Effects of Deception on Exercise Performance: Implications for Determinants of Fatigue in Humans

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ABSTRACT

STONE, M. R., K. THOMAS, M. WILKINSON, A. M. JONES, A. ST CLAIR GIBSON, and K. G. THOMPSON. Effects of Deception on Exercise Performance: Implications for Determinants of Fatigue in Humans. *Med. Sci. Sports Exerc.*, Vol. 44, No. 3, pp. 534–541, 2012. **Purpose**: The aim of this study was to investigate whether it was possible to reduce the time taken to complete a 4000-m cycling time trial by misleading participants into believing they were racing against a previous trial, when, in fact, the power output was 2% greater. **Methods**: Nine trained male cyclists each completed four 4000-m time trials. The first trial was a habituation and the data from the second trial was used to form a baseline (BL). During trials 3 and 4, participants raced against an avatar, which they were informed represented their BL performance. However, whereas one of these trials was an accurate (ACC) representation of BL, the power output in the other trial was set at 102% of BL and formed the deception condition (DEC). Oxygen uptake and RER were measured continuously and used to determine aerobic and anaerobic contributions to power output. **Results**: There was a significant difference between trials for time to completion ($F = 15.3$, $P = 0.00$). Participants completed DEC more quickly than BL (90% CI = 2.1–10.1 s) and ACC (90% CI = 1.5–5.4 s) and completed ACC more quickly than BL (90% CI = 0.5–4.8 s). The difference in performance between DEC and ACC was attributable to a greater anaerobic contribution to power output at 90% of the total distance ($F = 5.3$, $P = 0.02$, 90% CI = 4–37 W). **Conclusions**: The provision of surreptitiously augmented feedback derived from a previous performance reduces time taken for cyclists to accomplish a time trial of known duration. This suggests that cyclists operate with a metabolic reserve even during maximal time trials and that this reserve can be accessed after deception. **Key Words**: PACING STRATEGY, FEEDBACK, TIME TRIAL, PERCEIVED EXERTION

C yclists adopt a pacing strategy to delay fatigue and optimize performance (14). This pacing strategy is under central neural control whereby power output is determined before the start of exercise and is based on an estimate of the utmost physiological strain that can be maintained for the expected duration of the bout (38). During the exercise bout, feedback from afferents in the viscera and muscles are then processed by the brain, which dynamically modulates exercise intensity to ensure that anaerobic energetic reserves are never fully depleted (13) and that the magnitude of metabolite accumulation is not sufficient to severely disturb homeostasis (30,38,41). It is possible, therefore, that self-paced exercise is performed at a relative maximum intensity somewhat below an athletes' absolute physiological capacity (2,3,22,40). Gaining access to this metabolic reserve could have a beneficial effect on exercise performance.

The pacing schema and its associated performance outcomes have been shown to be consistent between repeated trials (39) and are unaffected by either the offer of extrinsic reward (19) or misleading feedback in the form of inaccurate visual and auditory timing cues (16,21), distance markers (1), and the actual length of the trial (29,33). Nevertheless, the provision of accurate feedback and competition have been shown to elicit improvements in performance (23,32,43–45). Mauger et al. (23) instructed cyclists to perform three track-based 4000-m time trials. The first trial formed a baseline, and during the remaining two trials, participants received either correct feedback based on their baseline or noncontingent feedback that falsely informed participants into believing they were performing either worse or better than their baseline. These authors found that speed and completion time were significantly improved under the accurate feedback condition when compared with the noncontingent feedback condition and attributed this finding to the benefits to motivation that feedback provides. This theory is further supported by the findings from a recent study that showed that, when cyclists

were able to compete against an avatar depicting their own previously recorded fastest uphill 8-mile time trial, they were able to complete the distance in a shorter amount of time (32). The magnitude of the change in mean performance was small; however, an important implication is that the cyclists aspired to improve on their own performance to such an extent that it either compelled them to exert greater than ordinary effort or alleviated their perceptions of exertion and enabled them to exercise at a higher than ordinarily optimal intensity. It is plausible that surreptitiously manipulating the feedback stimulus, such that the exercise intensity at which the avatar accomplishes the time trial is greater than the cyclists' actual best performance, could elicit an improvement in time trial performance.

