was reduced with a slower pacing strategy in comparison with the given information [20]. In contrast, when time was manipulated (modified chronometer) and actual time was slower than expected by the volunteers, participants increased their efforts, affecting both performance and pacing strategy [14,18].

Most of the findings in these previous studies are based on exercise in cyclists. Few studies are based on endurance runners [12,13], and only one study (in cyclists) applied the chronometer manipulation methodology in a closed-loop exercise [18]. Furthermore, physiological differences between running and cycling, together with terrain characteristics and the relationship between exercise duration and strength, may influence pacing differently in those exercise modes [21–23]. Therefore, it is still not clear how time manipulation, leading to different exercise endpoints, might affect physiological responses, exercise regulation, and performance in runners. To the best of our knowledge, this is the first study to apply chronometer alteration methodology in runners during a closed-loop activity. Given that training sessions are usually a closed loop exercises and time is often the tool use to control exercise duration [24], we believe that this study will contribute to the understanding of the time manipulation exercise responses to improve training models and to achieve the best of the athlete's performance. The aim of this study was to investigate if recreationally active subjects' given incorrect/correct information about the time, leading to different exercise endpoints (54, 60, or 66 min of exercise), would alter their pacing strategy, performance, and physiological responses. We hypothesized that the time information given about the exercise (regardless of the chronometer alterations) might influence the teleoantecipation process and result in similar physiological responses and pacing strategies, but different results for distance completed due to the different endpoints.

2. Materials and Methods

The Material and Methods is presented in five different topics: Participants, Overview, Maximal Aerobic Test, 60-min run protocol, and Statistics.

2.1. Participants

Ten recreationally active subjects (men, 31 ± 3 years old, mass = 75.8 ± 7.7 kg, height = 1.76 ± 0.02 m, body fat = 11.9 ± 4.5%, VO2max (maximal oxygen consumption) = 51.7 ± 4.6 mL·kg^{-1}·min^{-1}, HRmax (maximal Heart Rate) = 181 ± 5 bpm), with a minimum of one year of endurance training, who were running at least three times and 20 to 50 km per week, volunteered for this study. The participants signed an informed consent form. The research was approved by the local ethics committee (CAAE: 43514315.1.0000.5257) and performed in accordance with the ethical standards of the Helsinki Declaration. The study was a randomized cross-over clinical trial where neither the participants nor the researcher that monitored the tests knew the time alteration in each test (double-blinded).

2.2. Overview

All participants visited the laboratory five times (five tests) with seven to ten days between each visit, at the same time of day. Participants were requested not to ingest any food for 3 h before each visit and not to do any exercise, or consume caffeine, alcohol, energy drinks, or any other stimulant, twenty-four hours before each test. The protocol is similar to one previously described in the literature [18]. On the first visit, anthropometric measures and a maximal aerobic test were performed to assess the fitness level of each participant. During the following four visits, the participants performed a maximal effort run and the only information provided during the run was the time (a chronometer in front of a treadmill). In the second visit, the participants were familiarized with the 60-minute protocol using a normal chronometer (maximal effort). During the next three visits, and in a randomized order, the participants ran their maximal effort with a normal chronometer (NC; 60 s = 60 s) or with a modified chronometer that was 10% faster (Faster chronometer—FC; 60 s = 54 s) or 10% slower (Slower chronometer—SC; 60 s = 66 s) [14]. The participants did not know about the chronometer alterations, which were shown to them as a regular clock starting from 0 and finishing at 60 min, and they were informed that the purpose of the study was to verify the maximal VO_2 (oxygen consumption) during the trials.

2.3. Maximal Aerobic Test Protocol

Prior to the maximal aerobic test, the participants completed a 4-min warm up on a treadmill with a 5.2% incline (constant inclination until the end of the maximal test) and a starting speed of 6 km/h. The speed increased 0.5 km/h each minute, and then the maximal test started with a velocity of 8 or 9 km/h (depending on the total distance ran (training volume) in the last four weeks prior the test—8 km/h for up to 140 km and 9 km/h for more than 140 km). The speed was increased 1 km/h every 3 min until the participants reached 85% of their predicted maximum heart rate (HRmax) [25]. After that, the speed increment was 0.5 km/h every 3 min until exhaustion [26–28]. The participants wore a mask, and the expired air was analyzed by an automatic system (Vista Mini-CPX, Vacumed®, Ventura, CA, USA) using a 20-s time average to determine the peak oxygen uptake. The system was calibrated prior to every test using a 3-L syringe for volume calibration, as well as a gas cylinder (16% O_2 (oxygen); 4.1% CO_2 (carbon dioxide)) and an ambient air measurement in accordance with the manufacturer's guidelines [29]. The test was considered maximal and stopped when at least three of the following criteria were observed: (a) a VO_2 plateau (increase $\leq$ 150 mL·min $^{-1}$ or 2 mL·kg^{-1}·min $^{-1}$); (b) a respiratory exchange ratio (RER) $\geq$ 1.15; (c) 90% of the predicted HRmax; (d) a Rate of Perceived Exertion—RPE (Borg scale) $\geq$ 19 (6–20); (e) the participant was unable to maintain the required pace. The VO_2 was calculated as the average of the five highest values recorded during the final three stages of the test [30].

2.4. 60-Min Run Protocol

The total run time was manipulated by a modified chronometer. The participants were informed that they would complete a self-paced run for 60 min, with elapsed time as the only information provided to them (a chronometer in front of them). Participants were instructed to perform a maximal effort and to complete the greatest distance possible with the maximal intensity possible. Independent of the chronometer calibration, they all started at 0 and finished at 60 min (as observed on the chronometer in front of them). This information was revealed to the participants when they finished all tests. During the treadmill tests, the participant controlled their running intensity by changing the speed via a voice or gestural command to the evaluator. There was a constant gradient during all tests of 2%. The test was discontinued as soon as the participants had completed the "60 min" shown on the chronometer.

