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CURRENT OPINION

# Will the Conscious–Subconscious Pacing Quagmire Help Elucidate the Mechanisms of Self-Paced Exercise? New Opportunities in Dual Process Theory and Process Tracing Methods

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**Abstract** The extent to which athletic pacing decisions are made consciously or subconsciously is a prevailing issue. In this article we discuss why the one-dimensional conscious–subconscious debate that has reigned in the pacing literature has suppressed our understanding of the multidimensional processes that occur in pacing decisions. How do we make our decisions in real-life competitive situations? What information do we use and how do we respond to opponents? These are questions that need to be explored and better understood, using smartly designed experiments. The paper provides clarity about key conscious, preconscious, subconscious and unconscious concepts, terms that have previously been used in conflicting and confusing ways. The potential of dual process theory in articulating multidimensional aspects of intuitive and deliberative decision-making processes is discussed in the context of athletic pacing along with associated process-tracing research methods. In attempting to refine pacing models and improve training strategies and psychological skills for athletes, the dual-process framework could be used to gain a clearer understanding of (1) the situational conditions for which either intuitive or deliberative decisions are optimal; (2) how intuitive and deliberative decisions are biased by things such as perception, emotion and experience; and (3) the underlying cognitive mechanisms such as memory, attention allocation, problem solving and hypothetical thought.

**Key Points**

The extent to which athletic pacing is under conscious or subconscious control has been a significant point of discussion and disagreement among researchers in this field, yet has failed to produce notable advances in our understanding of pacing mechanisms.

The notion that conscious processes are independent of subconscious, preconscious and unconscious influence is conceptually flawed, restricted in theoretical scope and has limited investigative utility.

Key terms of conscious, preconscious, subconscious and unconscious are defined and dual process theory, which distinguishes between intuitive and deliberative action, is offered as an alternative framework for investigating the control of athletic pacing.

## 1 Introduction

Athletic pacing has been defined as the way power output, work or energy expenditure is controlled or distributed to complete an event in the fastest possible time, having

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utilised all available resources [1, 2]. One of the most common questions encountered at pacing symposia is whether regulatory mechanisms during self-paced exercise operate at a conscious or subconscious level. Indeed, this question has been the focus of much of the pacing literature, including the influential central governor theory [3–8]. Although conscious perceptual processes are a recognised component of this theory [7, 8], its main tenet is that a central controller subconsciously regulates the recruitment of motor units during exercise, acting as a protective homeostatic system that responds to afferent feedback about internal physiological disturbances [3–8]. A predominant alternative view is the psychobiological model [9], which contends that motor unit recruitment is a consciously regulated process, as evidenced by the negative effects that distracting, loading or fatiguing the conscious mind have on pacing [10, 11]. Not surprisingly, perceived exertion plays a central role and constitutes the main conscious component of these [6, 9] and other pacing models [8, 12–14]. Hence, the key point of disagreement between the models is not the inclusion of conscious processes, but rather the extent to which such processes are responsible for muscle recruitment and pacing behaviour.

Although perception of effort is a feature of central governor theory [5, 15], it is the existence and operation of a subconscious controller in the brain that is regarded as regulating muscle recruitment [5]. Importantly, the theory does not describe the existence of an anatomically distinct central governor structure in the brain, and our interpretation is that central governance refers to a functional property of the central nervous system, which likely involves interactions between various brain structures and neurological networks. In contrast, the psychobiological model argues that pacing behaviour is exclusively under conscious control and so a subconscious controller is not needed [9, 10]. Edwards and Polman [16] have proposed an explanation that involves both conscious and subconscious mechanisms. They suggest that, while minor homeostatic pacing modifications operate at a subconscious level, major threats to homeostasis lead to conscious awareness and a deliberate behavioural pacing response [16]. Although this explanation is plausible, it still remains narrowly focused on the issue of consciousness as a determinant of pacing behaviour. We also feel that, at present, there are competing and incongruent perspectives about the relative roles of conscious and subconscious processing in pacing and that simplistic definitions of these concepts are used in the various pacing models.

