Western Norway University of Applied Sciences

BACHELOR'S THESIS

Residual effects of deception on prior experience and performance during a self-paced 4 km cycle time trial

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I confirm that the work is self-prepared and that references/source references to all sources used in the work are provided, cf. Regulation relating to academic studies and examinations at the Western Norway University of Applied Sciences (HVL), § 12-1.

Forord

Denne teksten er en oppgavebesvarelse for ID3-302 bacheloroppgave idrett, fysisk aktivitet og helse. Temaet og problemformuleringen er valgt ut fra personlig interesse for prestasjon, og samspillet mellom psykologi og fysiologi som ligger bak idrettsprestasjoner, særlig i utholdenhetsidrett. Vi vil gjerne takke vår veileder Christian Frøyd for sitt engasjement, konstruktiv kritikk og tilbakemeldinger. En stor takk til våre deltakere som stilte opp, presterte og forble i eksperimentet, til tross for misinformasjon om studiets egentlige formål. Til sist vil vi gjerne takke alle de flinke bibliotekarene som hjalp oss med det tekniske.

Sammendrag norsk

Formål: Målet ved dette studiet var å undersøke i hvilken grad et prestasjonsbedrag på en tidligere 4 km selvregulert sykkel tidstest (TT) endret self-efficacy, gjennomføringstid (TTC) og kraftproduksjon (PO) på en etterfølgende tilsvarende tidstest. **Metode:** Fem veltrente syklister (11,7 ± 3,6 treningstimer per uke) gjennomførte en tilvennings-TT (FAM), en referanse-TT (BL) og en bedrags-TT (DEC). Etter gjennomføring av BL ble deltakerne fortalt at deres PO var 5% høyere enn det resultatene viste, i realiteten var dette ikke tilfellet. Self-efficacy ble målt på forhånd av BL og DEC, og TTC ble notert for hver TT. PO og hjertefrekvens (HR) ble målt kontinuerlig, og RPE ble målt etter oppvarming og for hver 500 m av TT. **Resultat:** TTC (p=0,979) og PO (p=0,996) var ikke signifikant forskjellig mellom BL og DEC. Intensitetsstyring målt som gjennomsnittlig PO for hver 500 m (0-500 m som første) viste ingen signifikant forskjell mellom BL og DEC (p=0,964). HR og RPE viste ingen signifikant forskjell mellom TT (RPE: p=0,131; HR: p=0,207). Summert og dividert på antall tider var self-efficacy ikke signifikant forskjellig mellom BL og DEC (p=0,051), men kun summert var self-efficacy signifikant forskjellig mellom BL og DEC (p=0,036). Statistisk signifikans var akseptert som ($p<0,05$). **Konklusjon:** Disse resultatene indikerer at en økning i PO på 5% er for høy til å oppnå et suksessfullt bedrag av tidligere erfaring på en 4 km sykkel TT, ettersom TTC og PO forble uendret mellom BL og DEC testene.

Abstract

Purpose: The aim of this study was to determine whether performance deception in a prior 4 km self-paced cycle time trial (TT) altered self-efficacy, time to completion (TTC) and power output (PO) in a subsequent time trial of the same nature. **Methods:** Five well-trained cyclists (11.7 ± 3.6 hours of training per week) performed a familiarization TT (FAM), baseline TT (BL) and deception TT (DEC). After completing BL participants were told that their PO was 5% greater than what was shown on the display, this was not true. TTC was collected for each TT. PO and heartrate (HR) were measured continuously, RPE was measured post warmup and for every 500 meters of the TT. **Results:** No significant differences (p<0.05) were found in TTC (p=0.979) or mean PO (p=0.996) between BL and DEC. Pacing strategies measured as mean PO each 500 meters remained unaltered showing no main effect between BL and DEC (p=0.964). Measures of heart rate (HR) and rate of perceived exertion (RPE) revealed no significant main effect between trials (RPE: p=0.131; HR: p=0.207). Mean self-efficacy demonstrated no significant main effect (p=0.051), while compiled self-efficacy was statistically significant between trials (p=0.036). **Conclusion:** These results indicate that an increased PO of 5% is too great for achieving a successful deception of prior experience in a 4 km cycle TT, as TTC and PO and remained unaltered between trials.

Contents

1.0 Introduction

At the very peak level of competitive sports athletes win by a small margin. In shorter bouts only a performance difference in the region of 1% is observed between gold medalists and non-medalists at the Olympics (Foster, Schrager, Snyder, & Thompson, 1994). Elite athletes of endurance sports seek marginal gains to improve their performance, and by doing so they are pushing the limits of fatigue. In order to achieve great results, athletes continuously have to pace themselves by deciding how and when to invest their energy (Smits, Pepping, & Hettinga, 2014). Knowledge of duration and endpoint regarding the effort is essential to the athlete when developing an adequate pacing strategy (Gibson et al., 2006; Tucker, 2009). Furthermore, there is evidence that pacing and performance is regulated in an anticipatory manner (Mauger, Jones, & Williams, 2009; Tucker, 2009; Ulmer, 1996). This regulation is not only based on feedback during the effort, but it is also influenced by prior experience, with the latter factor likely being as important as real-time feedback when developing a successful pacing strategy (Mauger et al., 2009; Tucker, 2009).

