The role of self-control in athletic performance

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Additional Information:

• A Doctoral Thesis. Submitted in partial fulfilment of the requirements for the award of Doctor of Philosophy of Loughborough University.

Metadata Record: https://dspace.lboro.ac.uk/2134/23326

Publisher: © Ruth Boat

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THE ROLE OF SELF-CONTROL IN ATHLETIC PERFORMANCE

By

Ruth Boat

Doctoral Thesis

Submitted in partial fulfilment for the requirements of the award of Doctor of Philosophy of Loughborough University

September 2016

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Abstract

This thesis is presented as a collection of four studies in which the role of self-control in athletic performance is examined. Considerable evidence has documented the beneficial effects of trait self-control and robust self-confidence on a wide range of behaviours. However, the relationships between these constructs have yet to be specifically explored within the sport domain. As well as exploring the trait perspective of self-control, research has employed self-control manipulations and laboratory performance to examine state self-control. The completion of tasks requiring self-control have led to impaired performance on physical tasks, also requiring self-control. But it remains unclear whether previous exertion of self-control impairs subsequent performance when self-regulation is potentially automatic, and if any observed effects are variable over different stages of performance. Building on this work, glucose supplementation, and the duration of self-control effort have been proposed as potential moderators that may influence performance effects, yet controversy exists surrounding glucose consumption, and task duration has not been appropriately considered. Furthermore, the identification of explanatory mechanisms for performance decrements following self-control use is of theoretical significance. In particular, research is yet to explore whether an individual’s perceptions of pain may explain why self-control exertion interferes with subsequent performance on a physical task. The current thesis aims to address these limitations of the extant literature.

Study One examined whether an individual’s general ability to exert self-control might be an important mechanistic variable that explains the relationship between robust self-confidence and athletic performance. Following an examination of trait self-control, an exploration of state self-control was deemed more relevant to situational performance. Therefore, Study Two and Three utilised a sequential-task paradigm to examine whether exerting self-control impairs subsequent endurance performance in well-trained individuals, and whether any observed effects are variable over different stages of endurance performance. Study Two and Three also examined moderators of the depletion effect. In particular, the potential for glucose supplementation (Study Two), and duration of self-control effort (Study Three), to attenuate any decrements in performance due to initial self-control exertion were explored. Following the investigation of moderators, Study Four examined whether performance decrements can be explained by an individual’s perceptions of pain.
Overall, the findings of this thesis suggest that trait self-control represents a potentially important mechanism by which athlete’s with strong robust self-confidence progress and perform successfully. Furthermore, prior exertion of self-control impairs subsequent self-regulatory efforts during well-practiced endurance performance, but these effects are variable over different stages of performance. In addition, extended self-control effort may lead to the conservation of self-control, whilst glucose supplementation does not moderate self-control ability. Finally, perceptions of pain may explain why self-control exertion interferes with subsequent performance on a physical task.
List of publications arising from this thesis

**Peer reviewed journal articles:**


**Conference proceedings:**

Boat, R., Hulston, C. J., & Taylor, I. M. (July, 2016). Self-control exertion and glucose supplementation prior to endurance performance. *Oral presentation presented at the 21st Annual Congress of the European College of Sports Sciences,* Vienna, Austria. Note: This was awarded a Young Investigator prize.
Dedications

To Mum and Dad.

This is for you both.
Acknowledgements

To Dr Ian Taylor, there are only two words that really capture what I want to say to you – Thank you. These two words will never show how truly grateful I am for the opportunity, guidance, and exceptional support that you have given me over the last three years of the PhD. Thank you for teaching me so much about theory, data analysis, writing manuscripts, and for providing me with a number of valuable opportunities beyond my PhD. All of this has enabled me to develop as a researcher more than I ever believed possible. I feel incredibly lucky to have been able to draw from your experience, knowledge, enthusiasm, and passion for what you do. You have most definitely sparked my academic and career ambitions. Thank you so much for being an excellent supervisor – I very much look forward to working with you in the future.

To Dr Carl Hulston. Thank you for providing a valuable input into various parts of my PhD. Thank you for being the ‘go to guy’ whenever I needed advice or support in the lab. I fear you may never want to open your lab door to a Sport Psychology student again!

To the guys and girls of NCSEM. Thank you for all the fun and laughs you have given me during my PhD. Thank you for sharing your ideas with me when I got stuck, and supporting me through the good times and the not so good times that the PhD journey threw at me. Above all, thank you for becoming so much more than work colleagues. I have met some amazing people throughout my time at Loughborough, many of which have most definitely become lifelong friends. I have created some amazing memories with you all that has made my PhD journey a very enjoyable experience, and one that I will never forget.

