

Deception studies manipulating centrally acting performance modifiers: A review

Emily L Williams¹, Hollie S Jones¹, S Andy Sparks¹, David Marchant¹, Dominic Micklewright² and
Lars R. Mc Naughton¹

1 Edge Hill University, Ormskirk, Lancashire, UK

2 University of Essex, Colchester Essex, UK

Address all Correspondence to:

Professor Lars Mc Naughton

Edge Hill University

Department of Sport and Physical Activity

Ormskirk

Lancashire L39 4QP

ENGLAND

Email: lars.mcnaughton@edgehill.ac.uk

Telephone: +441695 657296

CONFLICT OF INTEREST AND SOURCE OF FUNDING

The authors have no conflicts of Interest

There are no sources of funding for this work

ACCEPTED

Abstract Athletes anticipatorily set, and continuously adjust pacing strategies prior to and during events, in order to produce optimal performance. Self-regulation ensures maximal effort is exerted in correspondence with the endpoint of exercise, whilst preventing physiological changes that are detrimental and disruptive to homeostatic control. The integration of feedforward and feedback information, together with the proposed brain's performance modifiers, are said to be fundamental to this anticipatory and continuous regulation of exercise. Manipulation of central, regulatory internal and external stimuli has been a key focus within deception research, attempting to influence the self-regulation of exercise and induce improvements in performance. Methods of manipulating performance modifiers such as unknown task endpoint, deceived duration or intensity feedback, self-belief or previous experience creates a challenge within research, as although they contextualise theoretical propositions, there are few ecological and practical approaches which integrate theory with practice. Additionally the different methods and measures demonstrated in manipulation studies have produced inconsistent results. This review examines and critically evaluates the current methods of how specific centrally-controlled performance modifiers have been manipulated, within previous deception studies. From the 31 studies reviewed, 10 reported positive effects on performance, encouraging future investigations to explore the mechanisms responsible for influencing pacing, and consequently how deceptive approaches can further facilitate performance. The review acts to discuss the use of expectation manipulation not only to examine which methods of deception are successful in facilitating performance, but also to understand further the key components used in the regulation of exercise and performance.

Introduction

Paragraph Number 1 Pacing strategies are set according to an athlete's expectations of the task they are required to perform. Psychological and physiological state, expected distance, previous experience, motivation and self-belief are all informative factors used for a calculation of initial pace (44). Once the exercise task begins, on-going adjustments to pace operate via a feedback control loop, including both endogenous physiological information, and exogenous sensory information about the external environment (68,69). Physiological responses to exercise have been suggested to occur as part of a complex integration system, where physiological changes interact with each other through feedforward and feedback systems (52,62). The brain has a central control function whereby it integrates complex physiological information fed back from the periphery with exogenous sensory cues, such that feedforward regulation of exertion is sustainable given the proximity of the athlete to the endpoint, and that homeostasis is maintained (52,62).

Paragraph Number 2 The setting of pace is based upon prior knowledge and experience of the task, commonly referred to as the concept of teleoanticipation (68). It has been suggested that teleoanticipation has a greater influence on pace than physiological feedback (1), supported by the observation that athletes maintain submaximal levels of work for the majority of an event then suddenly increase effort towards the end (67). However, in very long duration events there is a high degree of uncertainty regarding changes in the environment and physiological status, which may demand a more responsive approach to pacing than the execution of a pre-formed anticipatory strategy (46). During extended duration events, a range of physiological, psychological and tactical factors are integrated and processed by the brain as a central mechanism to determine pacing strategies (50).

Paragraph Number 3 Task expectations alter the feedforward control of pacing strategies in an attempt to optimise performance. Athletes also continuously compare expected perceptions of exertion with how they actually feel during an event. The brain's central control modifies perceptions and expectations to produce optimal performance via internal and external stimuli, that govern exercise regulation. Figure 1 illustrates a number of centrally acting performance modifiers (44) that integrate with the feedforward and feedback regulation control-loop, each of which have previously been deceptively manipulated in an attempt to understand their influence and consequential importance in pacing and performance regulation. Deception is a strategy modifying athletes' expectations both prior to and during performance, and acts to alter the athletes' perceptions and knowledge of current or previous performances. There is still confusion regarding this issue in part because many different experimental designs have been used and to date there has been limited consolidated appraisal of what the findings of such studies mean. A recent review has aimed to provide clarity of the physiological and psychological effects of different deception methods; specifically the comparison of 'feedforward' and 'feedback' manipulations (28). The present review provides an additional mechanistic appraisal of these manipulation techniques upon specific performance modifiers. It evaluates the use of deception techniques to highlight the importance of such performance modifiers within the regulation of effort and pace during exercise. The studies are categorised in accordance to the modifier investigated, with the key approaches and findings summarised in Table 1.

Scope of the Review

Paragraph Number 4 The review of literature was conducted using electronic databases; PubMed, Google Scholar and EBSCO for articles reporting deception manipulations upon exercise and performance, up to the latest date of September 2013. The computer search was for English-language articles inclusive of, but not restricted to, the following search terms:

“deception”, “performance”, “expectation”, “manipulation”, “pacing”, “fatigue”, “perception”, “exertion”, “central-modifiers”, “**feedback**”, “attention” and “motivation”. The inclusion criteria was determined as studies employing deceptive manipulations upon centrally-acting performance modifiers, namely; knowledge of endpoint, intensity and time deception, **placebos**, self-belief, psychological influences, presence of competitors and prior experience. This approach yielded 31 studies with appropriate inclusion criteria.

Knowledge of Endpoint

Paragraph Number 5 It is proposed that the subconscious brain takes into account the projected ‘finishing points’ and the afferent feedback from the muscles to regulate an appropriate pacing template (21). Manipulation of exercise duration or distance endpoint is a deception method aimed to investigate the theory of teleoanticipation. Since optimal performance and pacing strategies are suggested to be pre-set upon a judgement of the endpoint, if the endpoint knowledge is unknown, incorrect or unexpectedly changed, in-task regulation using feedforward and feedback resources is affected (See Table 1).

Unknown Duration

Paragraph Number 6 When an athlete is unaware of the absolute distance or duration of a task, they reduce their work rate and perform more economically in their use of physiological resources, to maintain a reserve in anticipation of the endpoint (4,13,16,34). Once the endpoint is known and approaching, and the task is no longer an open-loop activity, caution subsides and work rate increases (61). Performance is then actively regulated using a calculation of the momentary sensations, and the relative amount of the event remaining (18). It has been proposed that the employment of a ‘Hazard Score’ created from the product of momentary-RPE with the fraction of distance remaining, links perceptual experience to distance remaining (18). The closer the athlete gets to the known endpoint, the higher they will allow RPE to rise,

given that the risk in doing so is within a calculation of the success-failure equation (61). This is clearly demonstrated when participants are only given instruction of their endpoint in the last kilometre of the bout (58). When the endpoint is revealed only when informed to terminate the task, thus the decrease in uncertainty is understandably inhibited and under-performances are seen (20). This is due to the lower initial work pace, and underutilisation of available resources.