The pace (m/s—electronic monitor—Inbramed treadmill, São Paulo, Brazil), distance (km—electronic monitor—Inbramed treadmill, São Paulo, Brazil), and Heart Rate (HR) (Polar® S810 Heart Rate Monitor, Kempele, Oulu, Finland) were collected every 54 s in the FC, every 60 s in the NC, and every 66 s in the SC. In other words, these data were collected every minute shown as by the chronometer to the volunteers, in minutes 1, 2, 3, etc., until the 60th minute (observed time (OT) by the participants). Oxygen consumptions were sampled online in breath-by-breath mode and averaged every 20 s using TurboFit 5.1 software (Vista Mini-CPX, Vacumed®, Ventura, CA, USA). The RPE (Borg scale—6 to 20) was collected every 3 min at the observed time (OT) by the participants (every 162 s in the FC, every 180 s in the NC, and every 198 s in the SC) (see Figure 1A).

2.5. Statistical Analysis

The statistical treatment was performed using the Statistical Package for Social Sciences® (SPSS® Inc., Chicago, IL, USA), SigmaPlot® (Systat® Software Inc., Chicago, IL, USA), and Microsoft Excel® for Windows® (Microsoft®, Redmond, Washington, DC, USA). The descriptive statistics used were mean $\pm$ standard deviation (SD), and the normality of the data was investigated using the Shapiro–Wilk test. For the RPE analysis, a non-parametric statistic was used (the Friedman test, and the Wilcoxon test for the multiple post hoc comparisons between the treatments). The effect size (d) was calculated as proposed by Cohen [31].

Four types of analyses were performed: an overall analysis, two partial analyses comparing the three conditions (slower chronometer—SC, normal chronometer—NC, and faster chronometer—FC), and a last 10-min analysis (L10). The overall analysis compared the means for HR, VO_2, speed, and RPE, as well as total distance, between the conditions. The partial analyses compared the average of the data collected for these same variables mentioned above every 10 min. The first partial analysis was based on the data from every 10-min period of the real time (RT), and the second partial analysis was based on the information from every 10-min period of the observed time (OT) (see Figure 1). For the OT analysis, the data from all variables were collected for every 9-min period in the FC, every 10-min period in the NC, and every 11-min period in the SC (or every 10-min period at the observed time—OT1, OT2, OT3, OT4, OT5, OT6) and compared between conditions (see Figure 1B). The L10 analysis compare the average of HR, VO2, speed, distance, and RPE of the last 10 min of real time for each condition (45 to 54 min for FC, 51 to 60 min for NC, and 57 to 66 min for SC—see Figure 1B).

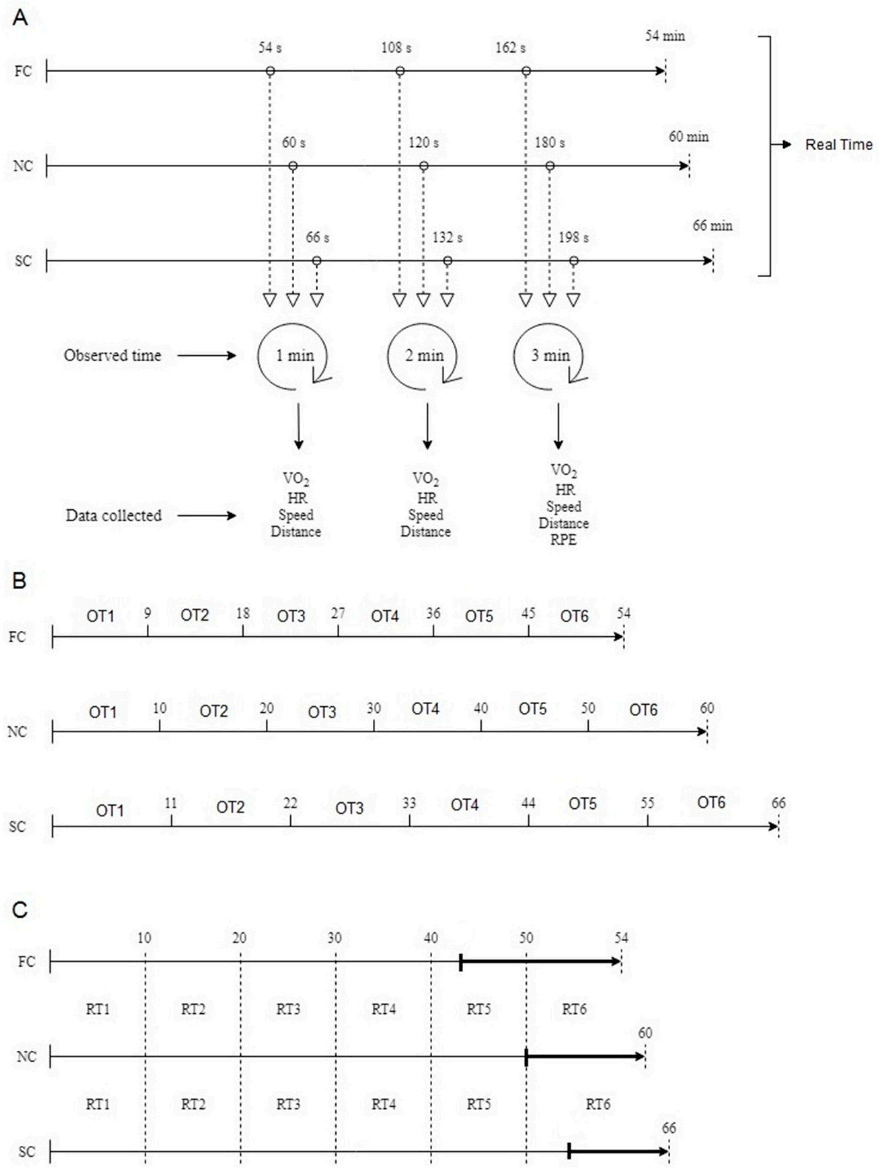

Figure 1. Representation of the first 3 min of each test (**A**), of the observed time (**B**), and of the real time (**C**) analyses. The bold arrows in 1C indicate the last 10 min of each condition. (**A**) Description of the real time, the time observed by the participants at the real time, and when data were collected for the first 3 min in each chronometer condition (Faster Chronometer—FC, Normal Chronometer—NC, and Slower Chronometer—SC). This pattern continues until the end of each test. HR = Heart Rate, VO2 = Oxygen Consumption, RPE = Rate of Perceived Exertion. (**B**) With respect to the real time, data were collected every 9 min in the FC, every 10 min in the NC, and every 11 min in the SC (OT1, OT2, OT3, OT4, OT5, OT6). (**C**) Data collected in every 10-min period of the real time (RT1, RT2, RT3, RT4, RT5) and in the final time period for each chronometer condition (RT6: FC = 4 min, NC = 10 min, and SC = 16 min). The thicker arrow in each condition indicates the last 10 min of the real time (i.e., L10).