There are a few studies in which real-time feedback based on a previous performance has been adjusted to mislead participants into believing that they were exercising at an intensity similar to a previous trial when, in fact, the intensity was greater than their true best performance (26–28). Ness and Patton (28) instructed participants to perform an incline bench press at 1-repetition maximum (1RM) each week for 6 wk. During week 5, the authors rearranged the labels on the weight stacks to mislead the participants who in turn were able to lift an average 20 lb more than what they perceived to be their 1RM. Similarly, in a recent study by Morton (27), participants were instructed to cycle to exhaustion at a fixed power output on three separate occasions. During one of these trials, the clock was calibrated accurately; however, the researcher secretly calibrated the clock 10% faster or 10% slower in the remaining two trials. Although there were no between-trial differences for "clocked" time, the actual amount of time for which participants were able to endure the imposed exercise intensity was significantly greater when the clock ran slowly. However, the use of recreationally active participants in these studies was a limitation because the variability between trials in an exercise task is approximately four times greater among recreationally active participants compared with those who are well trained (46). Therefore, these findings might not be readily transferable to an athletic population. Furthermore, it is not certain whether improvements in a time to fatigue protocol would necessarily translate to improved performance in simulated competition (20).

In another study, Micklewright et al. (26) instructed a cohort of well-trained cyclists to complete three 20-km time trials. During the first two trials, the speed that was shown to cyclists was 5% greater than their actual speed. During the third trial, in which participants were shown their true speed, they tried to match their perceived ability at the start of the trial. However, the intensity of exercise was unsustainable, and exercise intensity was subsequently impaired to the extent that speed was significantly lower during each of kilometers 14–20. The inability of the participants to sustain the higher intensity was probably due to the magnitude of the difference between an actual and expected performance. We and others have previously shown that the typical error for speed between time trials is low (0.8%–1.4%) (39,46) and

that the smallest worthwhile change in performance is similar to a typical error (39). The difference of 5% imposed by Micklewright et al. (26) was therefore up to five times greater than the minimum change in performance needed to indicate a real and meaningful improvement.

The main aim of the present study was to compare the effect of 1) accurate and 2) surreptitiously augmented performance feedback on time to complete a laboratory-based simulated 4000-m time trial among trained male cyclists. To reduce the likelihood that participants would detect the manipulation, the magnitude of the deception was no greater than the smallest worthwhile change in performance. We hypothesized that both treatments would enhance performance but that only the latter would be greater than typical error. Secondary objectives were to establish whether the change in performance was associated with greater metabolic cost and whether this was made possible by the alleviation of perceived exertion or the cyclists' propensity to knowingly exert more effort.

METHODS

Participants. Nine trained male cyclists volunteered to take part in the study. Mean ± SD age was 31.7 ± 6.8 yr, height was 178.6 ± 7.1 m, weight was 73.5 ± 6 kg, and peak oxygen uptake ($\dot{V}O_{2peak}$) was 4.8 ± 0.8 L·min^{-1}. Mean power outputs at LT_1, LT_2, and $\dot{V}O_{2peak}$ were 224 ± 28, 261 ± 22, and 329 ± 29, W respectively. The institutional ethics committee approved the project. At the start of the experiment, participants were informed that the purpose of the study was to assess the consistency of 4000-m cycling time trial performance when racing against their previous performance and were informed of the deception on completion of the experiment. Written informed consent was obtained before the study commenced. Intraparticipant testing was conducted at the same time of day to minimize circadian variation, with 3–7 d separating test sessions. Participants were instructed to maintain their normal diet and physical activity patterns throughout the experiment and to refrain from strenuous exercise and the consumption of caffeine or alcohol in the 24 h preceding each testing session.

Instrumentation. Testing was conducted on an electromagnetically braked cycle ergometer (Velotron Racermate, Seattle, WA), which has previously been shown to yield valid and reliable indices of power output (24,37). The ergometer was adjusted for comfort for each participant; this included fitting their own pedals and saddle. These adjustments were replicated for all subsequent trials. During the time trials, the cycle ergometer was interfaced with the Velotron 3D software (RacerMate), which was, in turn, projected onto a large screen in front of the cyclist. The 3D software supports the instantaneous generation of an onscreen avatar, which illustrates the cyclists' progress as they undertake a time trial on a track of a known duration. Comprehensive data from the performance can be stored, and the avatar can be replayed, serving

as an opponent for the cyclist to race against in future trials. The view seen by the cyclist was from behind the slower of the two avatars, meaning that they were able to monitor the performance of both and could estimate the distance separating their current and previous performances. Other information that could be seen on the projector included distance traveled. All other feedback was blinded from the participants.