Paragraph Number 7 Whilst no significant differences in power output, heart rate and pacing were identified in previous research during unknown trials (41, 64), subconscious attempts to conserve energy were indicated by significant reductions in heart rate and perceived exertion during other unknown endpoint manipulations (19). This concurs with the proposed principles of teleoanticipation, where knowledge of duration has been found to effect perceived exertion (17) and more specifically, the uncertainty of the endpoint influences a lower RPE to avoid premature fatigue (61). Participants have been consistently shown to perceive the same exercise intensity to be lower, producing lower RPE values, if they were expecting the duration to be longer (3,4,49).

Paragraph Number 8 Moreover, when participants are unaware of the task duration, they tend to have a greater dependence on afferent feedback from the periphery (13). This is supported by reports of afferent feedback having a greater emphasis as an exercise regulator (34). Conversely, false expectations of the distance or duration remaining, prevent the appropriate interpretation of physiological afferents (2,61), subsequently leading to under-performances. An under-performance represents the product of incorrect peripheral feedback, controlling the rate of increase in RPE. When the endpoint knowledge is omitted, it prevents the successful exercise regulation of allowing peak-RPE values to coincide with the endpoint of exercise.

False Information about Task Duration

Paragraph Number 9 Significant changes in RPE are also found during closed-loop activities, when the expectation of exercise **endpoint** has been manipulated (3,4,49), illustrated in Table 1. When participants are deceived about the duration of a task, they tend to perform on the basis of expected rather than actual distance (2,45). Participants who are incorrectly informed in this way perform slower (2), most likely because of disruptions to the ‘template-RPE’, set in anticipation of the false duration (69) not corresponding with the ‘actual-RPE’ elicited during the exercise (61). This supports the proposition that perceived exertion is not only the product of combined internal afferent signals, but also external and environmental cues (47,67).

Paragraph Number 10 When incorrect information regarding **absolute** duration is supplied, performance times vary but, there are limited effects on physiological measures such as heart rate and power output (41). Participants completed each time trial according to a pre-determined intensity, which they perceived to be optimal to perform the expected distance. This supports the notion that athletes perform on the basis of the perceived rather than actual distance remaining (41,45). This adds further emphasis to the importance of anticipation of the expected endpoint, used within the feedforward central control of pacing for optimal performance (43,52,67).

Unexpected Changes in Duration

Paragraph Number 11 Since it is suggested pacing is based on the anticipation of the expected endpoint, when an alternative task duration is announced during performance disruption to the pre-established template occurs. Methods of deception, as outlined in Table 1, announcing an unexpected modification to the duration during a performance, have previously led to under-performances (3,4,19). Although these methods create under-performances, the adopted pacing strategy differs depending whether it is an addition or a reduction in the duration. When an unexpected stop in duration is presented to athletes an underutilisation of resources is observed (3,61). This would suggest that the employment of the ‘endspurt’ is halted, hindering

performance and not fully exploiting the pacing template pre-set in anticipation of the informed, albeit incorrect, endpoint. Similarly, participants act with the expectation to complete the incorrectly informed distance, utilising all available resources to produce optimal performance. Therefore an unexpected addition of duration would subsequently produce an early termination or a disruption of homeostasis before the true end of the exercise bout (4,61).

Paragraph Number 12 The influence of this deception on RPE was evidenced only at the announcement of a change in duration (3,4). Whilst RPE was affected, physiological stress such as heart rate (HR) was not, suggesting that these changes in RPE profiles could not be limited to physiological mechanisms (47,51). It has been proposed that RPE changes could have been influenced by psychological emotions associated with the change in expectation of duration (1,54), supported in an additional study where increases in anger and frustration have been observed (13). Such findings are in agreement with the suggestion that physical sensations measured using RPE are distinct from sense of effort (59). It is important to note that a previous investigation found expected exercise length had little effect on RPE (17), which is in disagreement with other literature (3,4,19). The manipulation within this investigation was, however, slightly different as it involved shifting from an unexpected change in duration to an unknown duration. The results then reflect previous effects found on RPE when performing exercise with an unknown endpoint (13).

Paragraph Number 13 Whilst the methods used to deceive participants about task endpoint are not reflective of what happens in real race situations, such investigations have provided important insights about how knowledge and expectations of the endpoint are used to regulate effort. When deceived of a task's endpoint participants are seen to underperform either in reservation of resources as a precautionary measure, or they are unable to interpret afferent feedback correctly. Furthermore, deception studies have established that an athlete's pacing regulation is pre-set in correspondence with the perceived, albeit manipulated, endpoint.

Therefore the pacing strategy adopted is inappropriate for the actual duration performed. Additionally influences upon RPE were found to correspond in line with the suggestion that perceived exertion is related to the proportion of time or distance remaining (3,4,16,18,19,21,41,49).

Time Deception

Paragraph Number 14 Previously discussed deception studies modifying task endpoint expectations have provided deceived information through feedforward and feedback methods, and during both open and closed loop activities. However other methods investigating time expectations have employed time deceptions only through feedback information and only during ecological closed-loop events (Table 1). Within these studies methodological differences are seen regarding the presentation style of the feedback. Performance times are either blinded to participants, or displayed as accurate/inaccurate continuous or splits feedback. The different methods resulted in different outcomes. Inaccurate time splits did not affect performance (1,12), whilst continuous false time conditions did influence performance outcomes (40). However, this influence was upon time to exhaustion (40); a measure of exercise capacity, rather than time trial performance (1,12).

Paragraph Number 15 Although there was no difference in performance times across the time deception studies, the pacing strategy employed differed (36,60,65). Similar to having no knowledge of the endpoint prior to the activity commencing, when receiving inaccurate or blind time feedback during an exercise bout, pacing strategies are performed conservatively until better reference information is available and the endpoint proximity becomes more certain. Less exertion was performed at the beginning of the bout (40), and a greater endspurt was seen in a slower clock condition (60). Each illustrative of a reservation until able to allow the associated risk of increased exertion, approach the upper boundaries of the RPE-template.