This conscious–subconscious pacing quagmire is clearly an intellectually engaging debate, yet attempts to resolve it have not furthered our understanding of pacing mechanisms or how exercise intensity is regulated across an exercise bout. This should not imply that the consideration of consciousness and other related philosophical, psychological and psychoanalytical fields in sports science would not be efficacious. In fact, advances in these complex topics constitute some of the most important and exciting developments in contemporary science [17–19]. Our assertion is that the predominant dichotomy wherein either conscious or subconscious mechanisms govern pacing is both conceptually flawed and unlikely to yield significant gains in our understanding of how pace is regulated during exercise. Consequently, the conscious–subconscious question will be reframed into one of dual processes, which we believe provides greater investigative utility in elucidating pacing mechanisms. We would also like to point out that exploring the conscious–subconscious paradigm is only one facet of the multidimensional process of decision-making in the context of regulating exercise intensity. An overly strong focus on only this leaves other exciting and useful areas of exploring human behaviour in the sports context relatively unattended. For example, athlete–environment interactions, as described in a recent review [20], are a crucial factor in understanding the regulation of exercise intensity. In this review, a framework is proposed based on ecological psychology and the interdependence of perception and action. This framework allows us to incorporate, understand and explore athletic behaviour in more complex pacing situations, such as how athletes respond to actions of their opponents. With dual process theory, we can also provide a broader framework capable of incorporating processes of decision-making, pacing and performance in more complex, real-life competitive situations. It is our contention that conceptualising decision-making in pacing as involving intuitive or deliberative process provides a means through which progress can be made on parallel problems without getting ‘stuck’ on the singular issue of conscious versus subconscious control. In addition to the opportunities for exploring the multidimensional character of pacing, such an approach reflects the complex nature of athletic decision-making. We begin by clarifying fundamental conscious, subconscious, preconscious and unconscious concepts.

## 2 The Conscious, Subconscious, Preconscious and Unconscious

In some of the pacing literature, mechanisms are commonly discussed as being under either conscious or subconscious control [7, 9]. For several reasons, this is a false dichotomy. The terms subconscious and unconscious have unfortunately been used synonymously [21–24] but they are distinct, and the distinction has a particular relevance to the issue of pacing.

The *subconscious* relates to mental processes operating outside consciousness, such as habitual or instinctive action. This is clearly an important factor in athletic pacing, but it needs to be differentiated from the *unconscious* by which is meant the dynamic unconscious of psychoanalytic theory; this is explored below. According to the Freudian topographical model, there is also the *preconscious*, which is the location for those mental representations and processes of which you are unaware in the present but could be aware of if your attention was drawn towards them, either voluntarily or involuntarily [25]. During exercise an athlete might be unaware of certain actions such as pedalling or stride length, or physiological functions such as respiration unless their attention is shifted towards them, at which point conscious awareness would occur.

In contrast to the subconscious and the preconscious, the *unconscious* mind contains phantasies, memories and thoughts that an individual is unaware of and cannot readily access by redirecting their attention. The concept of the unconscious is firmly rooted in traditional psychoanalytic theory [25] and, while it has undergone considerable theoretical evolution [26–29], there are several principles that all perspectives share in common. The first is that the unconscious mind contains all mental representations and processes that, by definition, an individual is not aware of. The second is that the unconscious mind operates in a dynamic way, influencing our conscious experience, feelings, personality and behaviour. As such, rather than being distinct, a transactional relationship exists between the unconscious and conscious mind.

Autonomic physiological processes such as the cardiac cycle or perspiration operate at a subconscious level, as perhaps do elements of what have previous been described as pacing templates or schemas [30]. They are unconscious in that they are outside awareness, but are more usefully described as subconscious, so as to differentiate them from the psychoanalytic dynamic unconscious. By this is meant aspects of lived experience that individuals find traumatic, overly conflicted or otherwise difficult to cope with. Freud referred to repression as the mechanism by which these were placed in and kept in the unconscious rather than reaching our awareness [25]. For an athlete, this could include difficult experiences or perceptions that they experience during a race. It could also include unconscious conflicts about succeeding or failing, or other emotional conflicts that impede the optimum capacity to function at a particular moment or indeed driving one further to win. In this sense, repression is a defence mechanism that protects the conscious self from experiencing disturbing or threatening thoughts. While it could be argued that repression potentially benefits performance by regulating negative thoughts, feelings and anxieties, it might also limit performance by inhibiting and interfering with conscious drives and motivations. Whether debilitative or facilitative, psychoanalytic theory predicts that it is the dynamic relationship between unconscious and conscious mind that influences all behaviour, including athletic pacing.