Breath-by-breath oxygen uptake ($\dot{V}O_2$) and RER were measured continuously using an automated online metabolic cart (Cortex; Metalyzer, Leipzig, Germany), which is a valid and reliable instrument for the measurement of gaseous exchange during exercise (25). The gas analyzer and flow turbine were calibrated before each test using certified standard gases (15% O_2 and 5% CO_2) and a 3-L syringe (Hans Rudolph, Kansas City, KS). HR was recorded using short-range telemetry (Polar Electro Oy, Kempele, Finland), interfaced with the Cortex software. Data from the cycle ergometer and cardiorespiratory system were averaged and interpolated over 1-s intervals. On completion of the trial, participants were asked to provide a rating of their perceived exertion representing their effort during the whole trial (4).

Aerobic (P_{aer}) and anaerobic (P_{an}) contributions to total power output (P_{tot}) were calculated from P_{tot}, $\dot{V}O_2$, RER, and gross efficiency (GE). First, GE was determined during 5 min of cycling at 150 W during the warm-up using the equation GE = P_{tot} / P_{met}, where P_{met} is the aerobic metabolic power, which can be calculated using the following equation:

$$P_{met} = (\dot{V}O_2(4940RER + 16{,}040))/60 \qquad [1]$$

It assumed that an RER > 1.0 was attributable to buffering; therefore, in the calculation of metabolic work, RER values in excess of 1.0 were treated as if they equaled 1.0. Moreover, $\dot{V}O_2$ and RER measured during the time trial were interpolated to 1-s values and time aligned with the P_{tot} data. These data were then converted to a percentage of the total time taken to complete the trial and averaged into 10% "bins" to facilitate between-trial analyses. To calculate P_{aer}, we divided aerobic metabolic power for each 10% bin (equation 1) by GE. Given that P_{tot} is the sum of P_{aer} and P_{an}, P_{an} was calculated as:

$$P_{an} = P_{tot} - P_{aer} \qquad [2]$$

These methods were first described by Serresse et al. (34,35), have subsequently been used by several researchers (5,8, 12,13,17,18,39), and have recently been shown to be the most precise indirect estimate of anaerobic contribution to total power output during self-paced, simulated competition (31).

Preliminary testing session. On their first visit to the laboratory, participants performed a submaximal exercise test, and a standard incremental test to maximal exertion for the determination of peak oxygen uptake ($\dot{V}O_{2peak}$). After a 10-min self-paced warm-up, power output was set at 150 W and increased by 25 W every 4 min. Oxygen uptake was averaged during the final minute of each stage, and capillary blood was sampled and analyzed for blood lactate concentration ([La-]B). The submaximal exercise test was terminated after a second sharp rise in [La-]B was observed. Subsequently, the power output was adjusted to 200 W and continuously increased by 5 W every 15 s until volitional fatigue. The highest $\dot{V}O_2$ averaged during a 30-s period was defined as $\dot{V}O_{2peak}$. The linear relationship between power output and oxygen uptake was extrapolated for the estimation of the lowest power output, which elucidated $\dot{V}O_{2peak}$ ($P\dot{V}O_{2peak}$).

Time trials. Before each time trial, participants warmed up for 5 min at 150 W and then for a further 5 min at 70% of $P\dot{V}O_{2peak}$. They were then given 10 min to relax and prepare themselves for the subsequent time trial. A flat 4000-m time trial profile was then loaded using the Velotron 3D Software and was displayed on a large projector. The only instruction given to participants was to complete the time trial in the shortest amount of time possible. Standardized verbal encouragement and feedback on the distance covered were given every 400 m.

Participants performed a habituation 4000-m time trial during their second visit to familiarize themselves with the procedures and equipment. During the third visit, participants again completed a 4000-m time trial, and their performance in this trial was used as baseline (BL). Subsequently, participants completed a further two 4000-m time trials and were informed that they would be racing against a computer-generated avatar that represented their BL performance.