Experience from previous exercise and competitions produce a better anticipation of the upcoming effort as argued by Tucker (2009), and past performances have been shown to correlate well with how one currently performs (Burke & Jin, 1996). The athlete must analyse what he or she knows about the task prior to the effort, including both relevant previous experiences and external factors that might influence the task as shown in Figure 1 (Tucker, 2009). Prior performances enhance both motor control and rate of metabolism, leading to a more efficient and suitable pacing strategy in relation to a known distance or duration (Ulmer, 1996). In the same review Ulmer argues that the enhancements are due to a "central programmer" which regulate these factors in order to optimize the performance in a given effort. More recently this theory has been further explored and developed, resulting in the central governor model (CGM) by Noakes (2011).

The CGM postulates that continuous physiological and psychological afferent feedback is interpreted and integrated to regulate exercise through feedforward mechanisms modifying the number of working motor units in order to prevent fatigue (Noakes, 2011). The central nervous system is therefore the main regulator during exercise, and consequently determines performance (Noakes, 2011). Further it is proposed that this feedback-feedforward loop is managed by a central programmer in our brain (Lambert, Gibson, & Noakes, 2005), as first suggested by Ulmer (1996). Feedback during exercise consists of internal bodily sensations, external factors concerning the effort and perceptual information about the environment (Corbett, Barwood, Ouzounoglou, Thelwell, & Dicks, 2012; Mauger et al., 2009; Noakes, 2011). During a maximal effort the sensation of fatigue arises to alter our behaviour and subsequently prevents failure of homeostasis, therefore fatigue is not a biproduct of homeostasis failure (Noakes, 2011). The phenomena of the end-spurt demonstrate this, as athletes are able to increase performance during the latter stages of a race in spite of great fatigue (Tucker, 2009).

Performing to the best of one’s capabilities appears not to only be affected by the feedback-feedforward loop, as self-efficacy has been observed to correlate well with overall performance in a variety of different endurance sports (Burke & Jin, 1996; Martin & Gill, 1991, 1995; Okwumabua, 1985). Self-efficacy is defined as the “belief in one´s capabilities to organize and execute the courses of action required to produce given attainments” (Bandura, 1997, p. 3). It is a psychological factor which states a person’s confidence to perform a specific task at a given effort, such as the confidence to finish a 4 km cycle time trial (TT) at a certain time. Bandura (1994) argues that a greater self-efficacy is obtained through mastery experiences, vicarious experiences, verbal persuasion and emotional states. In mentioned order these terms refer to achieving success when facing adversity, witnessing similar people attain success in their pursuits, encourage heightened beliefs of self-efficacy through verbal persuasion, and reducing stress as well as controlling negative emotions (Bandura, 1977, 1994). Importantly, these sources vary in how effectively they influence self-efficacy, and subsequently increase task-specific confidence, with mastery experiences being the most effective one (Bandura, 1994). In other words, self-efficacy is an outcome of the interaction and regulation of external factors, prior experience and personal goals, and is used to set goals or anticipate performance, as shown in Figure 1 (Kane, Marks, Zaccaro, & Blair, 1996). Self-efficacy impacts the behaviour of athletes in sports, regulating pacing decisions, with high efficacy athletes being more willing to increase intensity to reach a goal they are falling short of (Bueno, Weinberg, Fernández-Castro, & Capdevila, 2008). This cyclical interaction between self-efficacy, personal goals and prior experience could lead to a greater performance (Earley & Lituchy, 1991). External factors such as information or encouragement from others, and the presence of competitors also play an important role in performance (Cooke, Kavussanu, McIntyre, & Ring, 2011; Marinho et al., 2015). This interaction of different factors results in an anticipation of exertion throughout the activity, with intensity being regulated accordingly to optimize performance (Ulmer, 1996).