It is important to point out that the term unconscious in this context is not referring to a sleeping state, although sometimes, through dreaming, elements of the unconscious mind can move into conscious awareness. In this model, the experience of not being able to remember a dream occurs because the meaning of the dream moves back into the unconscious mind. Psychoanalysts and psychodynamic psychotherapists often use methods such as free association to bring aspects of the unconscious mind to conscious awareness. Hypnosis, which Freud experimented with but then later abandoned, is another technique for gaining access to the unconscious. Interestingly, it has been found that changes to perceived exertion, cardiovascular activity and cerebral blood flow during cycling can be elicited using hypnotic manipulation [31–33], suggesting an unconscious influence on how individuals consciously experience exercise and further indicating that conscious experiences are only a relatively small part of what governs our decisions and reactions.

The *conscious* mind contains those thoughts that a person is aware of in the present. In the context of exercise, this would include perceived exertion, perceived fatigue, pain and other sensory–perceptual experiences. The consciousness of perception remains a highly debated issue [34], although in the context of regulation of pace it has been suggested that a continuum of conscious control exists from not aware to fully aware [16]. It would also include affective feeling states such as moods and emotions. A range of complex higher-order cognitive skills relevant to athletic pacing also proceed through conscious thought, such as problem-solving, mental rehearsal, mental simulation, logical reasoning and language-dependent strategies such as self-talk [35].

The conscious, preconscious and unconscious are not independent of each other and this has implications for the conscious–subconscious pacing debate. The conscious is a subset of the preconscious that is, in turn, a subset of the unconscious. Thus, every thought, perception and decision an athlete feels they have experienced or made consciously has unconscious origins [28, 29]. The question of whether pace is under conscious or subconscious control is therefore flawed because it implies one is distinct or separate from the other (see Fig. 1a), rather than the conscious being a subset of the unconscious (see Fig. 1b). Furthermore, during a race athletes are known to shift their attention between external and internal sensations [36, 37] as well as between associative and dissociative thoughts [35, 38]. Redirecting attention during an event in this way

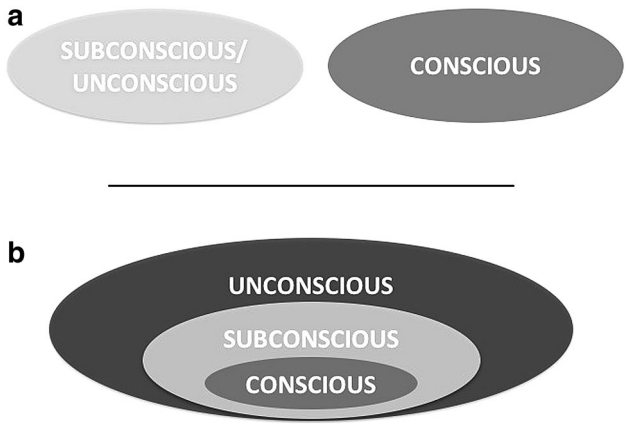


**Fig. 1** In previous pacing models the conscious and subconscious mind are conceptualised as distinct (conscious ⫩ subconscious) with no adequate definition or distinction of subconscious or unconscious being made (**a**). In contrast, the topographical model emphasises a psychodynamic relationship whereby conscious ⊂ subconscious ⊂ unconscious (**b**). Thus, all thoughts, perceptions and decisions that are experienced in conscious awareness have unconscious foundations. By redirecting attentional focus an individual can become aware of subconscious content [25]

is indicative of the dynamic interrelationship between the unconscious, preconscious and conscious mind. The predictable, trait-like pacing behaviours that have recently been demonstrated [39] perhaps have their roots in the unconscious origins of personality [40].