For the overall and L10 analyses, one-way Analysis of Variance (ANOVA) for repeated measures were applied to compare each dependent variable in the three conditions (slower, normal, and faster chronometer). For both partial analyses, two-way ANOVA (3 conditions—slower, normal, and faster × 6 times—RT1, RT2, RT3, RT4, RT5, and RT6 for RT analysis, and 3 conditions × OT1, OT2, OT3, OT4, OT5, and OT6 for the OT analysis) with repeated measurements were used to identify interactions. If an interaction was observed, a one-way ANOVA was applied for each time (RT: RT1, RT2, RT3, RT4, RT5, RT6 and OT: OT1, OT2, OT3, OT4, OT5, OT6) to determine if there was a significant difference between groups at that time. The Bonferroni post hoc test was used to locate the differences. The Mauchly's W sphericity test was applied in addition to the Greenhouse–Geisser correction for ANOVA repeated measures. The level of significance was set at $p \leq 0.05$.

3. Results

The results were divided into the four different analyses: Overall, Real Time (RT), Observed Time (OT), and Last 10 min (L10).

3.1. Overall Analysis

In this analysis, there were significant differences for total distance between the three conditions ($F(2, 18) = 130.341$, $p < 0.001$ and $d > 0.75$ for all comparisons), but no significant differences for HR, VO2, RPE, and speed ($p > 0.05$ and $d < 0.38$) (see Table 1).

Table 1. Overall and Last 10 min (L10) analyses.

Analysis	Chronometer	HR (bpm)	VO_2 (mL/kg/min)	RPE (6 to 20 Borg Scale)	Speed (m/min)	Distance (km)
Overall	Faster	157 ± 8	43.1 ± 5.0	14 ± 2	191.7 ± 16.7	10.3 ± 0.9 [a]
	Normal	159 ± 9	42.5 ± 5.0	14 ± 1	191.5 ± 18.3	11.5 ± 1.1 [a]
	Slower	156 ± 7	42.4 ± 4.5	14 ± 2	188.3 ± 20.0	12.4 ± 1.3 [a]
L10	Faster	169 ± 7	46.8 ± 6.7	17 ± 2	206.7 ± 18.3 [b]	2.06 ± 0.18 [b]
	Normal	169 ± 7	44.9 ± 5.7	17 ± 2	201.7 ± 23.3	2.02 ± 0.23
	Slower	166 ± 7	46.1 ±5.8	17 ± 2	198.3 ± 20.0 [b]	1.96 ± 0.20 [b]

Notes: Values are mean ± SD for each variable (except for distance, which is the total in each condition for overall analysis and the total of the last 10 min in each condition for L10 analysis). [a] significant difference between all three conditions. $p < 0.001$ and $d > 0.75$. [b] significant difference between Faster and Slower Chronometers. $p = 0.003$ and $d > 0.40$.

3.2. Real Time (RT) Analysis

In the RT analysis, there were significant condition-by-time interactions for distance ($F(10, 90) = 340.681$, $p < 0.001$), speed ($F(10, 90) = 3.342$, $p = 0.022$), and HR ($F(10, 90) = 3.052$, $p = 0.002$), but not VO2 ($F(10, 90) = 2.667$, $p = 0.054$) (see Figure 2B, Figure 3B, Figure 4B,D and Figure 5B). The following is a description of the results for each variable in this analysis.

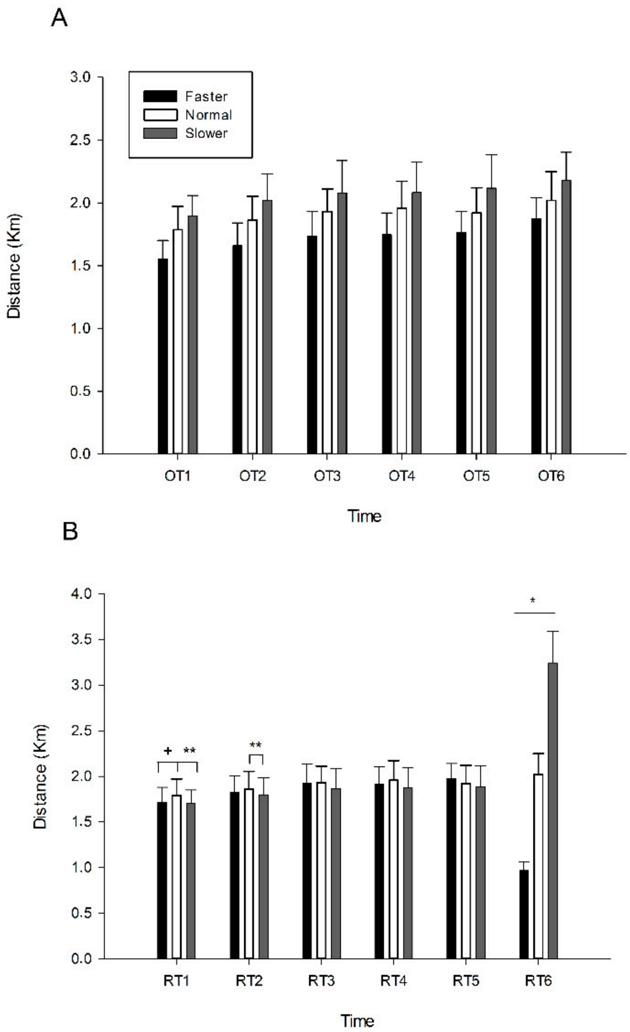

Figure 2. Distance (km) in the (**A**) observed Time (OT) and (**B**) real time (RT) analysis. Mean (±SD) data for distance for each condition with respect to (**A**) OT (every 10-min period of the observed time and (**B**) RT (every 10-min period of the real time). Notes: * Significant differences between the three conditions, ($p < 0.001$) for all comparisons. + Significant differences between NC and FC ($p = 0.026$) in T1. ** Significant differences between NC and SC in T1 ($p = 0.046$) and T2 ($p = 0.032$).