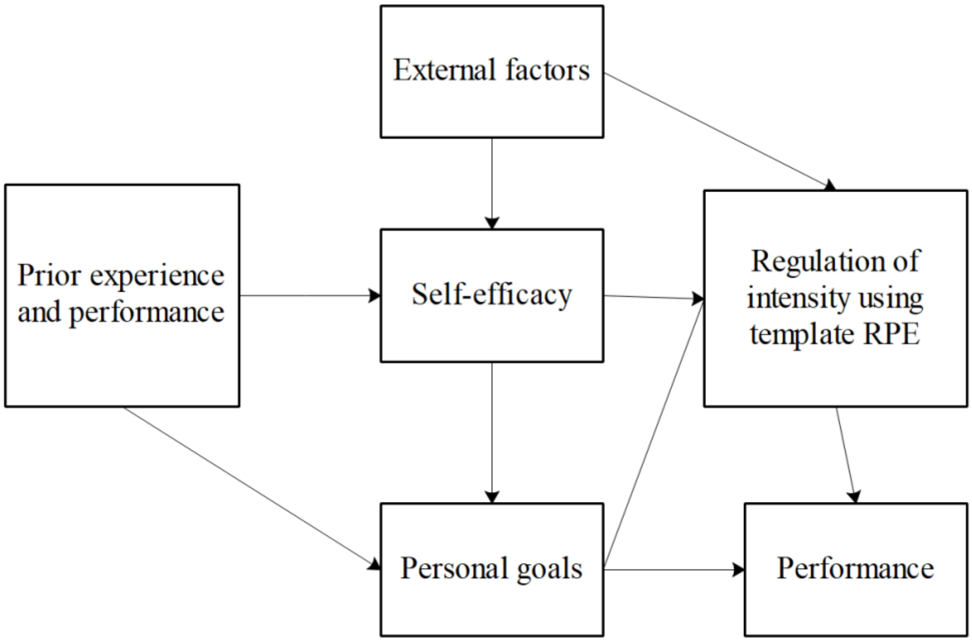

Figure 1: Factors influencing performance, self-developed model modified after (Kane, Marks, Zaccaro, & Blair, 1996; Noakes, 2011; Tucker, 2009)

The concept of a template RPE has been introduced as a tool to pinpoint the interaction between how fatigued an athlete feel at a given point of the activity, compared to their expected fatigue at this point prior to the start of the activity (Gibson et al., 2006; Tucker, 2009). This important aspect of intensity regulation is shown in Figure 1. Though a theoretical idea, this concept has been tested in vitro. The participants in a study were led to believe that their performance was 5% greater in a prior TT, and subsequently produced a higher than normal power output (PO) and speed during the first 5 km of a 20 km TT with accurate feedback (Micklewright, Papadopoulou, Swart, & Noakes, 2009). Before the start of an event athletes know how the effort is going to "feel", and by manipulating this feeling perhaps performance could be altered. As the event progress, the conscious RPE based on afferent feedback from numerous physiological systems, is continuously matched with the subconscious template RPE (Tucker, 2009). The extent of the mismatch between the subconscious and the conscious could be the most crucial factor when deceiving athletes. If the deception is appropriate the subconscious template RPE adapts and evolves, as were the case in two previous interventions applying a deception of 2% improvement in PO, resulting in acute decreased completion times (Stone et al., 2017; Stone et al., 2012). But if the mismatch is too great the conscious ceases the effort due to the sensation of fatigue, likely being the case in the 20 km TT. Although the participants paced themselves differently during the first 5 km, no change in overall performance was observed (Micklewright et al., 2009).

To get a better understanding on how different factors displayed in Figure 1 influence performance, prior interventions have used deception by providing athletes with inaccurate feedback on split times, speed, distance completed, end-point, prior experience, self-efficacy and intensity (Davies et al., 2016; Jones et al., 2013; Williams, Jones, et al., 2014). Deception has been defined as a "strategy modifying athletes´ expectations both before and during performance and acts to alter the athletes´ perceptions and knowledge of current or previous performances" (Williams, Jones, et al., 2014, p. 1442). Successful prior experiences and the concept of mastery experiences are closely intertwined, leading to the assumption that improving the belief of prior performance could increase self-efficacy, which in turn could improve performance. Positively manipulating self-efficacy has proven to lower internal work rate in running (Stoate, Wulf, & Lewthwaite, 2012), and increase overall endurance performance (Hutchinson, Sherman, Martinovic, & Tenenbaum, 2008; Miller, 1993). A few researchers have investigated the residual effects of deception on prior experience with mixed results, as only some riders experienced improvement in performance compared to baseline results (Jones et al., 2016b; Micklewright et al., 2009; Shei, Thompson, Chapman, Raglin, & Mickleborough, 2016). A distinction to make is that these studies intervened during the performance itself, done by manipulating the PO visually available to the riders. To our knowledge, no prior research has deceived participants postliminary to the effort, without meddling with the feedback during the effort. Thus, research is yet to fully discover how manipulation of prior experience affects self-efficacy and performance in future self-paced TTs.

Accordingly, the aim of this study was to determine whether performance deception in a prior 4 km self-paced cycle TT altered self-efficacy, time to completion (TTC) and power output in a subsequent TT of the same nature. It was hypothesised that the participants would attain a greater self-efficacy and thereby decrease their TTC in the final TT.

2.0 Methods

2.1 Participants

Five male participants with at least two years of cycling experience (12.0 ± 8.8 years) were recruited from a local cycling club (age: 36.8 ± 9.9 years; body mass: 77.6 ± 4.7 kg; height: 181.4 ± 5.4 cm) to participate in this study. All participants were regularly physically active (11.7 ± 3.6 hours of training per week). In order to achieve the true purpose of this study the participants were informed that they would partake in a study with the objective of examining how well a 4 km TT could estimate VO_{2max}. During the test period the participants were instructed that details regarding test results and procedures could not be discussed amongst themselves or others, and they were informed that they were free to withdraw from the study at any time without further explanation.