To the boys and girls of LE10. Thank you for providing me with much needed respite at key moments throughout my PhD journey, and for reminding me that there was actually a life outside of the PhD bubble. I very much look forward to being relinquished of the ‘you’re still a student’ title!

To my Grandparents, Nan and Grandad Boat, and Grandma Bonser, all of whom are no longer with us. I wish you were all here today to celebrate this achievement with me – I hope I have made you proud.

To Sam. Thank you for providing me with continued love and support. Thank you for being so understanding and always sticking by me through the more difficult times.

To Lauren and Leigh. Thank you both for your lifelong support and encouragement every step of the way. Thank you both for always being there for me whenever I have needed you.
And finally, to Mum and Dad. Thank you so much for providing me with unconditional practical, emotional, and financial support. Together, you have been the most supportive parents that I could have ever of wished for, not just over these three years, but throughout my whole life. I most definitely would have not achieved what I have today without your love, support, and guidance. I will be forever grateful. This is for you both.
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Chapter One

Literature Review
Defining Self-Control

Self-control has been defined as the mental capacity of an individual to alter, modify, change, or override, his or her impulses, desires, and habitual responses (Baumeister & Heatherton, 1996). Such conflict is subjectively aversive and can lead people to inhibit or suppress one set of responses and replace them with the second set (Inzlicht, Bartholow, & Hirsh, 2015). Self-control is understood to be applied when an individual opts to inhibit their immediate desires and to replace them with behaviour that aligns with their long-term goals (Milyavskaya & Inzlicht, 2016).

Alternative terms that have often been considered synonyms of self-control within the literature include willpower, self-discipline, and self-regulation (Duckworth & Seligman, 2005; Henden, 2008). Self-control and self-regulation, in particular, are most frequently used interchangeably (Baumeister, Vohs, & Tice, 2007). Self-control has been viewed as a specific form of self-regulation in which an individual exerts deliberate and conscious effort to control the self, whereas self-regulation is considered a global term that encapsulates automatic and nonconscious regulatory processes (Baumeister et al., 2007). A large body of literature has focused on individual differences in how good people are in suspending short-term temptation for their long-term goals (i.e., trait self-control).

Self-control is important for a variety of sport and exercise behaviours including superior athletic performance (Englert, 2016). In sports, for optimal performance, athletes are required to control their cognitive, emotional, and motor processes, as well as their behavioural tendencies (Englert & Bertrams, 2012; Wagstaff, 2014). For instance, athletes need to regulate their anxiety levels in high-pressure environments (e.g., athletic competitions; Englert & Bertrams, 2012), force themselves to work persistently on straining physical exercises (e.g., Wagstaff, 2014), or force themselves to comply with work-out plans over an extended period of time (e.g., Martin Ginis & Bray, 2011). Moreover, the ability to ‘dig deep’ and resist feelings of pain are critical elements of successful athletic performance, particularly for endurance athletes. Withstanding the urge to relieve the distress, even by small amounts, can be the difference between winning and losing.

Trait Self-Control

Dispositional (trait) self-control has been defined as the general capacity to alter one’s responses to achieve a desired state or outcome that otherwise would not arise naturally (e.g., Bauer & Baumeister, 2011; Baumeister & Vohs, 2007). In general, the ability to control oneself is considered a particularly stable individual characteristic that is related to a vast amount of behaviours (Tagney, Baumeister, & Boone, 2004). Individuals with high self-
control are better able to control their thoughts, regulate their emotions, and inhibit their impulses, compared to people with low self-control (De Ridder, Lensvelt-Mulders, Finkenauer, Stok, & Baumeister, 2012). They enjoy better psychological wellbeing, experience higher levels of achievement and performance, and better interpersonal relationships (Gailliot & Baumeister, 2007; Hagger, Wood, Stiff, & Chatzisarantis, 2010; Tagney et al., 2004). High self-control is relevant to nearly all forms of behaviour that contribute to a successful and healthy life; therefore, it has become a pertinent concept in numerous areas of psychological research (De Ridder et al., 2012).

**Trait Self-Control and Athletic Performance**

The empirical evidence discussed above supports the beneficial effect of self-control on a wide range of behaviours, but unfortunately, scarce research has explicitly examined the concept of self-control and its relationship with superior athletic performance. The capacity for self-control may facilitate athletic performance because, in order to be successful and achieve optimal levels of athletic performance, it is imperative for athletes to focus on long term goals and resist situational temptations and short-term gains (e.g., Gould, Moffett, & Diefenbach, 2002; McNamara, Button, & Collins, 2010). Individual differences in self-control ability have been linked with numerous desirable outcomes, including increased control of thoughts and emotions (Baumeister et al., 2007). Given that most sports require individuals to successfully control their cognitive, emotional, and motor processes (Englert & Bertrams, 2012), self-control may well function as a critical factor in determining superior sporting achievement.