Intensity Deception

Paragraph Number 16 Another approach in deception studies has been to misinform participants about the intensity at which they are performing. Similar to pre-task deceptions of duration, physiological (HR) variables, psychological (RPE) variables and performance times were not affected by manipulations of pre-task performance intensity (24,48). When participants were informed their subsequent trial would be two RPE values below their previous trial scores, it was found to have no influence on performance. Participants used actual judgement of sense of effort rather than relying on previous experience and knowledge of feelings (48). This is in contrast to when provided with incorrect distance knowledge. This actual judgement of regulation during exercise is inconsistent with the teleoanticipation principle (43,69) and template-RPE theories (61). As a consequence when deceived by intensity, the employment of pre-setting of pacing strategy based upon expectation is not evidenced.

Paragraph Number 17 Some studies have found improvements in performance when manipulating intensity feedback during the event rather than providing intensity information prior to commencement (39,55,57). These studies allowed no prior knowledge of, or any influencing expectation of the intensity; the deception was simply employed by manipulating the feedback received during the trial. It has been demonstrated pacing (39,57), performance and RPE (57) were positively influenced by deception of intensity. Evidently the differences in the presentation of the manipulation provide different outcomes; with feedback manipulation of intensity, during performance, having a greater facilitation on performance than feedforward intensity manipulations.

Influence of methods and modalities of deception

Paragraph Number 18 Contrasting results are seen in the use of different presentation modes; splits or continuous, in previous deception studies. Studies providing accurate and inaccurate

feedback splits, of distance or time, found no effect on performance in trained (1,12) and untrained participants (19). However others have provided continuous time or intensity feedback, which have seen improvements (39,40,57). This disparity and confusion could be due to differences in the type of feedback given. An evaluation of studies using time (12,40,60,65) and distance feedback (1,20), show no effect upon performance, conversely studies that manipulate intensity feedback (39,57) observe performance alterations. This could be interpreted as intensity information having a greater influence on performance regulation than centrally-controlled modifiers such as duration or distance knowledge. Additionally it could be due to the varying individual reliance on different feedback variables, as trained athletes, when offered, did not use heart rate as a physiological external cue to regulate their pacing (41). Furthermore, it remains unclear whether visual or verbal feedback impacts performance differently, nonetheless the use of an avatar compared to numeric feedback is assumed to provide additional motivation, stimulated by a “head-to-head” competition (15). Visual displays of feedback are suggested to buffer physiological perceptions when performing, as the perceptions of internal sensations are influenced by external environments and their effect on subjective emotional experiences (47).

Paragraph Number 19 A further explanation for the inconsistency in findings could be due to the magnitude of deception used, regardless of the type of information given; distance, time or intensity. Although similar ranges of magnitudes have previously been employed when trying to deceive the feedback of a performance, differences in results have been found. No effects upon performance times have been seen when using deception feedback magnitudes of 5% (12,39,65) and 10% (60), although all deceptions went undetected. The limited effects upon performance could be that the magnitude was too marginal to be effective, such that the decrements or increments produce a too small a range between actual and the false feedback presented (1). In contrast, a 12% deception appears too large a discrepancy to be

subconsciously undetected (2). The difficulty in comparing the deception methods is compounded by both the wide variety of methods used, as well as the magnitude of manipulations employed (Table 1). The outcomes of deceptive manipulations are specific to the duration and intensity of the exercise tasks, highlighting further difficulties determining optimal deceptive manipulations whilst ensuring such strategies remain undetected.

Paragraph Number 20 Positive results were elicited and deception undetected when using a 2% increase in required power output, during a cycling time trial (57). In this case 2% was employed as it represents the smallest worthwhile change in performance during the given time trial distance (56). This, alongside the suggestion that the typical error of time trial performance is less than 5% (25), supports the previous results of ineffective deception magnitudes of greater than 5%. Whilst confounding results are apparent within studies manipulating task expectations via endpoint knowledge, duration and intensity (performance characteristics); these previous studies have limited clarity due to the lack of psychological considerations for such expectancy effects. Whilst the full effects have not been investigated or quantified, previous theories can be drawn upon for suggestive impacts of the different approaches. Such that proposed mediators of perceived exertion and its effect on pacing and fatigue are suggested to be task expectancies, emotions, previous experience and memory (51).

Placebos

Paragraph Number 21 Task expectancies, prior to and during performance, have also been manipulated by using prescribed substances or placebos. Expectancies are an integral part of the placebo effect (29) and researchers conclude that both positive and negative beliefs associated with placebos and their effects, significantly affect performance (12). Psychological variables such as motivation, expectancy and the interaction of these constructs with physiological variables might be significant factors in driving positive and negative outcomes

(12). The investigation of placebos has become more popular in sport and exercise science; however the use of the placebo effect in sports is still in its infancy (11). There are also, many speculative anecdotal examples of what may be legitimate placebo effects (12). Expectations of substance-specific effects seem to trigger many physiological and psychological reactions (30), independent of the substance given (22,29,63). Within this type of expectancy manipulation, the deception element of the methodology is known, with the participant's acknowledgement prior to the investigation, of a substance's possible effects. This deception method is different to others explored within this review, in which the participants are fully unaware of any undue effect on performance that is due to take place. Although a different method, in that its prescription to enhance expectancies is known and a substance is administered, the 'placebo effect' is a positive outcome resulting from the belief that a beneficial treatment has been received (11). Moreover an athlete's recognition that the potential false beliefs could impact performance is of interest for sport scientists (10). A full review of the previous investigations employing placebo deceptions is beyond the scope of the current review, however, a recent comprehensive review provides more specific insight (11).

Self-belief and Psychological Influences

Paragraph Number 22 Athletes' expectancies of the task have also been altered via instructions (32), praise (27) or enhanced expectancies of a method (32). Changes in performance expectations prior to the start, applied with motivational anecdotal statements towards biased techniques, have elicited does-response effects (32). It has also been suggested that the change in expectation can influence the attentional thoughts an athlete has before and during exertion (32,66). Previous manipulations have tried to limit the frequency of associative thoughts directed towards peripheral symptoms and high perceived exertion when fatigue increases (5), in order to improve performance. Additionally, it has been suggested that manipulation of an individual's positive self-belief towards the benefits of dissociative

attentional thoughts, will gain a supplementary advantage on performance (32). These centrally-acting expectations are then combined with the peripheral systems, to influence physiological self-regulation either through changes in pacing, directing attentional focus or exercise termination (53).

Paragraph Number 23 It has been suggested that a person's self-efficacy beliefs determine their motivation and subsequent behaviour (7,24). This is specifically thought to be the case when performance is impeded by depriving or deceiving participants about performance or progress information (27). Self-efficacy manipulations using positive false feedback after an event increased performance on subsequent tasks (27,33,38). Positive self-efficacy feedback, although inaccurate, lowered perceived effort and increased task motivation (32,55), reduced anxiety (33) and heightened affective responses to the exercise (27,37). The opposite effect was found with negative performance feedback, where self-efficacy and performance decreased (27,36). These results together demonstrate both feedback of efficiency and of performance results enhance performance when positive, but are detrimental to performance when negative. A possible explanation is that the more positive an effective response is during exercise, the greater the desire to maintain or increase exercise intensity (8).