Even if it were possible to definitively establish which aspects of pace regulation an athlete was consciously aware of, which aspects shifted between preconscious and conscious, and which aspects an athlete was not aware of (unconscious), it is unlikely that such knowledge would advance our understanding of underlying mechanisms. For instance, establishing that a decision to increase speed was made consciously would reveal nothing about the information processing and cognitive processes that led to that outcome. Similarly, showing that some changes in speed are made without the athlete being consciously aware of them also tells us very little about the processes behind regulation of pace and how athletes select pace. In this sense, the prevailing issue of whether pacing control is conscious or subconscious, which may have developed from earlier peripheral versus central control discussions [3, 15], is rather one-dimensional and therefore of limited investigative utility.

## 3 Dual Processes: An Effective Alternative

We propose that the traditional debate about pacing in terms of either conscious or subconscious regulation should be reframed in terms of intuitive or deliberative control mechanisms. Although there is some overlap with conscious–subconscious, examining intuitive and deliberative processes introduces new questions regarding the potential influence of dual cognitive processes of pacing behaviour likely to enhance our understanding of the phenomenon.

The origins of dual processes in judgment and decision-making arose from several academic fields of study, including economic decision theory [41–48], social judgment theory [49, 50] and cognitive psychology [51–57]. The fundamental principle that underpins dual process theory is that, contrary to previous beliefs, individuals are not always fully rational when making decisions. Furthermore, decisions are often subject to a variety of influences, including emotional state, previous experience, perception and social context. This perspective is consistent with findings from two recent reviews of pacing [20, 21] in which the complexities of making pacing decisions were highlighted, particularly in regard to processing a wide array of situational cues and sensory–perceptual information. This article adopts a contemporary psychological perspective of decision-making in pacing, which is very accommodating of athlete–environment interactions.

The interdisciplinary literature on dual process control has revealed several consistent distinctions between intuitive and deliberative thought. Intuition is automatic and does not use working memory resources [57]. Consequently, it involves very little cognitive effort, is quick, powerful and facilitates parallel functions [58, 59]. Intuition is also associative and practical, meaning that complex tasks, problems and uncertain situations can be tackled by drawing on previous experience and beliefs [56, 60]. Intuition is not associated with general intelligence [61]. In contrast, deliberation involves conscious language-related reflection [62] that draws heavily on working memory resources [63, 64] and is linked with general intelligence [61, 65]. It is slow, sequential and requires much cognitive effort [66–68]. Deliberative thinking does, however, permit abstract and hypothetical thinking.

## 4 Heuristics and Biases

Dual process theory also provides a framework around which research studies can be designed to gain a better understanding of the cognitive mechanisms of pacing, and in this regard heuristics and biases are two useful concepts. A heuristic is a cognitive shortcut that enables people to make decisions, often quickly, in situations where there are large amounts of complex, confusing and competing sources of information that would be impossible to process. In other words, people reduce complex scenarios into simpler decision-making propositions by ignoring some of the information available to them, and this can proceed

either through intuitive or deliberative means [45]. Until the mid-1970s it was assumed that people are rational decision-makers, but in work that eventually earned them the 2002 Nobel Prize for Economic Science, Tversky and Kahneman [45] showed that most decision-making errors can be attributed to heuristic influences that have an irrational basis. In dual process theory, decision-making errors that are highly predictable are referred to as biases.

In the context of pacing, it would be impossible for an athlete to consider all of the possible factors and potential outcomes of taking certain actions; therefore, we propose that heuristic principles enable athletes to make pacing decisions in uncertain conditions. This is particularly relevant to early pacing decisions that are made during endurance activity at a point where a great deal of uncertainty exists about how external factors might change or how the athlete's physical condition will develop. The concept of heuristics is also far less deterministic than previous models [6, 8, 9, 12–14] that have suggested that the universal driver of pacing behaviour is perceived exertion. Dual process theory is less rigid, accommodating the possibility that perceived exertion might be just one of many other heuristic influences that athletes could utilise in making pacing decisions. This is consistent with a view put forward by Gigerenzer and Todd [69] that heuristics are used in an adaptive way, with individuals selecting heuristics according to the perceived demands of a situation or problem. Evidence also suggests that athletes are similarly adaptive in how they make decisions. For example, it has been shown that conditioned beliefs about performance strongly influence early pacing behaviour despite unsustainably high levels of perceived exertion [70], suggesting that in some circumstances the self-belief heuristic might have a stronger influence on decisions than the perceived exertion heuristic. In a number of other studies, the actions of a competitor have been strongly associated with pace change [71–73], perhaps indicating that, in some situations, it might be strategically advantageous to act in ways that would otherwise be contraindicated by the corresponding perceived exertion trajectory.