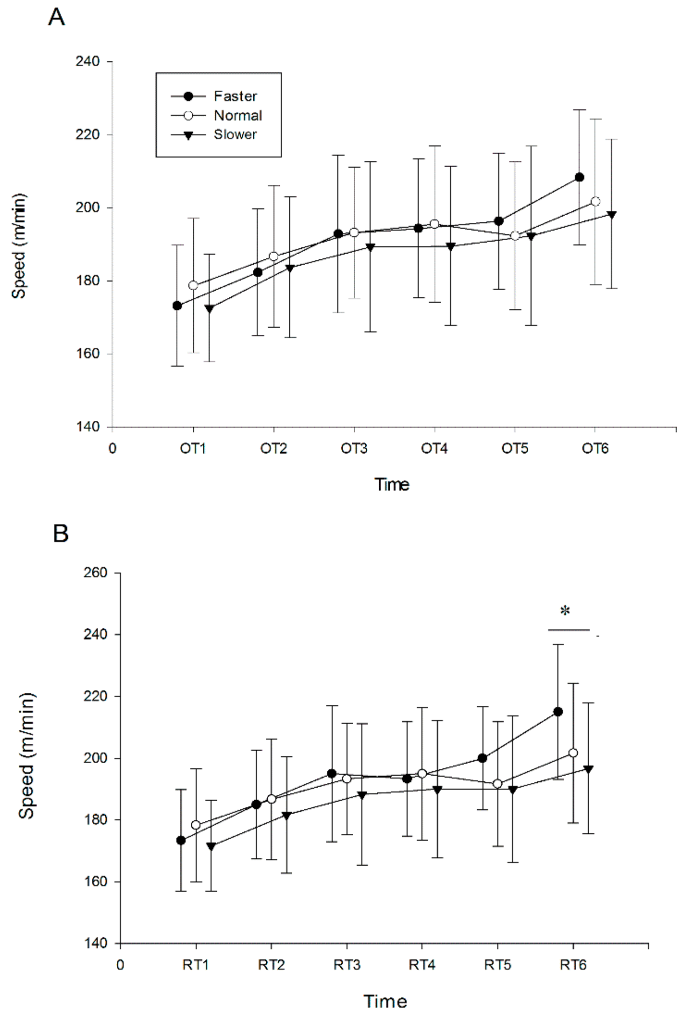

Figure 3. Speed (m/min) in the (**A**) observed Time (OT) and (**B**) real time (RT) analysis. Mean (±SD) data for speed for each condition with respect to (**A**) OT (every 10-min period of the observed time) and (**B**) RT (every 10-min period of the real time). Notes: * Significant differences between FC and both NC and SC.