In one of these time trials (ACC), the avatar was an accurate representation of their baseline performance. During the other time trial (DEC), the power output of the avatar was set at 102% of the baseline trial. A 2% increase was deemed to be appropriate because we have previously demonstrated, using participants with similar physiological characteristics to those in the present study, that this represents the smallest worthwhile change in performance in a laboratory-simulated 4000-m time trial (39). In the same study, we also reported that the typical error in measurement for a 4000-m time trial is ~1.8% of mean power output; therefore, because the deception was only marginally greater than typical error, it was deemed sufficiently discreet to make detection unlikely. The order in which participants were exposed to the ACC and DEC conditions was counterbalanced to minimize the potential for training- or habituation-induced bias.

Data analysis. Statistical analyses were conducted using SPSS 16.0 (Chicago, IL). Data are presented as mean ± SD. The precision of the estimates of outcome statistics is shown as a 90% confidence limit. Differences in RPE, $\dot{V}O_{2peak}$, HR_{peak}, and mean power output between BL, ACC, and DEC were established using a one-way ANOVA with repeated measures. Where a significant change in performance was seen, the clinical inference of the value of the effect statistic was determined using a published spreadsheet (13). To investigate differences in the pacing strategy, power output, P_{an}, and P_{aer} were calculated for each 10% section of each trial and statistically analyzed using a fully

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factorial 3 × 10 (trial vs distance covered) ANOVA. Significant main effects were followed by a Bonferroni *post hoc* test. Significance was accepted at $P < 0.05$.

RESULTS

There was a significant between-trials main effect for RPE ($F_2 = 12.0$, $P = 0.001$; BL = 18.2 ± 0.8, ACC = 18.9 ± 0.6, and DEC = 19.6 ± 0.5). Pairwise comparison showed that RPE after DEC was significantly greater than BL ($P = 0.001$, 90% CI = 1–2; Fig. 1). There were no differences between trials for mean cadence (BL = 106 ± 10, ACC = 107 ± 9, and DEC = 107 ± 9 rpm), $\dot{V}O_{2peak}$ (BL = 4.8 ± 0.5, ACC = 4.8 ± 0.4, and DEC = 4.8 ± 0.3 L·min^{-1}), HR$_{peak}$ (BL = 180 ± 12, ACC = 182 ± 11, and DEC = 180 ± 10 bpm), or RER (BL = 1.12 ± 0.06, ACC = 1.13 ± 0.06, and DEC = 1.14 ± 0.07).

Analysis of the differences in the distribution of energetic resources revealed a significant between-trials main effect for P$_{an}$ ($F_{2,9} = 5.3$, $P = 0.02$; DEC = 56 ± 8, ACC = 58 ± 6, and DEC = 64 ± 7 W). Pairwise comparisons showed that P$_{an}$ was significantly greater during DEC than ACC at 90% of the total distance completed ($P = 0.04$, 90% CI = 4–37 W), which ultimately resulted in greater whole trial mean P$_{an}$ for DEC compared with ACC ($P = 0.05$, 90% CI = 1–12 W). There were no differences between trials for P$_{aer}$ (BL = 278 ± 30, ACC = 280 ± 29, and DEC = 282 ± 25 W). The serial pattern of aerobic and anaerobic contributions to total power output is displayed in Figure 2.

There was a significant difference between trials for time to completion ($F_2 = 15.296$, $P = 0.00$; BL = 361.6 ± 12.6, ACC = 358.9 ± 11, and DEC = 355.4 ± 9.8 s). Pairwise comparisons revealed that DEC was completed in a significantly shorter duration that BL ($P = 0.01$, 90% CI = −2.1 to −10.1 s; 95% very likely beneficial) and ACC ($P = 0.01$, 90% CI = −1.5 to −5.4 s; 74% possibly beneficial) and that ACC was completed in a significantly shorter duration than

FIGURE 2—Mean serial pattern of aerobic and anaerobic contributions to total power output throughout BL, DEC, and ACC. Significant differences in anaerobic power between DEC and ACC are denoted by a *dagger* (†$P < 0.05$).

BL ($P = 0.04$, 90% CI = −0.5 to −4.8 s; 56% possibly beneficial and 44% possibly trivial). Mean and individual participant times to completion are shown in Figure 3. There was also a significant between-trials main effect for mean power output ($F_2 = 8.633$, $P = 0.003$; BL = 333 ± 32, ACC = 339 ± 29, and DEC = 347 ± 26 W). Mean power output during DEC was greater than both BL ($P = 0.05$, 90% CI = 2–26 W) and ACC ($P = 0.05$, 90% CI = 3–13 W), but there was no significant difference between BL and ACC.