Indirect evidence exists that links self-control to alternative factors that may facilitate optimal athletic performance, and may provide a rationale for exploring this process. For instance, it has been suggested that deliberate practice is fundamental to the development of sporting success (e.g., Baker & Young, 2014). This type of practice, however, is not always enjoyable, and demands effort and concentration (Baker, Cobley, & Frazer-Thomas, 2009). This means that sustaining large amounts of deliberate practice over time requires self-control (Toering & Jordet, 2015). Recently, Toering and Jordet (2015) reported that self-control was positively associated with practice quantity, as well as soccer performance in a sample of professional players. In light of this evidence, it is possible that high levels of trait self-control may be a crucial factor in achieving optimal levels of athletic performance.

**Robust Self-Confidence, Self-Control, and Athletic Performance**

Self-confidence has been defined as the degree of certainty one possesses about his/her ability to be successful in sport; Vealey, 1986). Although, a collection of
psychological components may be fundamental for sporting success, self-confidence may be especially important because it underpins resilience, the management of stress and pressure, and athletic performance (Fletcher & Sarkar, 2012; Galli & Vealey, 2008; Gucciardi, Jackson, Coulter, & Mallett, 2011). However, merely possessing sport confidence may not be enough to perform superiorly, rather athletes are required to hold robust confidence and maintain belief in one’s ability in the face of difficult experiences and possible setbacks (Bull, Shambrook, James, & Brooks, 2005; Vealey & Chase, 2008). The robust nature of confidence may actually contribute to success over and above the contribution level of general confidence (where high levels are perceived as sufficient; Bull et al., 2005).

Robust self-confidence has been defined as a set of enduring, yet malleable positive beliefs that protect against the ongoing psychological and environmental challenges associated with competitive sport (Thomas, Lane, & Kingston, 2011). Athletes perceived to be the most resilient against setbacks have identified robust self-confidence as an important characteristic (Jones, Hanton, & Connaughton, 2007) and described an ‘unshakable self-belief’ as fundamental for success (Sarkar & Fletcher, 2014). More specifically, robust self-confidence has been linked with goal attainment, increased effort and persistence, in addition to effective competition focus (Hays, Thomas, Maynard, & Bawden, 2009). Individuals who possess weak self-confidence may not remain focused and dedicated. On the contrary, those with robust confidence tend to stay focused even when performance is poor (Faghir, Tojari, & Amirtash, 2013). Consequently, an individual with robust self-confidence may have an increased general capacity to exert self-control in the sport environment. It has been conjectured that confidence may be related to good self-control (DeBono & Muraven, 2013), yet this line of enquiry has not been explicitly examined, despite potentially providing insight into the relationship between these psychological constructs. Accordingly, it would seem prudent to examine whether an individual’s general ability to exert self-control might be an important variable that explains the relationship between robust self-confidence and athletic performance. The first experimental chapter of this thesis explored whether self-control acts as an explanatory mechanism for the relationship between robust confidence and athletic performance.

**Self-Control Exertion and Subsequent Task Performance**

In addition to the trait perspective on self-control, a more recent approach has emphasised that exerting self-control on one task, impairs performance on subsequent, ostensibly unrelated tasks requiring self-control (Hagger et al., 2010). Typically, research has employed an experimental protocol consisting of two unrelated tasks requiring self-control,
known as the sequential-task paradigm (Baumeister et al., 2007). For participants randomly assigned to an experimental (self-control) group, both tasks require self-control. However, for participants allocated to a control (non-self-control) group, only the second task requires self-control while the first task does not require any, or very little, self-control (Baumeister, Bratslavsky, Muraven, & Tice, 1998). The self-control tasks utilised require participants to alter or modify an instinctive, well-learned response, akin to resisting an impulse or temptation (Baumeister et al., 2007). Research suggests that experimental group participants’ performance on the second self-control task will be impaired relative to that of control group participants, due to initial exertion of self-control on the first task (Baumeister et al., 1998). For example, individuals who were instructed to eat radishes and resist the temptation of appetising chocolates exhibited significantly lower persistence on a subsequent unsolvable geometric puzzle task compared to those participants who were asked to eat the chocolate and leave the radishes (Baumeister et al., 1998). Resisting the tempting food required self-control as individuals were required to override a habitual or dominant response (Baumeister et al., 1998); this led to reduced performance on a subsequent task that required self-control. This effect has been replicated on a number of occasions (e.g., Baumeister & Vohs, 2007; Baumeister et al., 2007; Martijn, Alberts, Merckelbach, Havermans, Huijts, & De Vries, 2007; Wright, Martin, & Bland, 2003).