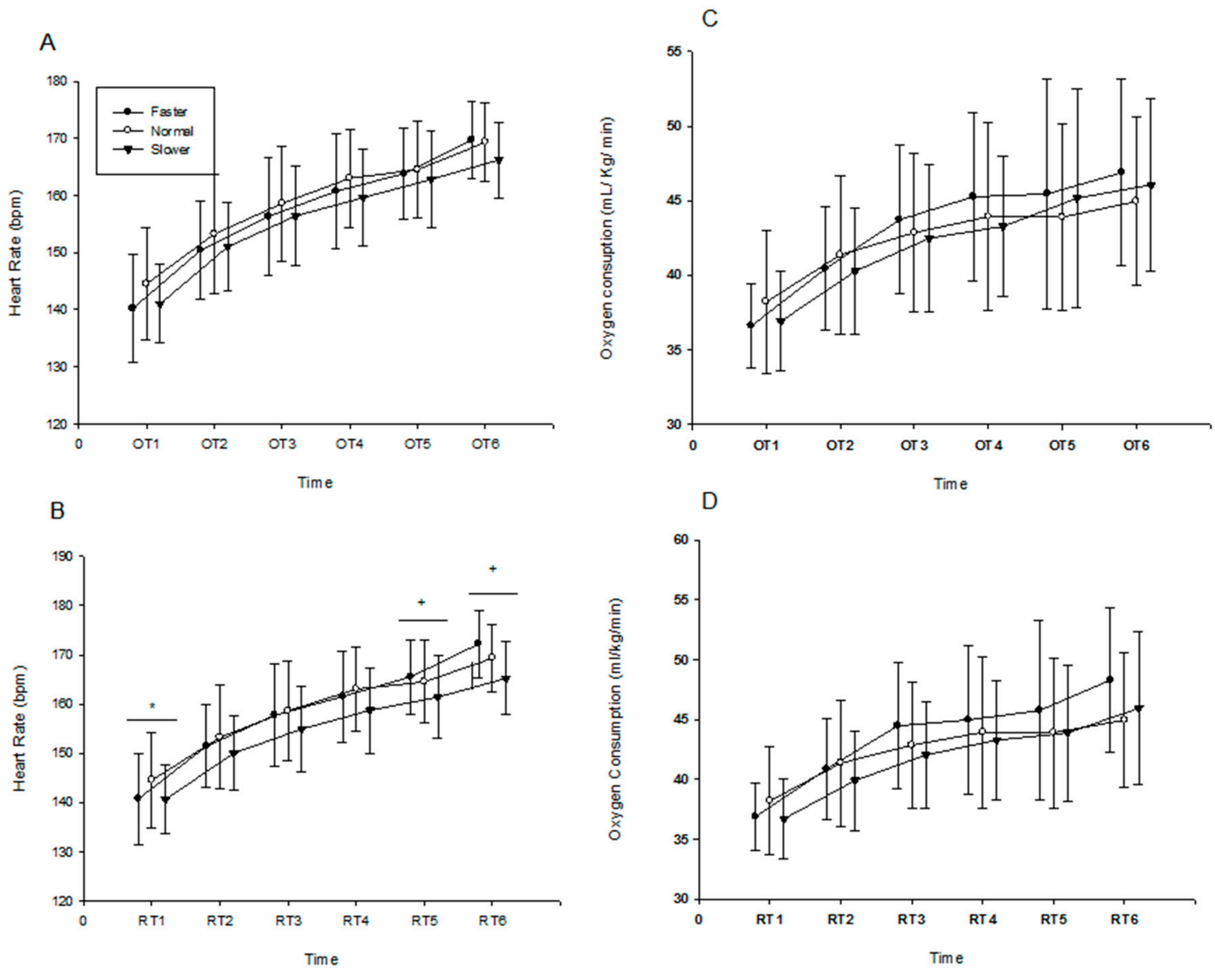

Figure 4. Physiological variables. Heart Rate (bpm) in the (**A**) observed Time (OT) and (**B**) real time (RT) analysis. Mean (±SD) data for heart rate for each condition with respect to (**A**) OT (every 10-min period of the observed time) and (**B**) RT (every 10-min period of the real time). Notes: * Significant differences between NC and both FC (p = 0.032) and SC (p = 0.043). + Significant differences between FC and SC, in T5 (p = 0.043) and in T6 (p = 0.004). Oxygen Consumption (ml/kg/min) in the (**C**) observed Time (OT) and (**D**) real time (RT) analysis. Mean (±SD) data for oxygen consumption for each condition with respect to (**C**) OT (every 10-min period of the observed time), and (**D**) RT (every 10-min period of the real time).

3.2.1. Distance

There were significant differences between conditions at RT1 (F(2, 18) = 6.144, p = 0.009), RT2 (F(2, 18) = 6.149, p = 0.009), and RT6 (F(2, 18) = 589.535, p < 0.001). The NC (distance = 1.79 ± 0.18 km) was greater than the FC (distance = 1.72 ± 0.16 km, p = 0.026, d = 0.41) and the SC (distance = 1.71 ± 0.14 km, p = 0.046, d = 0.50) for RT1. In RT2, NC values (distance = 1.86 ± 0.19 km) were higher than the SC (distance = 1.80 ± 0.19 km, p = 0.032, d = 0.32). In RT6, significant differences were found between all three conditions (FC = 0.97 ± 0.10 km, NC = 2.02 ± 0.23 km, SC = 3.24 ± 0.35 km, p < 0.001, d > 1.0) for all comparisons (see Figure 2B).

3.2.2. Speed

There were significant differences between the conditions only at RT6 (F(2, 18) = 14.137, p < 0.001). The speed was 8.5% faster in the FC (Velocity = 215.0 ± 21.7 m.min^{-1}) than in the SC (Velocity = 196.7 ± 21.7 m.min^{-1}, p = 0.002, d = 0.85) and 6.2% faster than in the NC (Velocity = 201.7 ± 23.3 m.min^{-1}, p = 0.005, d = 0.60; see Figure 3B).

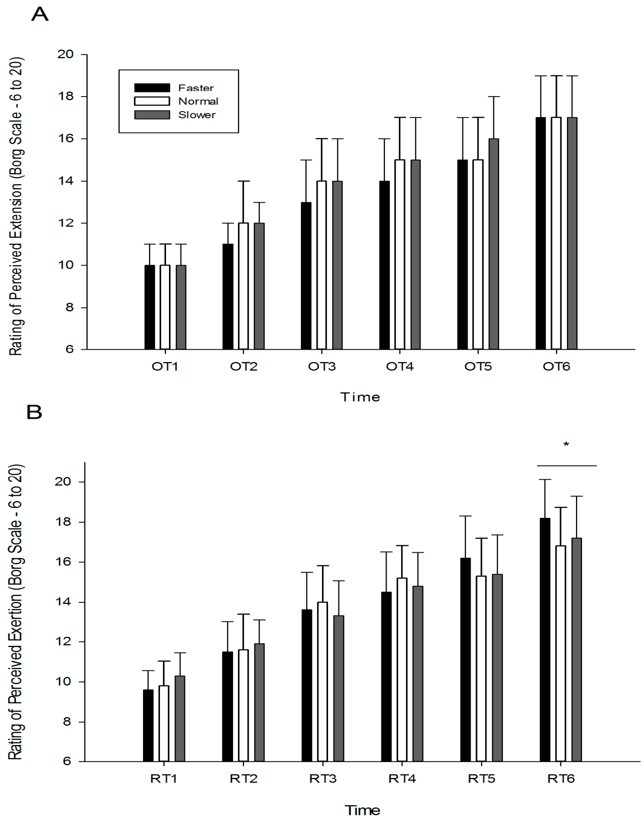

Figure 5. RPE (Borg scale 6 to 20) in the (**A**) observed time (OT) and (**B**) real time (RT) analysis. Mean (±SD) data for RPE for each condition with respect to (**A**) OT (every 10-min period of the observed time) and (**B**) RT (every 10-min period of the real time). Notes: * Significant differences between FC (18) and both NC (17) (p = 0.030) and SC (17), p = 0.015.

3.2.3. Heart Rate

Differences were found at RT1 (F(2, 18) = 5.914, p = 0.011), RT5 (F(2, 18) = 4.693, p = 0.023), and RT6 (F(2, 18) = 11.442, p = 0.001) between conditions. Higher HR values were observed in the NC (145 ± 10 bpm) compared to the FC (141 ± 9 bpm, p = 0.032, d = 0.42) and the SC (141 ± 7 bpm, p = 0.043, d = 0.46) at RT1. At RT5 and RT6, significantly higher values were observed in the FC (RT5, HR = 166 ± 8 bpm, p = 0.043, d = 0.63 and RT6, HR = 172 ± 7 bpm, p = 0.004, d = 1) than in the SC (RT5, HR = 161 ± 8 bpm, and RT6, HR = 165 ± 7 bpm) (see Figure 4B).