We reanalyzed these data by trial order to determine whether these findings were due to any learning or practice effect. There was a significant order effect for time to completion ($F_2 = 6.998$, $P = 0.007$; trial 1 = 361.6 ± 12.6, trial 2 = 357.7, and trial 3 = 356.7 s). Pairwise comparisons revealed that trial 2 was performed in a significantly shorter duration than trial 1 ($P = 0.01$, 90% CI = −1.0 to −6.8 s) and that the difference between trials 1 and 3 was approaching significance ($P = 0.06$, 90% CI = −0.2 to 10.0 s) but that there was no difference in time to completion between trials 2 and 3 (90% CI = −3.2 to 5.2 s). Similarly, there was a significant order effect for mean power output ($F_2 = 4.785$, $P = 0.24$; trial 1 = 333 ± 32, trial 2 = 341 ± 29, and trial 3 = 344 ± 27 W). Pairwise comparisons showed that mean power output was significantly higher during trial 2 than during trial 1
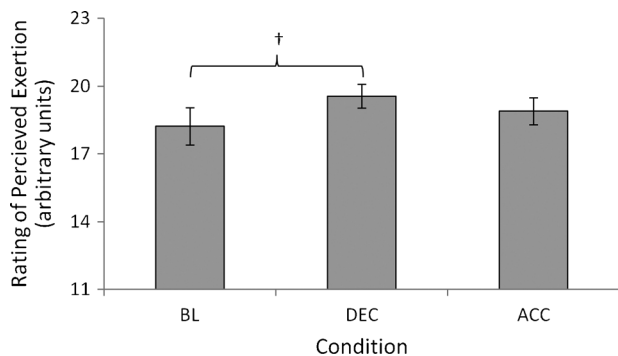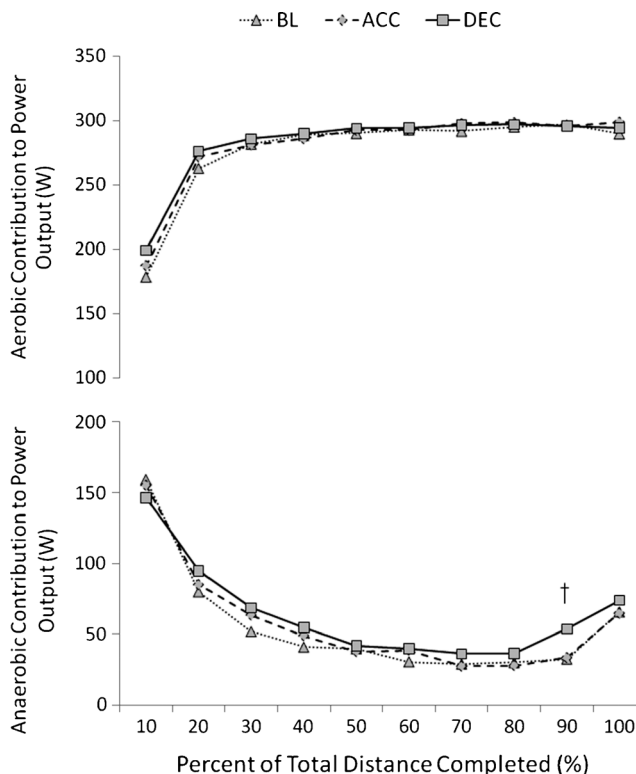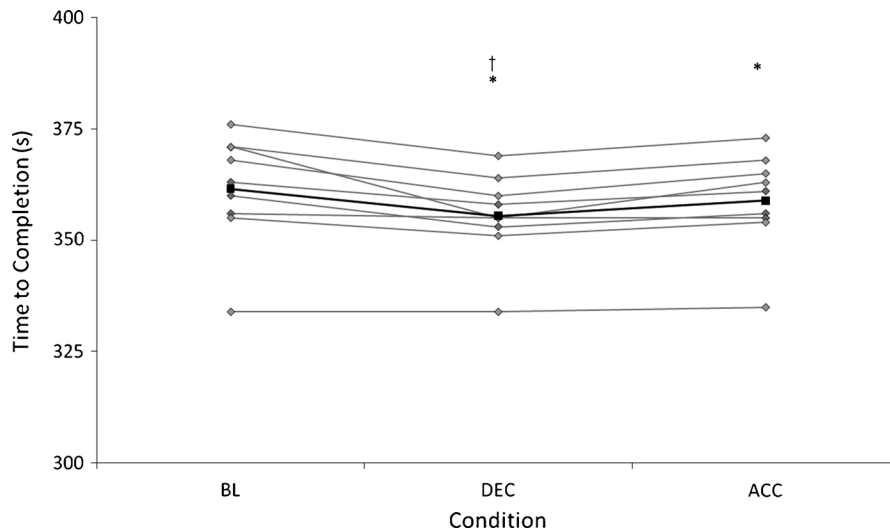