An associated component of self-efficacy is the confidence in being able to complete the exercise task required (7) without catastrophic failure before the end (23). Confidence may be reinforced through repeated performances or experience; the memory of which, has been proposed to be one of the determinants of perceived exertion and effort regulation during a subsequent similar exercise task (51). Furthermore emotions and emotion-regulation are offered as possible mediators for the performance or pacing modifications in different deception methods of previous performance alterations (discussed later in the review), which reinforce false beliefs or self-efficacy regarding previous or current performance capability

(12,39,57). The addition of emotional influences to the manipulations employed in these studies may be significant since improvements in performance are not apparent when only false physiological performance feedback is supplied (1,21,65,60). Although improvements have been observed in performances when increasing expectancies of subsequent tasks, more investigation into the mechanisms of expectancy manipulation and mind-body interactions are required (4,19,32,48,55).

Presence of Competitors

Paragraph Number 24 Motivation is an additional mediator of perceived exertion (51) where performances have been seen to increase due to the motivation that feedback brings (34). Alongside emotional responses, the visual use of “head-to-head” competition introduces competitor motivation which is thought to be a reason for the inconsistent results in previous deception studies comparing performing alone or in competitive trials (15). Accordingly, it is anticipated positive feedback or perceived greater ability than average or a fellow competitor can have permanent effects on motor learning and in-transfer and retention test performance (55,67). In contrast, extrinsic motivation of monetary reward did not affect cycling time trial performance, suggesting pacing strategies are stable and independent of motivation (26). Furthermore training status may influence motivational responses as it has been suggested that highly trained athletes may be able to use physiological reserve capacities irrespective of competition or performing alone (15).

Paragraph Number 25 The majority of previous deception methods have manipulated performance within an ‘alone’ condition. Whilst this isolates the specific effects of the chosen deception mechanism upon performance, the replication of a sport-specific competitive setting is an increasingly valid line of research. The influence of a competitor encourages the performer to make decisions they would not necessarily face if racing alone, and would not be initially incorporated into the anticipatory-pacing template (61,62). Support for the

enhancements seen in performance when employing competitors to manipulate external feedback, is that the anticipatory setting of such template is not entirely robust or fixed (15). It would seem enhancements can be elicited if the athlete risks the disruption of the template when responding to the actions of the competitor within a competitive situation. This could explain the reasons for magnitudes of deception having different effects, where a 5% alteration may be too great to maintain or too high an escalation away from the pacing-template boundary (39). Equally a smaller magnitude of 2%, could be established as being able to provide a positive influence upon the balance of the willingness to exert maximum effort, against the negative factors of fatigue and homeostatic disruption (14,15,42).

Paragraph Number 26 Alternatively the visual display of “head-to-head” competition could also provide external distraction which could improve performance by influencing attentional focus (15). It may act to direct attention away from the internal sensations of fatigue, with dissociative attention improving performance by deterring thoughts of perceived exertion, shown by reduced RPE (32). In contrast, RPE was not significantly altered and performance not increased when in the presence of another runner (9), however without the specific instruction to compete, a competitive environment could be considered indirect or subjective in this case.

Prior experience

Paragraph Number 27 Previous experience is also suggested to be an important variable in exercise performance (67) and a possible mediator for perceived exertion (51). Where manipulation of feedforward processes such as the omission of exercise duration negates the role of previous experience (61), the use of feedback, whether true or false allows the perception of current performance to be referred to past performances (1,34). This allowance of conscious interpretations of the performance feedback influences both perceived exertion and pacing of the current performance (39). Obscuring elapsed time prevents the adoption of a

conscious pacing strategy, whilst permitting an assessment of subconscious control to create a pacing strategy based on prior experience (2). Visual or clock manipulations have also previously instigated the subconscious reflection on previous experience, as athletes were perceived to be performing similar to, or against their previous baseline performance, through manipulated expectancy (39,57).

Paragraph Number 28 During exercise, sensations of exertion are consciously interpreted by drawing upon mental representations and beliefs that have been constructed and reinforced through similar previous occurrences (31). Athletes' performance beliefs can potentially influence their governance of efferent muscular control (39). While mechanisms for this are still speculative, it is proposed that accurate and objective performance feedback strengthens the comparison of schemas between past and present exercise bouts (34). Likewise an assumption would be that false feedback could be used to alter the performance template. Deceiving an increase in ability, would challenge the perceptual component of the performance template used for regulation within subsequent bouts (39). This alteration was seen in the feedforward manipulation of incorrect distance knowledge where performance increased in the subsequent bout after performing a longer than perceived task (45). Similarly manipulation of feedback during the task was also effective, allowing perceptions of a successful previous performance influence pacing strategy in a successive bout (39). However, whilst improvements were seen at the start of the successive trial, the participants were unable to maintain the 'actual' increased performance from what they perceived to have completed previously. The researchers interpreted that, although a mismatch between their afferent sensations and their expected outcomes caused elevated RPE levels, they have a conscious determination to persist based upon knowledge from previous experience that they can achieve a specific level of performance. Although this mentality is proposed, during the study RPE was not collected for the first two trials, since it is proposed it could emphasise attentional thoughts

towards to the mismatch between afferent sensations and the deceived digital feedback of the performance (39). This highlights a methodological obstacle within the use of deception and ensuring it is undetected.

Paragraph Number 29 Somewhat surprisingly, feedback has been found to be secondary in importance to previous experience, since cyclists deprived of performance feedback and prior distance knowledge, were able to gradually define their pacing strategy over four successive trials (34). Equally cyclists produced similar times when presented with incorrect distance feedback when compared to correct feedback (1). They suggested distance feedback was not a prerequisite for optimum performance when participants had previous experience of the distance. This is supported by the conclusion that the learnt pacing template is robust and not negatively affected by subsequent pacing variation (35). Subsequently it is suggested if there is an absence or lack of relevant experience then perhaps, pacing strategies become more dependent upon the interpretation of sensory afferent feedback or RPE, rather than external feedback (39). This is reported in a more recent investigation on untrained participants where the absence of feedback and distance knowledge had no effect in comparison to when full distance knowledge was provided (64).