A meta-analysis of studies published between 1998 and 2009 revealed that 198 separate studies had employed the sequential task paradigm (Hagger et al., 2010). Overall, a medium effect size (d = 0.62) for impaired performance on the second self-control task due to initial exertion of self-control on the first task was observed. However, it has been implied that Hagger et al.’s (2010) meta-analytic evidence may have been inflated as a result of publication bias. Re-analysis of Hagger et al.’s data (Carter & McCullough, 2013, 2014), as well as a new meta-analysis which included unpublished research (Carter, Kofler, Forster, & McCullough, 2015), exposed ‘small study’ bias in the effect size originally reported. As a result of their re-analysis and updated meta-analysis, Carter et al., (2015) concluded that the evidence does not support the premise that the use of self-control leads to poorer performance on subsequent self-control tasks.

Most recently, however, researchers have questioned the interpretation of the regression analyses conducted in Carter et al.’s (2015) meta-analysis (e.g., Cunningham & Baumeister, 2016; Hagger & Chatzisarantis, 2014). This ongoing debate led Hagger and colleagues (2016) to conduct a registered multi-lab replication of the depletion effect. Multiple studies (k = 23, total N = 2141) described replications of a standardised protocol
based on a sequential-task paradigm originally used by Sripada, Kessler, and Jonides (2014). The meta-analytic evidence revealed that if there is any effect of initial self-control exertion on subsequent unrelated tasks requiring self-control, it is close to zero. Although recent evidence raises questions as to the existence of the depletion effect and its replicability, Hagger et al. (2016) concluded that, although the size of the depletion effect is likely smaller than previously suggested, it may be too early to reject the effect altogether.

**Self-Control Exertion and Subsequent Physical Performance**

A considerable body of evidence exists that suggest that exerting self-control on one task impairs performance on subsequent physical tasks requiring self-control (Englert, 2016). These studies have typically demonstrated the effects of initial self-control exertion using a simple physical measure such as squeezing a handgrip for as long as possible. Albeit, squeezing an isometric handgrip primarily requires muscular strength, overcoming fatigue and overriding the urge to quit become primarily an act of self-control and mental persistence (Bray, Martin Ginis, Hicks, & Woodgate, 2008). To illustrate, individuals who were instructed to suppress their emotion expression whilst watching an emotionally-provoking video were unable to squeeze an isometric handgrip dynamometer for as long as individuals who were not given any regulatory instructions (Muraven, Tice, & Baumeister 1998). The ability for cognitive or emotion regulation to reduce subsequent isometric handgrip performance has been substantiated in a number of other experiments (e.g., Bray et al., 2008; Bray, Graham, Martin Ginis, & Hicks, 2011; Muraven & Shmueli, 2006; Tice, Baumeister, Shmueli, & Muraven, 2007).

The studies described above utilised a very simple measure of physical strength, therefore, in order to enhance the ecological validity of the evidence so that conclusions regarding more complex human performance can be drawn; research has utilised calisthenic measures of physical action. For instance, following a cognitively demanding task (counting backwards from 1000 in 7’s whilst holding a spirit level), competitive rowers performed significantly worse on a press-up task compared to when they completed a cognitively simple task (counting backwards from 1000 in 5’s; Dorris, Power, & Kenefick, 2012). Other research examining prior self-control exertion and physical performance has focused on the impact of self-control manipulation on skilled performance (e.g., Englert & Bertrams, 2012; Englert, Bertrams, Furley, & Oudejans, 2015a; Furley, Bertrams, Englert, & Delphia, 2013; McEwan, Martin Ginis, & Bray, 2013). To elaborate, following a cognitively demanding task (transcribing a neutral task while omitting the letters ‘e’ and ‘n’), individuals performed worse on a basketball free throw task as their anxiety increased, whereas no significant
relationship was observed when participants completed a cognitively simple task (transcribing a neutral task; Englert & Bertrams, 2012). Similar results have also been documented on a dart-throwing task (McEwan et al., 2013). Participants were assigned to a self-control or non-self-control experimental condition, and performed a dart-tossing task at two times of measurement, before the experimental manipulation of self-control and after the manipulation of self-control. The results revealed that participants in the self-control condition performed significantly worse on the dart-tossing task compared to the non-self-control condition.

Taken together, the aforementioned studies demonstrate that self-control impairment via cognitively demanding tasks can subsequently reduce persistence in straining physical exercises, callisthenic measures of physical action, as well as impair performance during skill-based tasks (Englert, 2016). It could be argued, however, that the dependent measures of physical performance reviewed above may have limited application to performance in many globalised sports involving gross motor skills (e.g., running, cycling, jumping, throwing; Wagstaff, 2014).