2.2 Design

A within-subjects experimental design was used in which all participants completed three 4 km cycle TTs to the best of their ability. Before each TT the participants completed a 20 min self-paced warm-up. The TTs were performed from a still start, and during the TTs they received continuous visual feedback on distance, PO, speed and time elapsed displayed as mean, real-time and peak values. Before testing began all subjects chose a cycle frame size (52, 54 or 56 cm) and a fitting seat height which could not be altered during the test period. All TTs were repeated with a recovery interval of 3-8 days and were performed at approximately the same time of day (± 4 hours). Participants were asked to refrain from vigorous training, as well as consumption of alcohol 24 hours prior to testing. Verbally reporting RPE and a countdown to start was the only communication between the test leader and the subjects during TTs.

2.3 Experimental procedures

Participants first completed a familiarization TT (FAM) in order to reduce the effects of familiarization (Sporer & McKenzie, 2007; Zavorsky et al., 2007). Subsequently a second TT (BL) of the same nature was completed to establish a baseline result. Immediately after BL the participants were individually informed of the deception, they were told that the feedback was inaccurately displayed by miscalibration of the cycle trainer, and the PO was actually 5%

greater. In reality this was not true, and the cycle trainer was correctly calibrated. The magnitude of the deception was based on prior research applying both 102% and 105% of mean PO from baseline TT (Stone et al., 2017; Stone et al., 2012). The final TT (DEC) was in part the intervention and the deception, all participants were informed that their display was calibrated and worked perfectly fine. The nature of BL and DEC demanded the trial order to be fixed, hindering random trial assignment. Upon completing the final TT all participants were individually informed of the true purpose of this study, and they were offered a VO_{2max} test as promised in the study they signed up for.

2.4 Apparatus

Subjects completed all TTs using a road bike mounted on a Computrainer Pro cycle trainer (RacerMate, Seattle, Washington) calibrated according to the manufacturer´s instructions. This electromagnetically braked cycle trainer has been shown to provide a relatively reliable measure of PO (Davison, Corbett, & Ansley, 2009; Mauger et al., 2009). The software (RacerMate Pro) continuously recorded PO, speed (km/h), time elapsed and distance (km). The subjective feeling of effort was recorded every 500 meters using Borg's rate of perceived exertion (RPE) scale from 6 to 20 (Borg, 1982). Heart rate was continuously monitored using a Polar M400 heart rate monitor (Polar Electro OY, Kempele, Finland), and HR_{max} was estimated according to the guidelines of the HUNT fitness study (Nes, Janszky, Wisløff, Støylen, & Karlsen, 2013). Self-efficacy was measured before BL and DEC using a customized questionnaire according to the guidelines of Albert Bandura´s guide (Bandura, 2006). In this questionnaire the participants were asked to rate their degree of confidence at intervals of 1 from 0 to 100 in completing the trials at different times (± 0, 3, 6, 9 and 12 seconds) based on their FAM performance (see Appendix 3).

2.5 Data analysis

Statistical analysis was conducted using GraphPad Prism V.8.3.0 (San Diego, CA, U.S.). The effects of deception on PO and time to completion (TTC) between trials was analysed by using a two-tailed independent t-test. Means of PO, speed, RPE, HR and percentage of HR_{max} were calculated for intervals of 500 meters (starting at 0-500 meters) to investigate differences in pacing strategies and intensity, the results were evaluated using a repeated measures two-way ANOVA with a Sidak *post hoc* analysis. The self-efficacy score was summed and divided by the total number of items as recommended by Bandura (1997), and the results were evaluated using a repeated measures two-way ANOVA with a Sidak *post hoc* analysis. In addition, the individual data on self-efficacy was compiled and analysed using a two-tailed independent t-test between BL and DEC in order to investigate further differences. This method of analysis does not match the recommendations of Bandura (1997). Statistical significance was accepted as $p<0.05$.

3.0 Results

3.1 Performance variables

TTC in BL (357 ± 18 s) and DEC (357 ± 20 s) did not significantly differ between trials ($p=0.979$). Neither did PO in BL (345 ± 40 W) and DEC (345 ± 43 W) significantly differ between trials ($p=0.996$). Individual results for TTC and PO in both trials are found in Appendix 1.

3.2 Pacing

A two-way ANOVA revealed no significant main effect for PO ($p=0.964$), and no significant effect for interaction distance x power output ($F=1.297$, $p=0.325$). PO measured at intervals of 500 meters for BL and DEC is displayed in Figure 2(A), and individual data is illustrated in Appendix 1. The same analysis was applied to speed revealing no significant main effect ($p=0.850$), and no significant effect for interaction distance x speed ($F=1.333$, $p=0.315$). Speed measured every 500 meters is displayed in Figure 2(B).