Change in Expectancies

Paragraph Number 30 Each deception method reviewed acted to influence the participants' expectancies of performance. Task expectation is a suggested mediator of performance (51). It creates a mismatch between perceived and actual performance from the manipulated information provided. The incongruity between the information provided and what is expected has been found to influence performance, although the true impact remains unclear. It has been suggested that when participants perceive they are performing poorly it would be expected for them to increase power output or modify RPE (61). This hypothesised observation was seen in

previous investigations (40,47,48,57) however in contrast, it has also been found that negatively manipulated feedback did not influence changes in performance times (60). Further an opposing belief is that when a goal is perceived to be unachievable, because of poor performance, performance decreases (36).

Paragraph Number 31 Additional disparity in results are seen when participants perceive performance to be better than expected. It has been suggested that this would pose no threat to the completion of the task, so physiological performance remains unchanged (47). Other arguments put forward are that when receiving positive feedback, although inaccurate, it induces significant alterations in physiological variables. Oxygen consumption decreased compared to false negative feedback (12), and blind feedback trials (65), although no significant difference in performance times were found (12,65). Conversely, when performing better than expected, athletes are seen to increase performance because of the influence of the success-motivation then optimising the setting and regulation of exercise intensity (36). It has been suggested that further reasons for the inconsistency in this area of research is arguably, a lack of data relating to the mechanisms of the underlying belief-effects, of which the perception of performance impacts (12).

Summary

Paragraph Number 32 It is clear that there is little consistency across previous interventions that manipulate performance modifiers. Previous investigations have largely differed in their methods of deception, the diverse measures and durations of performance, and the limited considerations for the mechanisms underpinning the deceived variables. Additionally, previous methods have chosen to elicit theory-based outcomes but are limited in ecological validity using protocols such as unknown and unexpected changes in duration or exercise capacity. From this review however, deception is highlighted as a useful methodological approach manipulating performance modifiers to understand their individual and combined importance

in an athlete's exercise regulation. It highlights different performance modifiers that are used during exercise regulation and whether such modifiers are more effective to performance as feedforward or feedback information.

Paragraph Number 33 Ten of the 31 studies reviewed have evidenced that deception methods can elicit improvements in performance (Table 1). Deception of task intensity has been found to have a positive influence when employed during the task rather than as an alteration of feedforward expectation. Time and distance deceptions have been shown to be less effective in eliciting performance improvements, despite alterations to pacing strategies. Psychological influences such as self-efficacy and motivation manipulation have been shown to improve performance, through expectancy modification. Deception research therefore significantly warrants further investigation into how deceptive interventions can be employed in practice to improve performance. Applications of manipulated information need to consider the variable used, the timing of deception; prior to or during, and the presentation style; verbal, visual, splits or continuous. Furthermore consideration towards presenting the optimal magnitude able to improve performance whilst remaining undetected, is of great importance. Successful methods of manipulations evidenced from the review of literature are those using deceptions of intensity variables, through visual feedback buffering physiological sensations and with the use of a competitive setting to stimulate motivation. Additionally implementing the use of a perceived, successful previous performance as experience and expectation for future tasks, would undoubtedly aim to see improvements in performance.

References

1. Albertus Y, Tucker R, Gibson ASC, Lambert EV, Hampson DB, Noakes TD. Effect of Distance Feedback on Pacing Strategy and Perceived Exertion during Cycling. *Med Sci Sports Exerc.* 2005b; 37(3): 461–468.
2. Ansley L, Robson PJ, St Clair Gibson A, Noakes TD. Anticipatory pacing strategies during supramaximal exercise lasting longer than 30 s. *Med Sci Sports Exerc.* 2004; 36(2): 309–14.
3. Baden DA, Warwick-evans L, Lakomy J. Am I Nearly There? The Effect of Anticipated Running Distance on Perceived Exertion and Attentional Focus. *J Sport Exerc Psychol.* 2004;26(2): 1–17.
4. Baden DA, McLean TL, Tucker R, Noakes TD, St Clair Gibson A. Effect of anticipation during unknown or unexpected exercise duration on rating of perceived exertion, affect, and physiological function. *Br J Sports Med.* 2005; 39(10): 742–6
5. Balagué N, Hristovski R, Aragonés D, Tenenbaum G. Nonlinear model of attention focus during accumulated effort. *Psychol Sport Exerc.* 2012; 13(5): 591–597.
6. Bandura, A. (1986). Social foundations of thought and action: A social cognitive theory. Englewood Cliffs, NJ: Prentice-Hall.
7. Bandura A. Self-efficacy: toward a unifying theory of behavioral change. *Psychol Rev.* 1997; 84(2): 191–215.
8. Baron B, Moullan F, Deruelle F, Noakes TD. The role of emotions on pacing strategies and performance in middle and long duration sport events. *Br J Sports Med.* 2011; 45(6): 511–7.
9. Bath D, Turner LA, Bosch AN, Tucker R, Lambert EV, Thompson KG, ST Clair Gibson A. The Effect of a Second Runner on Pacing Strategy and RPE During a Running Time Trial. *Int J Sport Phys Perf.* 2012;7(1):26-32
10. Beedie CJ, Coleman DA, Foad, AJ. Positive and negative placebo effects resulting from the deceptive administration of an ergogenic aid. *Int. J. Sport Nutr. Exerc. Metab.* 2007 17(3): 259–269.
11. Beedie CJ, Foad, A. The placebo effect in sports performance: a brief review. *Sports Med,* 2009;39(4):313-329
12. Beedie CJ, Lane AM, Wilson MG. A possible role for emotion and emotion regulation in physiological responses to false performance feedback in 10 mile laboratory cycling. *Appl Psychophysiol Biofeedback.* 2012; 37(4): 269–77.
13. Billaut F, Bishop DJ, Schaerz S, Noakes TD. Influence of knowledge of sprint number on pacing during repeated-sprint exercise. *Med Sci Sports Exerc.* 2001; 43(4): 665–72.
14. Brehm JW, Self EA. The intensity of motivation. *Annu Rev Psychol.* 1989; 40: 109-131
15. Corbett J, Barwood MJ, Ouzounoglou A, Thelwell R, Dicks M. Influence of competition on performance and pacing during cycling exercise. *Med Sci Sports Exerc.* 2012; 44(3): 509–15.
16. Coquart JB, Garcin M. Knowledge of the endpoint: effect on perceptual values. *Int J Sports Med,* 2008; 29 (12): 976-9.
17. Coquart JB, Stevenson A, Garcin M. Causal influences of expected running length on ratings of perceived exertion and estimation time limit scales. *Int J of Sport Psychol.* 2011; 42(2): 149-166.
18. de Koning JJ, Foster C, Bakkum A, Kloppenburg S, Thiel C, Joseph T, Cohen J, et al. Regulation of pacing strategy during athletic competition. *PloS one.* 2011 6(1)