To address this gap within the literature, research has recently begun to examine initial self-control exertion on subsequent gross motor skill endurance performance. For instance, following a cognitively demanding task (incongruent Stoop task), recreationally active participants displayed a lower power output and invested less effort during an indoor cycling task at a fixed gear for an 18 minute period, compared to when they completed a cognitively simple task (congruent Stroop task; Englert & Wolff, 2015). Furthermore, Wagstaff (2014) conducted a comparable study and reported a similar pattern of results. When endurance trained participants watched an upsetting video and were instructed to suppress their emotional responses, they completed a 10 km cycling time trial significantly slower and reported greater physical exertion compared to when they watched the upsetting video and were given no guidance regarding emotion suppression or regulation. Furthermore, although not examining sport performance per se, recreationally active participants exposed to a self-regulatory depletion manipulation generated lower levels of work during a 10 minute cycling task, and planned to exert less effort during an upcoming exercise bout, compared to control participants (Martin Ginis & Bray, 2011). Together, the results imply that apart from a number of important physiological variables (e.g., muscular strength); self-control seems to be critical in order to be able to achieve high levels of endurance performance (e.g., Bray et al., 2008; 2011; Englert & Wolff, 2015). Only a relatively small number of studies have considered the effects of initial self-control exertion on actual gross motor skill endurance.
performance over an extended period of time. However, literature from the cognitive fatigue domain may be informative of the effects of initial self-control exertion on subsequent endurance performance.

Research acknowledges that prolonged cognitive exertion can impair subsequent physical human performance. For instance, following a 90 minute demanding cognitive task (the AX-Continuous Performance Task; Carter, Braver, Barch, Botvinick, Noll, & Cohen, 1998), aerobically trained participants reached their maximal level of perceived exertion and disengaged earlier during a subsequent cycling trial at 80% peak power output, compared to when they completed a control task (90 minutes of watching emotionally neutral documentaries; Marcora, Staiano, & Manning, 2009). Slower 5 km running times and higher perceptions of exertion have also been observed following a 30 minute incongruent Stroop task, compared to a less demanding congruent Stroop task; Pageaux, Lepers, Dietz, & Marcora, 2014). In these two studies, there were negligible or no difference in heart rate across conditions, suggesting that mental fatigue limits exercise tolerance through higher perception of exertion rather than cardiorespiratory mechanisms (Marcora et al., 2009). The capability for cognitive fatigue to impair performance on subsequent endurance tasks has been replicated (e.g., MacMahon, Schücker, Hagemann, & Strauss, 2014; Martin et al., 2016).

It is, however, worth noting that there is current debate within the literature regarding whether depletion is a form of mental fatigue or not. There appears to be a significant difference between these two constructs (Englert, 2016). Tasks that are utilised to induce mental fatigue usually last considerably longer than the tasks that are employed in self-control depletion research. For example, Marcera et al. (2009) instructed his participants to perform a cognitively demanding task for 90 minutes, whereas, much of the self-control depletion research employs tasks that are significantly shorter (Hagger et al., 2010). Therefore, it has been argued that typical self-control depletion tasks, are not prolonged enough to induce subjective feelings of mental fatigue (Pageaux, Marcara, & Lepers, 2013). On the contrary, the two phenomena show many similarities (Evans, Boggero, & Segerstrom, 2015; Saunders & Inzlicht, 2016). Some researchers have suggested that both depletion and fatigue require the constant utilisation of effort that may stimulate negative feelings, including subjective fatigue (Hagger et al., 2010). Further, both psychological constructs lead to performance decrements, which may be due to an unwillingness to employ further effort rather than incapacity (Hockey, 2013; Inzlicht & Schmichel, 2012). Finally, depletion and fatigue may be overcome with adequate task-motivation (Muraven & Slessareva, 2003).
Despite the controversies, the cognitive fatigue literature provides an insight into the effects of initial self-control exertion on subsequent gross motor skill endurance performance.

Collectively, the prevailing self-control and endurance-based research discussed above provides valuable insight into self-regulatory processes and athletic performance. However, it is currently unknown whether previous exertion of self-control impairs subsequent endurance performance when self-regulation is potentially automatic. In expert populations, the frequent pursuit of the same cognitive goal can result in the automatization of cognitive processes commonly associated with the self-regulation of that behaviour (Schneider & Chein, 2003; Yarrow, Brown, & Krakauer, 2009). With repeated practice, one can learn to persist automatically (Chartrand & Bargh, 2002). Therefore, athletes who regularly push themselves during training sessions and competition may themselves have learned to persist nonconsciously (Dorris et al., 2012). When this automatic behaviour occurs, self-regulatory processes may not be necessary to the same degree as conscious self-regulation (Schmeichel & Baumeister, 2004). Therefore, a prior exertion of self-control would have no effect on subsequent physical performance because self-control is automatic.