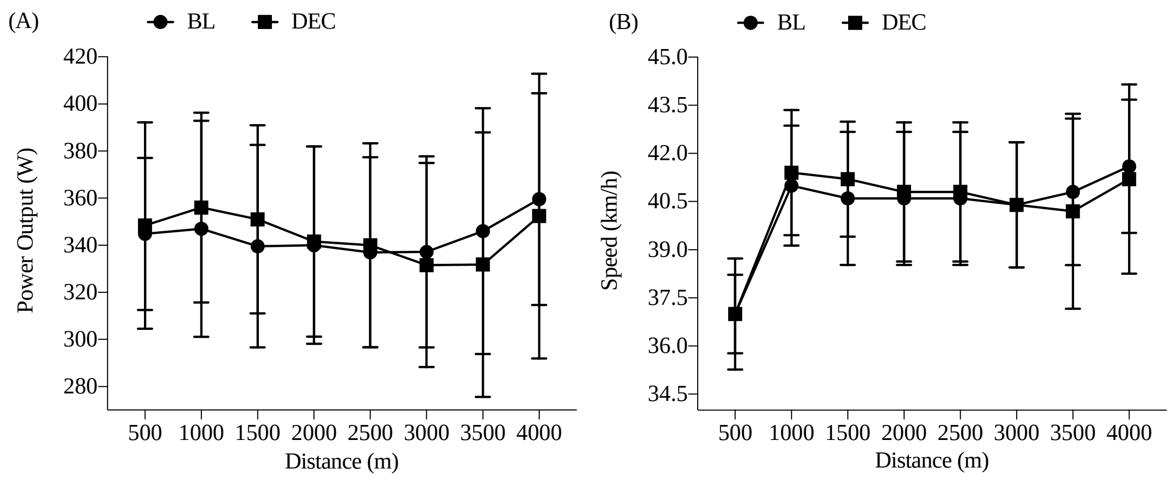

Figure 2: (A) Mean ± SD power output (PO) every 500 meters during baseline (BL) and deception (DEC) trials, and (B) mean ± SD speed every 500 meters during BL and DEC

3.3 Intensity variables

A two-way ANOVA revealed no significant main effect for RPE (p=0.131), and no significant effect for interaction distance x rate of perceived exertion (F=1.983, p=0.184). RPE measured prior to the effort, and every 500 meters for BL and DEC is displayed in Figure 3(A). As to HR, a two-way ANOVA revealed no significant main effect (p=0.207), and no significant effect for interaction distance x heart rate (F=1.488, p=0.308). Nor did the same analysis reveal any significant main effect for percentage of HR_{max} (p=0.205), and no significant effect for interaction distance x percentage of HR_{max} (F=1.490, p=0.308). Mean percentage of HR_{max} measured every 500 meters for BL and DEC is displayed in Figure 3(B).

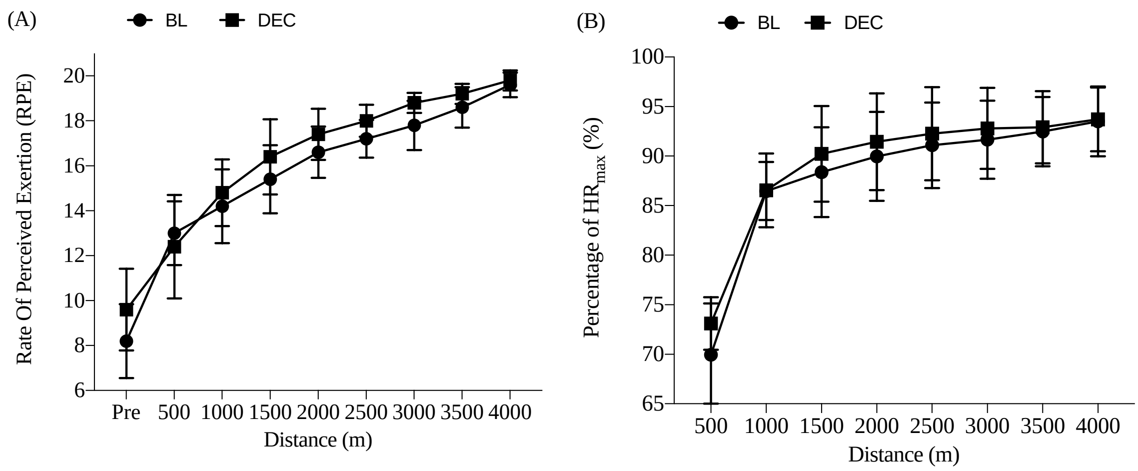

Figure 3: (A) Rate of perceived exertion (RPE) prior to, and for every 500 meters during baseline (BL) and deception (DEC) trials, and (B) percentage of max heart rate (HRmax) every 500 meters during BL and DEC

3.4 Self-efficacy

A two-way ANOVA revealed no significant main effect for self-efficacy (p=0.051), and no significant effect for interaction completion time x confidence (F=2.063, p=0.211). The compiled self-efficacy score was analysed using a two-tailed independent t-test, showing a significant difference (p=0.036) between BL (448 ± 105) and DEC (646 ± 141). Mean degree of confidence for different completion times between trials and compiled self-efficacy scores are displayed in Figure 4(A) and Figure 4(B), respectively. Individual data for mean and compiled self-efficacy is illustrated in Appendix 2.