3.2.4. RPE

The only significant differences between conditions were in RT6 (p = 0.005), with higher RPE values in the FC (18 ± 2) compared with the other two conditions (NC—17 ± 2, p = 0.030, d = 0.50, and SC—17 ± 2, p = 0.015, d = 0.50; see Figure 5B).

3.3. Observed Time (OT) Analysis

In the OT analysis, there were no significant interactions between condition and time for distance (F(10, 90) = 0.947, p = 0.449), speed (F(10, 90) = 1.766, p = 0.078), HR (F(10, 90) = 1.613, p = 0.199), or VO2 (F(10, 90) = 2.542, p = 0.067) (see Figure 2A, Figure 3A, Figure 4A,C and Figure 5A). However, there was a main effect of time for all variables (VO2, F(5, 45) = 18.391, p < 0.001; distance, F(5, 45) = 14.878, p < 0.001; speed, F(5, 45) = 15.683, p < 0.001; HR, F(5, 45) = 98.880, p < 0.001). In addition, there was a main effect of condition for distance (F(2, 18) = 134.821, p < 0.001).

3.4. Last 10 Min

In L10, there were significant differences for distance (F(2, 18) = 4.276, p = 0.030) and speed (F(2, 18) = 4.167, p = 0.033) when conditions were compared. There were no significant differences for HR (F(2, 18) = 2.495, p = 0.123), VO_2 (F(2, 18) = 1.139, p = 0.337), and RPE (p = 0.163) between conditions (see Table 1).

4. Discussion

The aim of this study was to investigate if recreationally active subjects, when given incorrect information about time, leading to different exercise endpoints (54, 60, or 66 min of exercise), would alter their pacing strategy and performance. It was hypothesized that the time information given about the exercise (regardless of the chronometer alterations) might influence the teleoantecipation process, and result in similar physiological responses and pacing strategies, but different results for distance completed due to the different endpoints. To test this hypothesis, recreationally active subjects performed three treadmill running tests with three different time manipulations (without knowledge of this manipulation). The only overall difference between conditions was the total distance completed. Pacing strategy and physiological responses were similar between conditions, but in the final minutes FC adjustments were made to reach a maximal effort, and greater distance and speed were observed when compared with both the normal and slow conditions.

4.1. Overall Performance

The first finding was that the total distance completed by the participants was different between the three conditions. As the conditions had different finishing times and similar average speeds, it was expected that there would be a shorter distance in FC and a greater distance in SC. Using the same concept as our study, but manipulating distance, other studies observed differences in the total time when comparing three different conditions (distances) [15,16]. While in both studies total distances were manipulated, resulting in different total performance times, our study manipulated total time, resulting in different total distances between the three chronometers. Although manipulation was different between both studies cited and the present study, it seems that these methods can show differences in total performance because of the exercise duration differences between conditions. It can be stated that the 10% difference between the chronometers (FC, SC, and NC) was enough to cause significant differences in the total distance, while other variables were similar [32]. This indicates that previous information would affect total distance when time duration is manipulated.

4.2. Physiological Variables

Although participants ran different total times in the three conditions (54, 60, and 66 min), their overall average for VO_2, HR, and RPE were not significantly different between conditions. Other studies involving self-paced exercise with a defined endpoint, regardless the deception method [15,16,18,33], also reported no significant differences for HR, VO_2, and RPE between conditions. As in the present study, these studies reported a similar average intensity between conditions, which indicates a strong link between exercise intensity and physiological variables. Moreover, the increase in speed during the trials in the present study was followed by a comparable increase in VO_2, HR, and RPE throughout each condition. Therefore, these results are in accordance with our study hypothesis, where the total time information given would influence the pre-programmed template, resulting in similar physiological variables.

4.3. Pacing and Performance Based on Observed Time

A further finding was that speed, according to both partial analyses (RT and OT), increased over time during all three conditions in the present study, which is consistent with a "slow start" strategy during exercise [6,34]. When analyzing the observed time, interactions between condition and time for speed (or any other variable) were not observed; however, a main effect of time was observed for all variables, including speed (see Figure 3). It appears that the continuous, incorrect time information, with a difference of 10%, was not sufficient to alter the created template and consequently did not affect pacing strategy, physiological variables, or RPE. It has previously been suggested that any effect of incorrect information on the performance would depend on the magnitude of the difference between the true information and information provided [32]. Furthermore, it seems that the chronometers differences were not able to change significantly muscle power output during the exercise, producing similar metabolic stress in the various peripheral physiological systems. As a result, this metabolic activity would be incorporated by the brain ("teleoantecipatory system") together with knowledge of the endpoint and the participant previous experience to determine the pacing strategy applied, trying to achieve an optimal performance, and protect the physiological systems from failure [9]. These results support the hypothesis that participants regulated their speed based on the previous information and the observed time.

4.4. Pacing and Performance Based on Real-Time

Although the OT analysis did not find differences between conditions, in the first periods of the RT analysis (RT1 and RT2), we identified differences between NC and the other two conditions. This may be an indication that the adjustments of the trials were made not just taking into consideration some factors previously described, such as knowledge of the endpoint and previous experience, but also the time observed during the trial. Further, in the final period of the RT analysis (RT6), there was a greater speed in FC than in both NC and SC. In RT6, the participants in the FC condition were closer to the finish than in the other two conditions, so to achieve the best possible performance, they had higher speed values in a shorter time and were closer to their final sprint (endspurt). At the beginning of RT6 in FC, participants had been exercising for less time and would have felt less fatigued and this may have encouraged them to complete a faster final burst. Furthermore, this faster endspurt may also be related with the participant's unconscious perception that the endpoint of the FC trial was closer than to what they had anticipated based on the information provided, altering their preprogrammed template. Since pacing strategy has been proposed to be regulated by muscle activation based on afferent feedback from the various physiological systems, this increase in intensity may indicate that the fatigue of the peripheral muscles was less than expected, allowing them to increase their final speed [35,36]. The possible mechanism behind this is that during the exercise, the intensity may be regulated by a complex algorithm in the brain involving peripheral sensory feedback and the remaining exercise to achieve the best performance [6]. In RT6, there was also a greater distance in SC than in both NC and FC, and a greater distance in NC than in FC. These results are predominantly due to different endpoint times in each condition (4, 10, and 16 min of running in the final period, respectively).