On the contrary, successful endurance performance involves substantial levels of discomfort and overcoming these demands may provoke the need for conscious self-regulation. This latter hypothesis suggests that engaging in an initial task requiring self-control may impair subsequent endurance performance because the self-regulation required to maintain effort and persistence and resist discomfort is salient. It remains unclear, whether well-practiced human performance requires enough in the way of conscious self-regulation to be impaired by previous exertion of self-control. Consequently, the second and third experimental chapter of this thesis examined whether the completion of a task requiring self-control may negatively impact on subsequent self-regulatory efforts during a well-practiced endurance task.

Research has also recently investigated the effects of self-control exertion on performance over time. Specifically, Englert and Wolff (2015) continually assessed participants’ performance during a cycling task. Hierarchical linear modelling revealed that participants performed consistently worse over a period of 18 minutes following the completion of a cognitively demanding task (incongruent Stroop task), compared to when they completed a cognitively simple task (congruent Stroop task). Even more interesting, is that this effect became more pronounced over time. It is important to note that this study is the first to examine how initial self-control exertion affects performance over an extended period of time. To extend this work, the second and third experimental chapter of this thesis also explored whether any observed effects of self-control exertion are variable over different
stages of endurance performance. It is possible that the effects of exerting self-control on subsequent performance may well be dependent on the timing of performance examination.

**Theoretical Models of Self-Control**

The major theoretical model that has been utilised to explain self-control failures following a primary self-control act is the *strength model of self-control*, which suggests that self-control is based on a fuel that powers the will (Baumeister et al., 1998; Baumeister & Heatherton, 1996; Muraven & Baumeister, 2000). According to this model, performance on tasks requiring self-control draws energy from a general resource (Baumeister et al., 1998; Muraven, Collins, Shiffman, & Paty, 2005). This resource is limited and is consumed by use; therefore, it is vulnerable to becoming depleted over time (Baumeister et al., 1998). Accordingly, after initial acts of effortful control, an individual’s capacity to exert further self-control becomes exhausted, leading to decreased performance on subsequent acts of self-control (Hagger et al., 2010). The state of self-control resource depletion is termed ‘ego depletion’ (Baumeister et al., 1998). Although this resource explanation has been used as the primary model to explain the findings of studies employing the sequential-task paradigm, it has received some major challenges. For example, a number of studies have identified methods to sustain self-control, including incentives (e.g., Muraven & Slessareva, 2003), providing choice (Moller, Deci, & Ryan, 2006), and meditating (Friese, Messner, & Schaffner, 2012). Individuals prior beliefs about self-control can also moderate self-control decrements (Clarkson, Hirt, Jia, & Alexander, 2010; Job, Dweck, & Walton, 2010). If self-control is a limited and expendable resource, then it is unclear why meditating, for instance, can replenish this resource.

Given the challenges associated with the popular resource model, alternative explanations as to why self-control is reduced following prior exertion have been suggested. An alternative perspective is the *shifting priorities model of self-control*, which is centred on motivational and attentional processes (Inzlicht & Schmeichel, 2016; Milyavskaya & Inzlicht, 2016). According to this model, a subjective ‘valuation’ process leads to decrements in self-control, whereby alterations to distal and proximal choice evaluations occur (Berkman, Livingston, Kahn, & Inzlicht, 2015). That is, following the use of self-control, the value of exerting further self-control diminishes, while the value of giving in to the tempting impulse increases (Kool & Botvinick, 2014). Ultimately, self-control represents a decision to apply effort to resist a tempting goal in favour of a distal goal (Milyavskaya & Inzlicht, 2016). This valuation process can be influenced by a number of motivational inputs. For instance, proximal choices are usually more immediately satisfying and enjoyable, compared
to distal goals (Kahneman & Tversky, 1979; Milyavskaya & Inzlicht, 2016). However, distal goals that are autonomous (i.e., freely chosen and of personal meaning; Deci & Ryan, 2012) are less likely to be affected by proximal temptations (Milyavskaya, Inzlicht, Hope & Koestner, 2015), are perceived as being easier to pursue (Werner, Milyavskaya, Foxen-Craft, & Koestner, 2016), and are less fatiguing (Moller et al., 2006), compared to non-concordant goals. In the contexts of athletic performance, motivational inputs that may influence the valuation process include physiological sensations of discomfort, importance of the competition, as well as crowd size and noise.