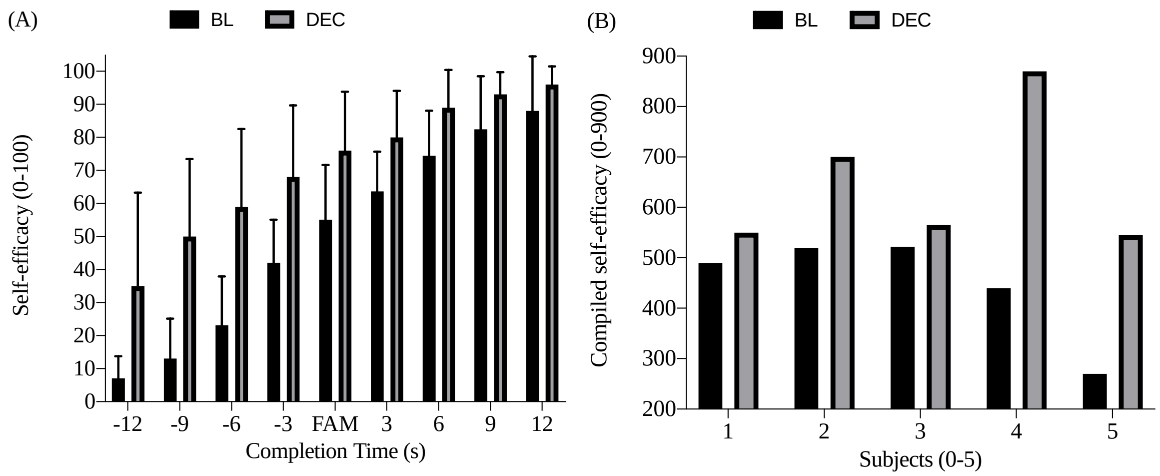

Figure 4: (A) Self-efficacy as measured in degree of confidence for different completion times prior to baseline (BL) and deception (DEC) trials, and (B) compiled self-efficacy score for each subject prior to BL and DEC

4.0 Discussion

4.1 Findings

The aim of this study was to determine whether performance deception in a prior 4 km self-paced cycling time trial altered self-efficacy and performance in a subsequent time trial of the same nature. Making the participants believe that their power output was 5% greater in a prior time trial did not significantly alter mean self-efficacy, time to completion or power output in a subsequent time trial. Neither were RPE, heart rate or pacing strategy significantly altered by the deception. Contrarily, a significant difference was observed in compiled self-efficacy between BL and DEC (p=0.036). The fact that RPE increased linearly throughout the effort in every trial as illustrated in Figure 3(A), and mean RPE for BL and DEC in the final 4000m split registered close to maximal values (19.6 ± 0.5 and 19.8 ± 0.4, respectively) indicate that the participants put forth a maximal effort and was highly motivated as previously discovered by Marcora and Staiano (2010). These results suggest that a deception of this nature does not alter performance, but it may strengthen the self-efficacy of athletes.

Previous interventions have successfully improved completion time with a mean wattage deceit of 2%, when using a competitor displayed as an avatar on a computer screen (Shei et al., 2016; Stone et al., 2017; Stone et al., 2012). However, the presence of a competitor has been shown to improve performance in itself (Corbett et al., 2012; Stone et al., 2012; Williams, Massey, et al., 2014), perhaps acting as a confounder regarding the components of performance gains (Jones et al., 2016a). In addition, the number and behaviour of the competitors have proven to influence pacing strategy differently (Jones et al., 2016a; Konings, Schoenmakers, Walker, & Hettinga, 2016). This reflects the presence of a central governor executing pacing decisions not only based on internal feedback, but also external (Noakes, 2011). The effect of a competitor could also be a source that strengthens self-efficacy, being a vicarious experience for the participants (Bandura, 1994). Using the method of deception described in the present study, and excluding the use of avatar competitors, the causality of the improvement could be more apparent. Our findings suggests that without the aid of a competitor as used by Stone et al. (2017), a deception of 5% power output is too large. Furthermore, our deceit was based on mean power output and not that of an individual pacing profile, as one ideally would if competing against own previous performances (Corbett et al., 2012; Stone et al., 2012; Williams, Massey, et al., 2014). Pacing oneself using a set RPE, rather than aiming for a mean power output, has been shown to lower internal measures of physiological strain in submaximal efforts (Lander, Butterly, & Edwards, 2009). These results suggest that pacing based on perception of effort is more efficient compared to pacing based on a mean power output goal. Accordingly, future studies should take use of a natural pacing profile to enable the greatest possible performance outcome.