We are not suggesting that perceived exertion is not an important heuristic in pacing, but rather, as part of an adaptive system, athletes have other heuristic principles that they might draw on in making pacing decisions. The affect heuristic [45], whereby a person's present emotional state influences their decisions, is one of the most common and powerful heuristics known and, as some research has indicated, has a relevance to pacing [74]. As previously noted, perceived exertion shares many characteristics of an emotion [15], and in this regard may act similarly to the affect heuristic in the determination of pace as many of the models predict [6, 8, 9, 12–14]. However, sometimes perceived exertion models of pacing are unable to account for failures in performance resulting from poor pacing which, for example, in the central governor model should be prevented through homeostatic control [3–6], or in perceived exertion trajectory models [8, 12–14] would result in preventative pacing adjustments. It is through the availability of other heuristics, and athletes' ability to use them in adaptive ways, that it becomes conceptually possible to account for both successful and unsuccessful pacing outcomes on both an intra-individual and inter-individual basis. Specifically, the availability of other heuristics means that pacing successes and pacing errors can be explained in terms of the situational appropriateness of heuristic selection and utilisation, or attributed to cognitive biases or dysfunctional cognitive shortcuts that have driven the decision. Dual process theory can also account for the interesting suggestion that different individuals adopt different decision-making strategies, according to the particular heuristics they prefer. In summary, dual process theory is much more flexible and accommodating of varied pacing behaviour than previous perceived exertion centric models.

## 5 Pacing as a Multidimensional Process

Returning to the conscious–subconscious discussion, a further point we would like to make is that pacing is a multidimensional process. If we limit ourselves to only one facet of this multidimensional process, the conscious versus subconscious control issue, other exciting and useful areas of exploring human behaviour in sports context will remain relatively unattended. Therefore, as proposed in several recent reviews [20, 21], we argue for a broader focus aimed at exploring how decisions are made in real-life competitive situations and what information is used to inform such decisions. It has been demonstrated that opponents in 'real-world' athletic competitions appear to influence athletic decision-making and tactics [75, 76], supporting the interdependence of perception and action as advocated by the ecological perspective [20]. Action possibilities are afforded by the environment, and the perception of these action possibilities will be affected by the action capacity of the exerciser. This allows us to explain and further investigate human–environment interactions, such as racing against opponents, as well as analysing in-competition behaviour exploring new facets of pacing not possible with existing models. In addition, it is important to explore what other factors influence pacing and decision-making. There are indications that cognitive performance and potentially decision-making ability are compromised when individuals become physically fatigued [77], or as a consequence of low self-efficacy [78] or high anxiety [79]. The effects of physical fatigue on decision-making are

clearly very relevant for occupations such as the military and emergency services where physical capacity and decision-making ability are crucial for optimal performance. An overly strong focus on the conscious–subconscious paradigm neglects the multiplicity of factors relevant to athletic decision-making that might be accommodated better with dual process theory.

## 6 Implications for Pacing Research

Dual process theory and the distinctions between intuitive and deliberative cognitive processes outlined above provide several new directions and questions for pacing research, and an opportunity to more effectively explore the multidimensional characteristics of pacing. Conceptually, it can accommodate the idea that pacing behaviour and associated muscle recruitment can arise out of both intuitive and deliberative cognitive processes. This is useful because research can focus on understanding how particular tasks, situations and triggers create the conditions under which intuitive and deliberative processes are more likely, when certain heuristics are selected in preference to others, and how they influence or bias pacing decisions. For example, it might be hypothesised that pre-planned pacing strategies that are consciously formulated by an athlete and coach well in advance of the race are deliberative, and follow a systematic control strategy based on the execution of pre-planned algorithms. Equally, it could be hypothesised that intuitive decision-making processes are better in situations during the race, where there are complex, incomplete or conflicting cues and a high degree of outcome uncertainty. Intuitive processes may also provide an important means by which athletes can make rapid pacing decisions, perhaps in response to sudden and unexpected competitor behaviour.