Goals are generally established on a number of motives; consequently, attentional process can be manipulated to emphasise some more than others and impact upon self-control (Woolley & Fishbach, in press). For instance, following self-control exertion, basket players paid greater attention to distracting verbal stimuli, and performed worse, during a free-throw task, compared to a non-self-control condition (Englert et al., 2015a). Similar results have also been documented during a pressured dart-tossing task, individual’s visual attention shifted following self-control use, relative to no self-control use (Englert, Zwemmer, Bertrams, & Oudejans, 2015b). However, this attentional shift was not supported during a hypothetical basketball decision-making task (Furley et al., 2013). Ultimately, motives that underlie a goal can influence attentional processes which determine the self-control dilemma by shifting the balance towards the immediately gratifying tempting goal or the distal goal (Woolley & Fishbach, in press).

A third theoretical model of self-control is the affect alarm model of self-control (Inzlicht & Legault, 2014). This model suggests that self-control is an emotional process that is an adaptive and fundamental component of athletic performance. Similar to other models described above, the affect alarm model implies that self-control is initiated by self-monitoring processes that identify conflict between competing goals (Wooley & Fishbach, in press). This goal conflict stimulates negative affect, which alerts an individual to the need to inhibit or modify their behaviour to resolve the goal conflict (Gray & McNaughton, 2000). Without this aversive experience, goal conflicts would not be identified and therefore, resolution would not take place (Inzlicht & Legault, 2014; Woolley & Fishbach, in press). On the flip side, continuously exerting self-control can heighten the aversive experience (Kool & Botvinick, 2014); reducing the likelihood of resisting the temptation.

This affect alarm model and shifting priorities model may provide alternative explanations as to why self-control fails following a primary self-control task. Many of the physical second tasks that have been employed in previous self-control experiments are
unpleasant and induce elevated levels of discomfort (e.g., Bray et al., 2011; Dorris et al., 2012; Englert & Wolff, 2015). Seemingly, therefore, individuals are required to ‘dig deep’ and resist feelings of pain that such tasks evoke, in order to maintain persistence and achieve high levels of performance. In light of this fact, it is possible that self-control exertion leads to increased attention on perceptions of pain (i.e., the aversive experience) during a physically-demanding task. This leads to greater focus on relieving the pain (proximal goal), during the valuation process and consider it more important than persisting on the task and achieving high levels of performance (distal goal; Berkman et al., 2015). Therefore, an individual’s motivational orientation is shifted towards the immediately gratifying tempting goal (Woolley & Fishbach, in press); leading to performance declines (Inzlicht & Schmeichel, 2016).

The extant research has yet to explicitly consider whether performance decrements in physical tasks following initial self-control exertion can be explained by an individual’s perceptions of pain. Nonetheless, research examining dispositional self-control has shown that individuals with higher levels of trait self-control persisted longer at the painful cold pressor test compared to those participants with lower levels of trait self-control (Schmeichel & Zell, 2007), implying that those with higher self-control may be more successful at tolerating pain than those with lower self-control. However, this does not explain why a bout of self-control exertion reduces subsequent physical performance. Consequently, it seems reasonable to explore whether performance decrements following a primary task requiring self-control can be explained by an individual’s perceptions of pain. Digging deeper into potential causal explanations would provide a greater insight into the possible processes that underpin self-control. Furthermore, this line of inquiry is particularly pertinent, given the call for an increased focus on the actual mechanisms behind performance decrements following a primary self-control task (Englert, 2016).

**Moderators of Performance Decrement Following Initial Self-Control Exertion**

Recent avenues of inquiry have explored the nature of the resource that underlies self-control (Baumeister et al., 1998). Most popular is the proposed role of glucose (Gailliot et al., 2007). Even though the majority of the brain’s activities consume some glucose, many cognitive processes are unaffected by subtle or negligible fluctuations in glucose levels within the normal or healthy range (Gailliot et al., 2007). Controlled, effortful processes that rely on executive function, however, are unlike most other cognitive processes in that they seem highly susceptible to normal fluctuations in glucose (Gailliot et al., 2007). Seemingly, therefore, tasks requiring controlled, effortful self-control demand increased cerebral
functioning, possibly causing a concomitant rise in the requirement for blood glucose in the brain (Benton, Parker, & Donohoe, 1996).

According to several initial studies, engaging in a self-control task (e.g., Stroop task) consumed a relatively large amount of glucose; compared with completing a cognitive task that does not require self-control (Gailliot et al., 2007). Because there exists an equilibrium between glucose in the blood and the brain (Lund-Anderson, 1979), low blood glucose levels after an initial self-control task (e.g., Stroop task) have been found to impair performance on subsequent behavioural measures of self-control (Gailliot et al., 2007; DeWall, Baumeister, Gailliot, & Maner, 2008; Masicampo & Baumeister, 2008; Wang & Dvorak, 2010). Glucose is rapidly digested, absorbed, and available for oxidation (Jeukendrup et al., 1999). Hence, glucose drinks may be a viable means of increasing the amount of glucose available for self-regulatory tasks, providing that one allows time for the glucose to reach the bloodstream. Replenishing glucose to optimal levels with a drink containing glucose has been shown to restore performance during cognitive tasks that require self-control (Baumeister et al., 1998; DeWall et al., 2008; Gailliot et al., 2007; Masicampo & Baumeister, 2008; Wang & Dvorak, 2010), leading Hagger et al. (2010) to conclude that there is a large homogenous effect (\( d = 0.75 \)) of experimental glucose supplementation on the depletion effect.