In order to minimize the effect of the different RT6 times between conditions, the L10 analysis was made. In this analysis, distance in the final 10 min was 90 m greater in FC than in SC, and speed proved to be significantly faster during the FC when comparing to SC (4% between FC and SC, 2.4% between FC and SC, and 1.7% between NC and SC—see Table 1), while the physiological responses remain similar. Those differences were unable to influence HR, VO2, and RPE, as described previously in other studies [13,33]. This may be an indication that during a self-paced exercise, the performance may be not just linked with physiological systems but also with other aspects (e.g., pre-programmed template, information given). In addition, the participants in SC ran 2.13 km (12 min) more than in FC before the final 10 min began. These results support the hypothesis that participants were less fatigued at the start of the final 10 min in the FC compared with the other two conditions. It has previously been suggested that the pacing strategy would be adjusted according to a continuously calculation by the brain's teleoantecipation center using the algorithm pre-exercise, the current metabolic variables, and the ones required to finish the exercise with the aim to achieve the best performance and maintain metabolic reserves necessary to preserve the system homeostasis [6]. Nonetheless, possibly due to a pre-programmed template, the continuous time information (time manipulation) did have some influence on earlier time points, and it also seems that the observed time had a greater impact on exercise intensity not just in the RT6 analysis but also in the L10 analysis, adding new findings to our study.

5. Conclusions

Our study was able to combine pacing and performance in different analyses. First, it was demonstrated that the provided time information (regardless of the chronometer alterations) was the main determinant of the pre-programmed pacing template. Secondly, although a similar pacing strategy was observed in the OT and RT analysis, the RT6 and L10 analyses demonstrated that adjustments were made in the final stages to achieve the best performance. Finally, the results of the present study indicate that the observed time was an important determinant of the regulation of exercise intensity, because, although the pacing strategy (slow start) adopted in all conditions was likely regulated according to previous exercise information, adjustments were made manly during the final stages of the FC to reach the maximal effort. The manipulation of the total time of the activity through the altered chronometer (correct or incorrect continuous visual information) supports the idea that recreationally active subjects regulated their activity according to both the information previously provided and the information received during the activity.

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Data Availability Statement: The data from this study can be found at Biometry Laboratory (School of Physical Education and Sports), Federal University of Rio de Janeiro—Brazil.

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References

1. Jones, H.S.; Williams, E.L.; Bridge, C.A.; Marchant, D.; Midgley, A.W.; Micklewright, D.; Mc Naughton, L.R.; Marchant, D. Physiological and Psychological Effects of Deception on Pacing Strategy and Performance: A Review. *Sports Med.* **2013**, *43*, 1243–1257. [CrossRef]
2. Kayser, B. Exercise starts and ends in the brain. *Graefe's Arch. Clin. Exp. Ophthalmol.* **2003**, *90*, 411–419. [CrossRef]
3. Lambert, E.V.; St Clair Gibson, A.; Noakes, T.D. Complex systems model of fatigue: Integrative homoeostatic control of pe-ripheral physiological systems during exercise in humans. *Br. J. Sports Med.* **2005**, *39*, 52–62. [CrossRef]
4. Noakes, T.D.; Gibson, A.S.C.; Lambert, E. From catastrophe to complexity: A novel model of integrative central neural regulation of effort and fatigue during exercise in humans: Summary and conclusions. *Br. J. Sports Med.* **2005**, *39*, 120–124. [CrossRef] [PubMed]
5. Noakes, T.D. Time to move beyond a brainless exercise physiology: The evidence for complex regulation of human exercise performance. *Appl. Physiol. Nutr. Metab.* **2011**, *36*, 23–35. [CrossRef] [PubMed]
6. St Gibson, A.C.; Lambert, E.V.; Rauch, L.H.G.; Tucker, R.; Baden, D.A.; Foster, C.; Noakes, T.D. The role of information pro-cessing between the brain and peripheral physiological systems in pacing and perception of effort. *Sports Med.* **2006**, *36*, 705–722. [CrossRef] [PubMed]