19. 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. *Psychophysiology*. 2012; 49(4): 462–9.
20. 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*. 2011; 21(6): 176–83.
21. Faulkner J, Parfitt G, Eston RG. The rating of perceived exertion during competitive running scales with time. *Psychophysiol*. 2008; 45(6): 977-85.
22. Foad AJ, Beedie CJ, Coleman DA. Pharmacological and psychological effects of caffeine ingestion in 40-km cycling performance. *Med Sci Sports Exerc*. 2008; 40(1): 158.
23. Foster C, Hendrickson KJ, Peyer K, deKoning JJ, Lucia A, Battista RA, Hettinga FJ, Porcari JP, Wright G. Pattern of developing the performance template. *Br J Sports Med*. 2009; 43(10): 765-9
24. Hampson DB, St Clair Gibson A, Lambert MI, et al. Deception and perceived exertion during high-intensity running bouts. *Percept Mot Skills*. 2004; 98: 1027–38
25. Hopkins WG, Schabert EJ, Hawley JA. Reliability of power in physical performance tests. *Sports Med*. 2001; 31(3): 211–34.
26. Hulleman M, De Koning JJ, Hettinga FJ, Foster C. The effect of extrinsic motivation on cycle time trial performance. *Med Sci Sports Exerc*. 2007; 39(4): 709.
27. Hutchinson JC, Sherman T, Martinovic N, Tenenbaum G. The Effect of Manipulated Self-Efficacy on Perceived and Sustained Effort. *J Appl Sport Psychol*. 2008; 20(4): 457–472.
28. Jones HS, Williams EL, Bridge CA, Marchant D, Midgley AW, Micklewright D, Mc Naughton LR. Physiological and Psychological Effects of Deception on Pacing Strategy and Performance: A Review. *Br J Sports Med*. 2013; Sept 4[Epub ahead of print]doi:10.1007/s40279-013-0094-1
29. Kalasountas V, Reed J, Fitzpatrick J. The Effect of Placebo-Induced Changes in Expectancies on Maximal Force Production in College Students. *J Appl Sport Psychol*. 2007; 19(1): 116–124.
30. Kirsch I. Specifying nonspecifics: Psychological mechanisms of placebo effects. In A. Harrington, *The placebo effect: Interdisciplinary explorations*. Cambridge, MA: Harvard University Press, 1997: 166-186
31. Lambert EV, St Clair Gibson A, Noakes TD. Complex system model of fatigue: integrative homeostatic control of peripheral physiological systems during exercise in humans. *Br J Sports Med* 2005; **39**;52-62
32. Lohse KR, Sherwood DE. Defining the focus of attention: effects of attention on perceived exertion and fatigue. *Front Psychol*. 2011; 2; 332.
33. Marquez DX, Jerome GJ, McAuley E, Snook E, Canaklisova, S. Self-efficacy manipulation and state anxiety responses to exercise in low active women. *Psychol & Health*, 2002; 17(6), 783–791.
34. Mauger AR, Jones AM, Williams CA. Influence of feedback and prior experience on pacing during a 4-km cycle time trial. *Med Sci Sports Exerc*. 2009; 41(2): 451–8.
35. Mauger AR, Jones AM, Williams CA. Influence of exercise variation on the retention of a pacing strategy. *Europ J App Physiol*. 2010; 108(5): 1015-23
36. Mauger AR, Jones AM, Williams CA. The effect of non-contingent and accurate performance feedback on pacing and time trial performance in 4-km track cycling. *Br J Sports Med*. 2011; 45(3): 225-9
37. McAuley E, Talbot HM, Martinez S. Manipulating self-efficacy in the exercise environment in women: Influences on affective responses. *Health Psychol*, 1999; 18, 288–294.

38. McKay B, Lewthwaite G, Wulf, G. Enhanced expectancies improve performance under pressure. *Front in Psychol.* 2012; 3(8): 1-5
39. Micklewright D, Papadopoulou E, Swart J, Noakes TD. Previous experience influences pacing during 20 km time trial cycling. *Br J Sports Med.* 2010; 44(13): 952–60.
40. Morton RH. Deception by manipulating the clock calibration influences cycle ergometer endurance time in males. *J Sci Med Sports.* 2009; 12(2): 332–7.
41. Nikolopoulos V, Arkinstall MJ, Hawley JA. Pacing strategy in simulated cycle time-trials is based on perceived rather than actual distance. *J Sci Med Sports.* 2001; 4(2): 212–9.
42. Noakes TD, St Clair Gibson A. Logical limitations to the “catastrophe” models of fatigue during exercise in humans. *Br J Sports Med.* 2004; 38(5):648-9
43. Noakes TD, St Clair Gibson A, Lambert EV. 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(2): 120–4.
44. Noakes TD. Time to move beyond a brainless exercise physiology: the evidence for complex regulation of human exercise performance. *Appl Physiol Nutr Metab,* 2011; 36(1): 23–35.
45. Paterson S, Marino FE. Effect of deception of distance on prolonged cycling performance. *Percept Mot Skills,* 2004; 98 (3): 1017-26
46. Parry D, Chinnasamy C, Papadopoulou E, Noakes T, Micklewright D. Cognition and performance: anxiety, mood and perceived exertion among Ironman triathletes. *Br J Sports Med.* 2011; 45(14): 1088-94
47. Parry D, Chinnasamy C, Micklewright D. Optic flow influences perceived exertion during cycling. *J Sport Exerc Psychol.* 2012; 34(4): 444–56.
48. Pires FO, Hammond J. Manipulation effects of prior exercise intensity feedback by the Borg scale during open-loop cycling. *Br J Sports Med.* 2012; 46(1): 18–22.
49. Rejeski WJ, Ribisl PM. Expected task duration and perceived effort: an attributional analysis. *J Sport Psychol.* 1980;39: 249–54.
50. Renfree A, West J, Corbett M, Rhoden C, St Clair Gibson A. Complex interplay between determinants of pacing and performance during 20-km cycle time trials. *Int J Sports Physiol Perf,* 2012; 7(2): 121–9.
51. St Clair Gibson A, Baden DA, Lambert MI, Lambert EV, Harley YXR, Hampson D, Russell VA, Noakes, TD. The conscious perception of the sensation of fatigue. *Sports Med.* 2003; 33(3): 167-76
52. St Clair Gibson A, Noakes TD. Evidence for complex system integration and dynamic neural regulation of skeletal muscle recruitment during exercise in humans. *Br J Sports Med.*2004; 38(6): 797–806.
53. St Clair Gibson A, Goedecke JH, Harley YX, Myers LJ, Lambert MI, Noakes TD, Lambert EV. Metabolic setpoint control mechanisms in different physiological systems at rest and during exercise. *J Theor Biol.* 2005; 236(1): 60-72
54. St Clair Gibson A, Lambert EV, Rauch LHG, Tucker R, Baden DA, Foster C, Noakes TD. The role of information processing between the brain and peripheral physiological systems in pacing and perception of effort. *Sports Med.*2006; 36(8): 705–22.
55. Stoate I, Wulf G, Lewthwaite R. Enhanced expectancies improve movement efficiency in runners Enhanced expectancies improve movement efficiency in runners. *J Sports Sci.* 2012; 30 (8): 37–41
56. Stone MR, Thomas K, Wilkinson M, St Clair Gibson A, Thompson, KG. Consistency of perceptual and metabolic responses to a laboratory-based simulated 4,000-m cycling time trial. *Eur J Appl Physiol.* 2011; 111 (8): 1807–13