Although the mean difference in self-efficacy between trials was not statistically significant ($F=7.571$, $p=0.51$), it was still great enough to suggest a trend as seen in Figure 4(A). However, there was a significant difference between BL and DEC when the self-efficacy scores were compiled ($p=0.036$) as seen in Figure 4(B). As all the participants had a greater score prior to DEC compared to BL, the significance is probably due to the lack of deviations when assessing compiled data (see Appendix 2). In the absence of a control group the difference could be due to the effects of familiarization, but prior research has shown that self-efficacy in a control group remains unchanged between trials similar to the present study (Hutchinson et al., 2008). Hence, one could argue that the deception resulted in a boost of morale amongst the participants which culminated in a greater degree of confidence prior to DEC. As the participants never actually experienced the 5% improvement in power output, in a way they were only persuaded to believe the improvement, it is unknown whether the increase in self-efficacy was due to a mastery experience or verbal persuasion (Bandura, 1994). It is possible that a greater self-efficacy led to a more aggressive pacing strategy in the opening stages of DEC as the greatest split occurred at 1000 m in DEC, whilst in BL it occurred at 4000 m achieving a PO of 356 ± 40 W and 360 ± 45 W (see Appendix 1), respectively. Individuals with a high self-efficacy are more likely to set themselves more challenging goals (Locke & Latham, 2002), this may have been the case as DEC resulted in early fatigue for the participants who started off too hard and finished too weak.

In addition, though not statistically significant, the differences in mean power output between BL and DEC at splits 1500 m (-11 W; p=0.132) and 3500 m (14 W; p=0.232) suggests a different pacing strategy or regulation between trials as portrayed in Figure 2(A). The same initial alterations in pacing as observed by Micklewright et al. (2009). In both BL and DEC, the participants performed an end-spurt as displayed in Figure 2(A), suggesting that the adjustment of intensity did not occur as a repercussion of failure of homeostasis in the working muscle. Rather it seems that the reduction in power output arose in advance to avoid such failure as a consequence of the mismatch between anticipated and perceived effort, since they were able to reinvigorate the power output in the last 500 m of the DEC. This behaviour matches the theory of the CGM and a template RPE (Noakes, 2011; Tucker, 2009). However, the development in RPE did not differ significantly between BL and DEC, suggesting that intensity was not regulated based on perceived exertion. These results differ from those of Micklewright et al. (2009), as the participants in the deception condition reported 1-2 points greater RPE compared to the participants in both the accurate and the blind conditions. Further research is necessary in order to fully understand the role of RPE in pacing strategies.

4.2 Methodological considerations

Our sample was small (n=5), and they had varying experience with the use of wattage in training as a measurement of performance. We sought to accommodate this when collecting data on self-efficacy by rating their degree confidence in different completion times (see Appendix 3), rather than mean power output. It is plausible that not all participants fully understood the implications of a 5% increase in power output. However, one could argue that the participants interpretation of the increase in power output is trivial, as the goal of the deception was to increase self-efficacy by manipulating prior experience. Though not significant (p=0.051), this tendency of a greater self-efficacy in DEC compared to BL, indicates that the deception perhaps was successful in altering self-efficacy. Furthermore, the small sample size likely influenced the statistical analysis, in effect making it challenging to determine differences between trials. The formalities concerning inclusion criteria with no vigorous exercise within 24 hours of time trial were enforced, but we did not monitor the participants weekly training load, nor did we fully define “vigorous”. Consequently, two participants reported in retro not feeling fully rested from personal training activities prior to DEC.

4.3 Practical implications

Interestingly, the CGM postulates that our central nervous system determines performance outcome. Assessing real-life factors such as (e.g.), competitors (Cooke et al., 2011; Corbett et al., 2012), sleep deprivation (Arnal et al., 2016; Keramidas, Gadefors, Nilsson, & Eiken, 2018), prior experience (Mauger et al., 2009), temperature (Van Cutsem, Roelands, De Pauw, Meeusen, & Marcora, 2019) and other centrally acting performance modifiers (Noakes, 2011) is essential in order to further deepen our understanding of performance and fatigue. Our bodies need oxygen to perform, and VO_{2max} values tell us a lot about how good we are at consuming and making use of oxygen. But athletes, coaches and researchers alike should consider a broader spectrum of factors in the attempt to improve performance. Endurance research should also include psychological measurements in order to understand how our psychology and physiology interacts regarding performance (Venhorst, Micklewright, & Noakes, 2018). Most research depend on performances accomplished in laboratory settings, scientists and researchers can only observe real-life performances and interpret it accordingly. Eliud Kipchoge recently ran the marathon in under 2 hours setting an unofficial world record (Vaughan, 2019), a historical feat no doubt. His performance enables other athletes to view it as a possible achievement, in the same way as Dr. Roger Bannister ran a mile in less than 4 minutes enabled others to repeat his performance (Silver, 2018). Perhaps these mental barriers could be disabled by deception on prior experience, and in effect the athlete only has to replicate a past performance.

When studying the performance enhancing effects of self-efficacy, competitors and other components of the CGM, the question of stacked effects arises. Even though a throng of factors have been shown to improve performance in endurance settings (Noakes, 2011), it is unknown whether these benefits would stack up without overall diminishing returns. Swart et al. (2009) found that ingesting an amphetamine improved cycling performance at 16 RPE, as the participants cycled 32% longer than the control group before their power output dropped to 70% of their starting value. The effects of adding competitors to this condition is unknown, therefore the question of stacked effects needs to be further explored. There might be a finite extent to which the central governor could be pushed by interventions seeking to improve performance, before overall diminishing returns eliminate additional beneficial effects. Endurance research should help athletes and coaches develop and evolve in order to perform at a superior level. The goal of future research should be to bring athletes as close as possible to homeostasis failure in order to maximise potential performance, of course without impairing health or violating rules of fair play. By taking advantage of centrally acting performance modifiers, and further explore the concept of stacked effects the athletes of tomorrow have a greater possibility of succeeding.