7. Swart, J.; Lamberts, R.P.; Lambert, M.I.; Lambert, E.V.; Woolrich, R.W.; Johnston, S.; Noakes, T.D. Exercising with reserve: Exercise regulation by perceived exertion in relation to duration of exercise and knowledge of endpoint. *Br. J. Sports Med.* **2009**, *43*, 775–781. [CrossRef]
8. Tucker, R. The anticipatory regulation of performance: The physiological basis for pacing strategies and the development of a perception-based model for exercise performance. *Br. J. Sports Med.* **2009**, *43*, 392–400. [CrossRef]
9. Ulmer, H.V. Concept of an extracellular regulation of muscular metabolic rate during heavy exercise in humans by psycho-physiological feedback. *Experientia* **1996**, *52*, 416–420. [CrossRef]
10. Williams, E.L.; Jones, H.S.; Sparks, S.; Marchant, D.C.; Micklewright, D.; McNaughton, L.R. Deception studies manipulating centrally acting performance modifiers: A review. *Med. Sci. Sports Exerc.* **2014**, *46*, 1441–1451. [CrossRef]
11. Les Ansley, P.J.; Gibson, A.S.C.; Noakes, T.D. Anticipatory pacing strategies during supramaximal exercise lasting longer than 30 s. *Med. Sci. Sports Exerc.* **2004**, *195*, 309–314. [CrossRef]
12. Baden, D.; McLean, T.L.; Tucker, R.; Noakes, T.D.; Gibson, A.S.C. Effect of anticipation during unknown or unexpected exercise duration on rating of perceived exertion, affect, and physiological function * Commentary. *Br. J. Sports Med.* **2005**, *39*, 742–746. [CrossRef]
13. Eston, R.; Stansfield, R.; Westoby, P.; Parfitt, G. Effect of deception and expected exercise duration on psychological and physiological variables during treadmill running and cycling. *Psychophysiol.* **2012**, *49*, 462–469. [CrossRef]
14. Morton, R.H. Deception by manipulating the clock calibration influences cycle ergometer endurance time in males. *J. Sci. Med. Sport* **2009**, *12*, 332–337. [CrossRef] [PubMed]
15. Nikolopoulos, V.; Arkinstall, M.J.; A Hawley, J. Pacing strategy in simulated cycle time-trials is based on perceived rather than actual distance. *J. Sci. Med. Sport* **2001**, *4*, 212–219. [CrossRef]
16. Palmer, G.S.; Backx, K.; Hawley, J.A. Perceived rather than actual distance determines pacing strategy during simulated cy-cling time trials. *Med. Sci. Sports Exerc.* **1998**, *30*, 305. [CrossRef]
17. Paterson, S.; Marino, F.E. Effect of Deception of Distance on Prolonged Cycling Performance. *Percept. Mot. Ski.* **2004**, *98*, 1017–1026. [CrossRef]
18. Thomas, G.; Renfree, A. The effect of secret clock manipulation on 10km cycle time. *Int. J. Arts Sci.* **2010**, *3*, 193–202.
19. Wingfield, G.; Marino, F.E.; Skein, M. Deception of cycling distance on pacing strategies, perceptual responses, and neural activity. *Pflügers Arch.-Eur. J. Physiol.* **2018**, *471*, 285–299. [CrossRef] [PubMed]
20. Wingfield, G.; Marino, F.; Skein, M. The influence of knowledge of performance endpoint on pacing strategies, perception of effort, and neural activity during 30-km cycling time trials. *Physiol. Rep.* **2018**, *6*, e13892. [CrossRef] [PubMed]
21. Mastroianni, G.R.; Zupan, M.F.; Chuba, D.M.; Berger, R.C.; Wile, A.L. Voluntary pacing and energy cost of off-road cycling and running. *Appl. Ergon.* **2000**, *31*, 479–485. [CrossRef]
22. Millet, G.Y.; Lepers, R. Alterations of Neuromuscular Function after Prolonged Running, Cycling and Skiing Exercises. *Sports Med.* **2004**, *34*, 105–116. [CrossRef] [PubMed]
23. Millet, G.P.; Vleck, V.E.; Bentley, D.J. Physiological differences between cycling and running: Lessons from triathletes. *Sports Med.* **2009**, *39*, 179–206. [CrossRef]
24. Midgley, A.W.; McNaughton, L.R.; Jones, A.M. Training to enhance the physiological determinants of long-distance running performance: Can valid recommendations be given to runners and coaches based on current scientific knowledge? *Sports Med.* **2007**, *37*, 857–880. [CrossRef]
25. Tanaka, H.; Monahan, K.D.; Seals, D.R. Age—Predicted Maximal Heart Revisited. *J. Am. Coll. Cardiol.* **2001**, *37*, 153–156. [CrossRef]
26. Åstrand, P.-O. Quantification of exercise capability and evaluation of physical capacity in man. *Prog. Cardiovasc. Dis.* **1976**, *19*, 51–67. [CrossRef]
27. Saltin, B.; Astrand, P.O. Maximal oxygen uptake in athletes. *J. Appl. Physiol.* **1967**, *23*, 353–358. [CrossRef] [PubMed]
28. Beltz, N.M.; Gibson, A.L.; Janot, J.M.; Kravitz, L.; Mermier, C.M.; Dalleck, L.C. Graded Exercise Testing Protocols for the Determination of VO_2max: Historical Perspectives, Progress, and Future Considerations. *J. Sports Med.* **2016**, *2016*, 3968393. [CrossRef]
29. Paulucio, D.; Nogueira, F.; Velasques, B.; Ribeiro, P.; Pompeu, F. Day-to-Day Variation of Cardiopulmonary Variables Obtained during an Incremental Cycling Test to Volitional Exhaustion. *J. Exerc. Physiol. Online* **2015**, *18*, 81–90.
30. Howley, E.T.; Bassett, D.R.; Welch, H.G., Jr. Criteria for maximal oxygen uptake: Review and commentary. *Med. Sci. Sports Exerc.* **1995**, *27*, 1292–1301. [CrossRef]
31. Sullivan, G.M.; Feinn, R. Using Effect Size—Or Why the P Value Is Not Enough. *J. Grad. Med Educ.* **2012**, *4*, 279–282. [CrossRef]
32. Tucker, R.; Noakes, T.D. The physiological regulation of pacing strategy during exercise: A critical review. *Br. J. Sports Med.* **2009**, *43*, e1. [CrossRef] [PubMed]
33. Faulkner, J.; Arnold, T.; Eston, R. Effect of accurate and inaccurate distance feedback on performance markers and pacing strategies during running. *Scand. J. Med. Sci. Sports* **2010**, *21*, e176–e183. [CrossRef]
34. Abbiss, C.R.; Laursen, P.B. Describing and Understanding Pacing Strategies during Athletic Competition. *Sports Med.* **2008**, *38*, 239–252. [CrossRef] [PubMed]

35. Amann, M.; Dempsey, J.A. Locomotor muscle fatigue modifies central motor drive in healthy humans and imposes a limita-tion to exercise performance. *J. Physiol.* **2008**, *586*, 161–173. [CrossRef] [PubMed]
36. Amann, M.; Proctor, L.T.; Sebranek, J.J.; Pegelow, D.F.; Dempsey, J.A. Opioid-mediated muscle afferents inhibit central motor drive and limit peripheral muscle fatigue development in humans. *J. Physiol.* **2009**, *587*, 271–283. [CrossRef] [PubMed]