57. Stone MR, Thomas K, Wilkinson M, Jones AM, St Clair Gibson A, Thompson KG. Effects of deception on exercise performance: implications for determinants of fatigue in humans. *Med Sci Sports Exerc.* 2012; 44 (3): 534–41
58. Swart J, Lamberts RP, Lambert MI, Lambert EV, Woolrich RW, Johnston S, Noakes TD. Exercising with reserve: exercise regulation by perceived exertion in relation to duration of exercise and knowledge of endpoint. *Br J Sports Med.* 2009a; 43(10): 775–81.
59. Swart J, Lindsay TR, Lambert MI, Brown JC, Noakes TD. Perceptual cues in the regulation of exercise performance - physical sensations of exercise and awareness of effort interact as separate cues. *Br J Sports Med.* 2012; 46(1): 42–8.
60. Thomas G, Renfree A. The effect of secret clock manipulation on 10km cycle time. *Int J Art Sci* 2010; 3 (9): 193–202.
61. 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(6):392–400.
62. Tucker R, Noakes TD. The physiological regulation of pacing strategy during exercise: a critical review. *Br J Sports Med.* 2009; 43(6):265-71.
63. Walsch H, Schmidt S, Bihr Y, Wiesch S. The Effects of a Caffeine Placebo and Experimenter Expectation on Blood Pressure, Heart Rate, Well-Being, and Cognitive Performance. *Eur Psychol.* 1999;6(1);15-25
64. Williams CA, Bailey SD, Mauger AR. External exercise information provides no immediate additional performance benefit to untrained individuals in time trial cycling. *Br J Sports Med.* 2012; 46(1): 49–53.
65. Wilson MG, Lane AM, Beedie CJ, Farooq A. Influence of accurate and inaccurate “split-time” feedback upon 10-mile time trial cycling performance. *Eur J Appl Physiol.* 2012; 112(1): 231–6.
66. Wulf G. Attentional focus and motor skills learning: a review of 10 years of research. *Bewegung Training.* 2007b;1:4-14
67. Wulf G, Chiviawosky S, Lewthwaite R. Normative feedback effects on learning a timing task. *Res Q Exerc Sport.* 2010; 81(4): 425-431.
68. Ulmer H-V. Perceived exertion as a part of a feedback system and its interaction with tactical behaviour in endurance sports. In: Borg G, Ottoson D, editors. *The perception of exertion in physical work.* Hampshire and London: Macmillan Press Ltd 1986:317-26
69. Ulmer, H-V. Concept of an extracellular regulation of muscular metabolic rate during heavy exercise in humans by psychophysiological feedback. *Experimentia* 1996; 52(5): 416-420.

Table 1. Summary table of previous deception manipulations used and their implications.

Author	N	Exercise Mode	Duration	Outcomes	Implications	Performance
Unknown Duration						
Billaut et al. (2011)	1 4	R	6 s	- Lower work accumulated in unknown duration*** - No difference in RPE	Unknown endpoint has negative effects on performance	↓
Mauger et al. (2009)	1 8	C	4 km	- Unknown and no feedback slower than known****	Difference reduced over successive trials so previous experience more important than external feedback	↓
Swart et al. (2009)	1 8	C	100 km	- RPE changed in relation to the knowledge of the endpoint and the distance remaining - Performance increased when knew endpoint	Knowledge of endpoint and prior experience influential in pacing	↑
Williams et al. (2012)	2 2 *	C	4 km	- No effect on time to completion or pacing strategy	Distance feedback and previous experience had no effect on performance	—
Incorrect Duration						
Nikolopoulos et al. (2001)	6	C	34-40 km	- No effect on pacing strategy	Athletes judge performance based on perceived rather than actual feedback	—

Paterson & Marino (2004)	2 1	C	24-36 km	- No difference in RPE - Time to completion and pacing strategy affected in successive trials	Pacing strategy set based on previous experience and effort template	/
--------------------------	--------	---	-------------	--	--	---

Unexpected change in Duration

Baden et al. (2004)	1 8	R	8-10 mile	- RPE affected - Significantly higher RPE in correct endpoint trial***	RPE was lower when expected duration was longer	—
Baden et al. (2005)	3 0	R	20 min	- Speed, $\dot{V}O_2$, HR and stride frequency were not different - RPE and affect affected***	RPE not just physical measure of exertion as affected at announcement of unexpected change	/
Coquart et al. (2011)	2 6 *	R	80% of Time To Exh	- RPE and estimated time limits did not differ across trials - RPE increased in relation to exercise duration****	RPE linked with anticipation of expected endpoint	—
Eston et al. (2012)	2 0 *	R + C	To Exh	- Increased RPE and affect when announced unexpected change	RPE lower in unknown – conservation of reserve capacity	/

Intensity Deception

Hampson et al. (2004)	4 0	R	1680 m	- No effect on RPE	Feedforward manipulation has no effect on	—
-----------------------	--------	---	-----------	--------------------	---	---

							post-trial measures of RPE
Micklewright et al. (2010)	2 9	C	20 km	- Pacing strategy affected - No difference in time	Interaction of feedback and previous experience	—	
Parry et al. (2012)	1 5	C	20 km	- Difference in pacing strategies between slow trials no difference fast - Lower average RPE in slow than normal	Visual feedback offers as a buffer and influences performance	/	
Pires et al. (2012)	8 *	C	To Exh	- Deception of intensity did not affect RPE	Deception of intensity via RPE ineffective on performance	—	
Stone et al. (2012)	9	C	4 km	- Deception affected time to completion and pacing - Deception trial was faster than control - Greater anaerobic contribution in deception trial	Deceived feedback derived from previous performances enabled improved performance	↑****	