5.0 Conclusion

This study demonstrates that deception of prior experience with an improved performance of 5% in power output does not alter mean self-efficacy or performance in a subsequent time trial of the same nature. A compiled self-efficacy score revealed a significant difference between BL and DEC, suggesting that the participants had a greater confidence in their own abilities following the deception. Due to insignificant individual results from this study and successful prior research, it seems reasonable to assume that a deceit of prior experience may be successful under optimal conditions. We suggest that future research on this topic should include elite athletes who are accustomed to wattage as a tool in training, and they should use their own bikes in order to eliminate any performance deficit. Further, the magnitude and type of deception must be explored in the interest of understanding how athletes best respond to these factors. Finally, a number of centrally acting performance modifiers must be examined collectively and separately in order to understand how they interact with each other, and how much they improve performance independently.

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Appendix 1 – Performance outcomes and power output

Performance outcomes

Table 1: Time to completion (TTC) and mean power output (PO) for each subject in both baseline (BL) and deception (DEC) trials.

Variable	Subject 1		Subject 2		Subject 3		Subject 4		Subject 5	
	BL	DEC	BL	DEC	BL	DEC	BL	DEC	BL	DEC
TTC (s)	347	349	352	351	345	348	388	392	351	346
PO (W)	374	370	349	353	373	365	276	269	351	366

Power output

Table 2: Mean power output (PO) calculated from intervals of 500 meters (starting at 0-500 meters) for each subject in both baseline (BL) and deception (DEC) trials. In addition, the mean ± SD for all intervals and both trials are displayed.

Power Output	Subject 1		Subject 2		Subject 3		Subject 4		Subject 5		Mean ± SD	
	BL	DEC	BL	DEC	BL	DEC	BL	DEC	BL	DEC	BL	DEC
500 m	386	393	332	356	372	378	313	281	321	334	345 ± 32	348 ± 44
1000 m	396	383	352	368	372	389	274	289	341	351	347 ± 46	356 ± 40
1500 m	368	378	350	369	369	371	265	281	346	356	340 ± 42	351 ± 40
2000 m	370	359	350	367	375	360	271	270	334	352	340 ± 42	342 ± 40
2500 m	368	362	349	365	359	355	267	263	342	355	337 ± 40	340 ± 43
3000 m	360	353	349	340	365	344	266	256	346	365	337 ± 41	332 ± 43
3500 m	360	352	343	340	373	347	259	236	395	384	346 ± 52	332 ± 56
4000 m	378	372	365	312	391	369	281	276	383	433	360 ± 45	352 ± 60

Appendix 2 – Self-efficacy

Table 3: Self-efficacy score for each individual, and mean ± SD, regarding every completion time in both baseline (BL) and deception (DEC) trials. In addition, the compiled self-efficacy score is illustrated for BL and DEC

Completion time	**Subject 1**		**Subject 2**		**Subject 3**		**Subject 4**		**Subject 5**		**Mean ± SD**	
	BL	**DEC**	**BL**	**DEC**	**BL**	**DEC**	**BL**	**DEC**	**BL**	**DEC**	**BL**	**DEC**
-12	15	20	10	20	10	30	0	85	0	20	7 ± 6	35 ± 25
-9	25	40	20	50	20	40	0	90	0	30	13 ± 11	50 ± 21
-6	30	40	40	70	30	50	10	95	5	40	23 ± 13	59 ± 21
-3	50	50	50	80	50	60	40	100	20	50	42 ± 12	68 ± 19
Fam (0)	60	60	60	90	75	65	50	100	30	65	55 ± 15	76 ± 16
+3	60	70	70	90	80	70	60	100	48	70	64 ± 11	80 ± 13
+6	80	90	80	100	82	75	80	100	50	80	74 ± 12	89 ± 10
+9	80	90	90	100	85	85	100	100	57	90	82 ± 14	93 ± 6
+12	90	90	100	100	90	90	100	100	60	100	88 ± 15	96 ± 5
Compiled	490	550	520	700	522	565	440	870	270	545		

Appendix 3 – Self-efficacy measurement

Appendix 3 contains the questionnaire that was used to measure self-efficacy before the baseline (BL) and deception (DEC) trials. The familiarization (FAM) trials were individually used as a reference point, and other possible outcomes was calculated based on this performance.

Self-Efficacy Scale

Participant: TT:

You are about to complete a 4 km cycle time trial, how certain are you in your ability to complete the time trial in the times described below?

Rate your degree of confidence by recording a number from 0 to 100 using the scale given below:

0	10	20	30	40	50	60	70	80	90	100
Cannot do at all					Moderately certain can do					Highly certain can do

Completion times	Certainty (0-100)
-12 sec	
-9 sec	
-6 sec	
-3 sec	
TTC in FAM	
+3 sec	
+6 sec	
+9 sec	
+12 sec	