FIGURE 1—Difference between conditions in rating of perceived exertion on completion of the 4000-m distance. Significant differences increases in RPE from baseline are denoted by a *dagger* (†$P < 0.05$).

FIGURE 3—Mean (*dark line*) and individual (*gray lines*) differences in time to complete the 4000-m distance (BL, DEC, and ACC). A significant reduction in time to completion compared with BL is denoted by an *asterisk*, and a *dagger* denotes a significant reduction in time to completion compared with ACC ($P < 0.05$).

($P = 0.03$, 90% CI = 2–15 W) but that there were no significant differences between trials 1 and 3 or between trials 2 and 3.

DISCUSSION

It was hypothesized that receiving surreptitiously augmented feedback derived from a prior performance would enable participants to complete a 4000-m time trial more quickly than at baseline or after receipt of accurate feedback. Our principal findings were that participants in the deception condition completed the trial 1.7% more quickly than at baseline and 1.0% more quickly than in the accurate feedback condition. This improvement is particularly striking in light of evidence that the difference between winning gold and silver medal in events ranging from 1000 to 4000 m is only ~1.0% in elite competitions (14). These findings complement those previously reported by Ness and Patton (28) and Morton (27) in which participants were able to significantly increase their maximal incline bench press performance or cycling time to exhaustion, respectively, when misleading performance feedback was provided. However, the present study is the first to have reported a beneficial effect of deception based on a previous trial, on self-paced time trial exercise, and using trained participants.

In contrast to our findings, Mauger et al. (23) have previously shown that the provision of noncontingent feedback based on a previous performance can increase the time taken to complete a track based 4000-m time trial and that accurate performance feedback elicits significant benefits to performance when compared with noncontingent feedback. Mauger et al. (23) inferred that the decrease in performance in the noncontingent condition was attributable to the demotivating

effect of negative feedback, and this was supported by observations that participants seemed to slow down after being informed that they were underperforming, irrespective of the veracity of this information. This is particularly likely given the stochastic nature of the feedback given, which could have served to confuse the athletes pacing schema, and the limited information provided to participants whereby they were unaware of the magnitude of the difference between their present and previous performances. In contrast, the continuous nature of feedback provided in the present study, and the discreet difference in power output during DEC meant that participants were generally able to stay slightly ahead of the avatar throughout the time trial, without experiencing undue fatigue. This theory is strengthened by the disparity in findings presented by Micklewright et al. (26) and the present study. In the present study, the power output of the pacer in the deception condition was 2% greater than the power output at baseline. This equated to an average increase of approximately 7 W. In the former study (26), the speed shown to participants in the deception condition was 5% greater than their actual speed. Although speed and power output are not linearly related, modeling has shown that a 1% increase in speed is similar to a 2.9% increase in mean power output (11). Power output at baseline in the former study was 259 W (26). Therefore, participants would have had to sustain an additional mean power output of approximately 38 W to match their expected performance. Elucidating the magnitude of the tolerable deception that enhances performance could be a fertile field for future research.

Data from our laboratory have indicated that the distribution of energetic resources is consistent between repeated 4000-m time trials when performed under normal conditions (39). However, in the present study, the difference in performance between the experimental trials was attributable

to a greater mean anaerobic contribution during DEC. This was most pronounced at 90% of the total distance covered between DEC and ACC. These findings indicate that our participants were able to start their end spurt earlier in the race and sustain the additional exercise intensity until completion of the trial. A limitation with this method of estimating the relative contributions of P_{aer} and P_{an} is the assumption that GE is the same during low-intensity steady-state cycling as it is during strenuous, self-paced simulated competition. It has recently been shown that GE increases in a curvilinear fashion with an increase in exercise intensity (10), and Uitlsag et al. (42) recently found that GE decreased across the course of 4 min of high-intensity time trial exercise. This might have led to an underestimation of aerobic energy contribution in the present study. Nonetheless, Gastin et al. (15) have previously shown that changes in efficiency during supramaximal exercise do not introduce meaningful errors into the calculation of anaerobic energy expenditure; however, indirect estimates of aerobic and anaerobic contributions to P_{tot} should be treated with caution.