Time Deception

Albertus et al. (2005)	1 5	C	20 km	- No effect on time to completion or pacing strategy	Pacing robust and unaffected by external feedback	—
Ansley et al. (2004a)	8 *	C	30 s	- No effect on pacing strategy	Pacing pre-set on anticipated endpoint and previous experience	/

Beedie et al. (2012)	7	C	10 mile	<ul style="list-style-type: none"> - No differences in power output or time to completion between delayed/premature feedback 	False feedback influenced emotions but not performance outcomes	—
Faulkner et al. (2011)	13*	R	6 km	<ul style="list-style-type: none"> - No feedback affected time to completion and pacing strategy - RPE not affected 	Inaccurate distance feedback did not affect pacing and performance	↓****
Mauger et al. (2011)	5	C	4 km	<ul style="list-style-type: none"> - Faster performance with correct feedback than inaccurate feedback *** - Inaccurate feedback also affects pacing strategy 	Feedback is important for pacing	↑***
Morton (2009)	12*	C	To Exh	<ul style="list-style-type: none"> - Longer in time to exhaustion in slow trial** - No difference in time to exhaustion in fast trial 	Feedback influential on performance	↑****
Thomas & Renfree (2010)	8	C	10 km	<ul style="list-style-type: none"> - Clock manipulation affected pacing strategy but not time to completion 	Support anticipatory RPE model – conscious RPE compared to template RPE during exercise	—
Wilson et al. (2012)	7	C	10 mile	<ul style="list-style-type: none"> - No affect time to completion but affected pacing strategy 	Pacing strategies affected by	—

inaccurate and
no feedback

**Psychological
Influences**

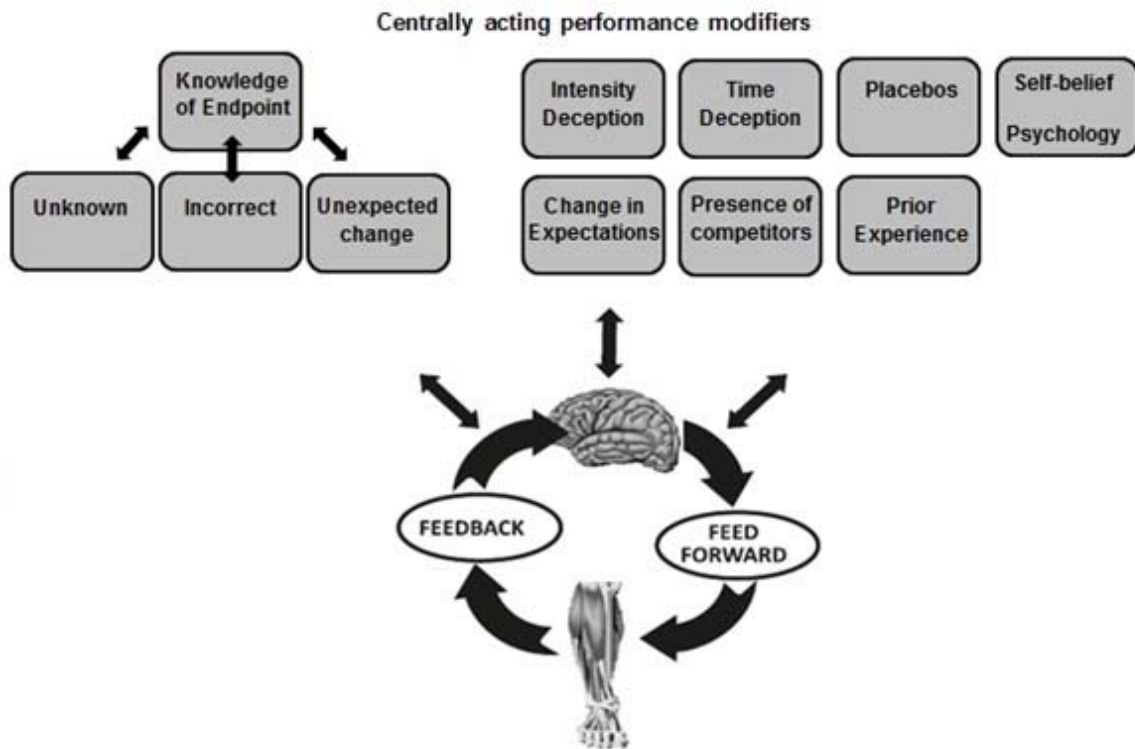
Hutchinson et al. (2008)	2 7 *	S	To Exh	-	False positive feedback increased time to exhaustion	Self-efficacy is influential on performance	↑
Marquez (2002)	5 9	R	20 min	-	False positive feedback decrease anxiety in subsequent bout, false negative reduced self-efficacy	Self-efficacy manipulation reduces state anxiety responses	/
McAuley (1999)	4 6 *	O	20 min	-	False positive self-efficacy increased positive effect and decrease negative	Self-efficacy influence affective responses to exercise	↑
McKay (2012)	3 1	O	40 throws	-	False positive self-efficacy statements significantly increased throwing accuracy	Enhancing expectancies of performance influences subsequent performance	↑****
Lohse et al. (2011)	6 0 *	S	To Exh	-	Deception of expectation affected time to exhaustion	Enhancing expectancies improved performance	↑
Stoate et al. (2012)	2 0	R	10 min	-	Lower $\dot{V}O_2$, greater movement efficiency with false feedback - RPE was affected ***	Enhancing expectancies improved performance – possible motivation effects	↑***

Presence of Competitor

Bath et al. (2012)	8	R	5 km	-	No effect on pacing strategy, running speed, HR or RPE	Pacing strategy is robust and unaltered by the presence of a competitor	—
Corbett et al. (2012)	1 4 *	C	2 km	-	Faster time in HH than alone TT*** - Greater rate of anaerobic energy yield in final 1km	Simulated competition affected time to completion and pacing strategy	↑***

*Denotes untrained participants, R=Running, C=Cycling, S=Strength Exercise,
 ** Denotes significance $p < 0.01$,
 *** Denotes significance $p < 0.05$,
 **** Denotes significance $p < 0.001$,
 ↓ denotes a decline in performance,
 ↑ denotes an improvement in performance,
 — denotes no effect on performance,
 / denote an effect of performance dependent on the manipulation direction.

FIGURE 1—The possible interventions that can modify exercise performance adapted from a schematic summary (Noakes, 2011) that have previously been deceptively manipulated.



ACCEPT

List of Figures

Figure 1. The possible interventions that can modify exercise performance adapted from a schematic summary (Noakes, 2011), that have previously been deceptively manipulated.

List of Tables

Table 1. Summary table of previous deception manipulations used and their implications.

ACCEPTED