Future research could focus on identifying and understanding the heuristic principles that athletes rely on to make intuitive pacing decisions in complex situations that are otherwise difficult to resolve through deliberation. But we also need to develop a better understanding of how heuristic decision-making can in some circumstances lead to outstanding performance yet failure in other instances. Overall, greater insight about how heuristics and biases affect pacing and performance could help develop methods to improve intuitive decision-making skills in athletes to help them effectively adapt and respond to novel or difficult situations.

While in some situations intuitive decision-making capacity is useful, other circumstances lend themselves to deliberative processes. To illustrate this point, Tversky and Kahneman [45] analogised that "…making decisions is like speaking prose—people do it all the time, knowingly or unknowingly" (p. 341). In pacing research we must gain a clearer understanding of (1) the situational conditions for which deliberative processes are most advantageous; and (2) the hidden pre-decisional cognitive processes through which deliberation proceeds. The first point is important because it will help break the impasse in pacing research associated with the issue of conscious versus subconscious control. The second point is important because what should emerge from such understanding is the development of conscious attention, perceptual and problem-solving strategies that athletes can use to improve pacing decisions. In the pacing literature a great deal of emphasis is placed on the importance of anticipation [3, 5–8], yet very little has been done to understand the cognitive processes involved in anticipating the demands of a future task, or how such appraisals influence subsequent pacing decisions. The ability to anticipate involves hypothetical thinking [80] and prospective mental simulation [81]. For prospective thought to accurately predict events, two essential conditions must be met: (1) the context we are in or imagine we are in during simulation does not vastly deviate from the actual future context that transpires; and (2) the memories used to simulate are sufficiently vivid and realistic representations of the future event [81]. In the context of athletic pacing, especially during the early stages of an endurance event, the likelihood of inaccurate mental simulation is high owing to the potential for internal or external conditions to change that could result in pacing errors and negative effects on overall performance. A further complication is the influence that opponents in 'real world' athletic competitions might have on athletic decision-making and tactics [75, 76], for which circumstance, intuition and hypothetical thinking may play a crucial role. A fuller understanding of deliberative cognitive processes will help develop conscious decision-making skills for athletes.

There are many practical issues that need to be considered to operationalise dual process athletic pacing research. The first is to recognise the limitations of time series measurements of speed and power which, although useful indicators of post-decisional pacing behaviour, reveal very little about pre-decisional cognitive processes, whether intuitive or deliberative. The issue is further complicated by the fact that many of the pre-decisional cognitive processes are hidden and not directly observable, so a special category of research techniques known as process-tracing is needed. These and other operational research issues are discussed more comprehensively in Electronic Supplementary Material Appendix S1, along with an introduction to process tracing methods and their application to dual process athletic pacing research.

## 7 Conclusions

The one-dimensional conscious–subconscious debate that has reigned in the pacing literature has suppressed our understanding of the multidimensional processes that occur in pacing decisions. If we limit ourselves to only one facet of the multidimensional process of pacing, the conscious–subconscious debate, other exciting and useful areas of exploring human behaviour in a sports context will remain relatively unattended. We need to explore how, and based on which information, athletes make their decisions using smartly designed experiments that incorporate, for example, athlete–environment interactions. It is our contention that conceptualising decision-making in pacing as involving intuitive or deliberative process provides a means by which further research progress can be made on parallel problems without being constrained by the singular issue of conscious versus subconscious control. In addition to the opportunities for exploring the multidimensional character of pacing, such an approach reflects the complex nature of athletic decision-making.

In attempting to refine pacing models and improve training strategies and psychological skills for athletes, the dual process framework could be used to gain a clearer understanding of (1) the situational conditions for which either intuitive or deliberative decisions are optimal; (2) how intuitive and deliberative decisions are biased by perception, emotion and experience; and (3) the underlying cognitive mechanisms such as memory, attention allocation, problem solving and hypothetical thought.

#### Compliance with Ethical Standards

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