The finding that athletes operate within a metabolic reserve is consistent with recent studies that have shown that the analgesic effects of pharmaceutical interventions, designed either to block the pathway of opioid-mediated muscle afferents or to elevate the pain threshold in such a way that a greater amount of pain is required to develop before it is felt, disinhibit the central neural regulation of effort enabling cyclists to operate at a higher relative percentage of their true physiological capacity (3,22,40). The psychological reasons underlying the improvement in performance in DEC are currently unknown. However, one explanation that warrants further investigation is the notion of a limited channel capacity whereby occupying available space with a dissociative task increases an individual's tolerance to fatigue because of their inability to simultaneously process distress-related cues from afferent sensory inputs (37). Therefore, in the present study, participants may have been so focused on the synthesis of external, environmental cues, i.e., the performance of their opponent, that they were unable to process the afferent sensory inputs from peripheral physiological systems.

In contrast to previous studies that have all reported no change in RPE although power output and metabolic strain were increased (3,22,40), we observed a marked increase in perceived exertion on completion of DEC, compared with BL. A limitation of the study was that we did not track the pattern of increase in RPE throughout the trial, and therefore, we cannot identify the point at which participants began to knowingly exert greater effort than under normal conditions. However, it is possible that this occurrence would correspond with the relative increase in anaerobic energy contribution at ~80%–90% of the 4000-m distance.

A second possible explanation for the improvement in performance in DEC, which warrants further research, is that cognitive processes independent of RPE, regulate the amount of effort that an athlete is disposed to exert in the pursuit of an exercise challenge and the extent to which the potential physiological capacity is made available. It has previously been reported that afferents from physiological cues in the viscera and muscles and from external motivational stimuli reach areas of the brain linked to affect (6); that affective response steers the amount of effort a person is disposed to exert toward appetitive behavior (7) and that, while affect and RPE are related, they are not necessarily isomorphic constructs, especially during high-intensity exercise (9). Therefore, future studies should consider the affective response to self-paced exercise in addition to perceived exertion.

Our observation that time to completion was significantly lower in ACC than BL conflicts with a previous report in which Noreen et al. (32) assert that a simulated time trial is repeatable when constant feedback is given, enabling the cyclist to compare his or her current progress with that of a previous performance. However, Noreen et al. (32) also acknowledged that the low probability statistics, large change in the mean, and small sample size raised the likelihood that a Type II error had occurred in their study. It is likely that, in the present study, the improvement in performance in ACC was attributable to the effects of competition because in previous studies, in which participants have performed several repeat time trials without racing against any competitor and in which participants had similar characteristics to those who took part in the present study, performance did not change between trials after acclimatization (36,37,39). The present study was limited by the fact that we did not have a trial during which the avatar which was set at 102% of BL, and in which participants were informed about the true nature of the trial. Therefore, we cannot confirm whether the change in performance was solely attributable to the use of deception, or whether competition alone could have elicited similar improvements. However, previous studies have shown that performance is greater when participants compete against an opponent whom they expect to be able to beat and that performance can be impaired when participants believe that their opponent is better than them (43–45). We propose that in the present study the assurance of having previously accomplished the same task at the target exercise intensity empowered these participants to exert greater than ordinary effort to beat DEC and that knowledge of the true power output of the avatar could negate the effect of DEC.

To summarize, this is the first study to have shown that the provision of surreptitiously augmented feedback derived from a previous performance enabled cyclists to accomplish a dynamic exercise task in a shorter amount of time, with significantly greater mean power output. These findings were attributable to greater anaerobic energy contribution, which enabled a higher power output during the final third of the exercise bout. This was associated with an increase in the perceived exertion reported at the termination of the trial. These results indicate that cyclists typically operate with a metabolic reserve even during maximal time trial performance and that this reserve can be accessed after deception.

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This has implications for performance enhancement in elite athletes and for our understanding of the nature of "fatigue" during "maximal" exercise, for example, it would appear that a proportion of P_{an} is conserved which can be used given a belief that the exercise will be sustainable.

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