However, the idea that the exertion of cognitive effort leads to measurable drops in glucose has proven controversial. These aforementioned effects have failed to replicate with more precise measurements of blood glucose (Molden et al., 2012), and results of the initial studies (Gailliot et al., 2007) are not supported by re-analysis of the original data (Kurzban, 2010; Schimmack, 2012). The role of glucose supplementation in counteracting the depletion effect has also been challenged. In a recent study that utilised a selective attention task (delay discounting) as the self-control manipulation and dependent measure, glucose administration did not moderate the depleting effect (Lange & Eggert, 2014). Similar results were also observed following an emotionally upsetting video (versus an emotionally neutral video; Dvorak & Simons, 2009), as well as a go/no-go paradigm (versus an infrequent no-go paradigm; Lange, Seer, Rapior, Rose, & Eggert, 2014). However, when considering the design features of these studies, Lange and Eggert’s (2014) experiment exposed participants to the same act of self-control twice. The sequential-task paradigm requires that participants engage in two acts that belong to different spheres of self-control (Baumeister et al., 2007). Therefore, Lange and Eggert’s (2014) design failed to control for the influence of cognitions or affective experiences that augment during the primary self-control task, on willingness to exert effort on the second self-control task (Chatzisarantis & Hagger, 2015a; Wallace &
Baumeister, 2002). It has been suggested, that the methodologies that have been utilised in such experiments may have concealed glucose effects (Chatzisarantis & Hagger, 2015a; Chatzisarantis & Hagger, 2015b). In light of the aforementioned limitations surrounding research design, together with the controversy surrounding the role of glucose in counteracting self-control depletion, it would seem reasonable to further test this line of inquiry. Therefore, the second experimental chapter of this thesis explored the potential for glucose administration to attenuate any decrements in performance on the second self-control task, due to prior self-control exertion.

An additional moderator that may potentially influence the extent to which initial self-control exertion impairs subsequent performance is the length of time spent on the initial self-control task within the sequential-task paradigm (Hagger et al., 2010). Primary self-control tasks lasting longer in duration may possess increased complexity, and require a greater a number of cognitive processes; therefore, they may consume more resources, leading to increased performance effects on the second task (Hagger et al., 2010). Alternatively, spending longer on the initial self-control task may actually heighten an individual’s desire to conserve the limited resource (Baumeister & Vohs, 2007; Muraven, Shmueli, & Burkley, 2006). This is because individuals may attempt to retain some of their self-control resources in anticipation of future exertion on the second self-control task (Baumeister & Heatherton, 1996; Muraven & Baumeister, 2000). Individuals may try to minimise the amount of self-control strength they deplete by being selective in their self-control efforts (Muraven et al., 2006). By limiting how much effort is exerted, it may be unlikely that an individual will be sufficiently depleted to show increased performance effects on the subsequent task (Lee, Chatzisarantis, & Hagger, 2016).

Meta-analytic evidence has reported a marginally significant relationship between duration of depleting task and performance effects on the second task (Hagger et al., 2010). Spending longer on the initial self-control task led to increased performance effects on the second task. However, the range of task durations in the studies that were included in the meta-analysis was relatively small. This is because many of the initial self-control tasks employed in previous experiments are somewhat brief in duration, consistent with the significant emphasis on short-term self-control failure in experimental investigations of depletion effects (Hagger et al., 2010). Also, the studies that were included in the meta-analysis only examined one time period. Research is yet to systematically manipulate the duration of the initial task, within the sequential-task paradigm, and examine its effect on performance during the second task (Hagger et al., 2010; Lee et al., 2016). Such findings may
help to inform the designing and evaluation of future experiments exploring self-control exertion and subsequent performance, as well as, help to ascertain the most suitable duration required for the first task of the sequential-task paradigm to reliability lead to performance decrements on subsequent task performance (Lee et al., 2016). Accordingly, the third experimental chapter of this thesis manipulated initial task duration in a dual task-paradigm, and examined its effect on performance during the second self-control task.

**Summary and Overview of the Thesis**

Empirical evidence supports the beneficial effects of trait self-control on a wide range of behaviours (e.g., Tagney et al., 2004), but scarce research has explored the concept of self-control and its relationship with superior athletic performance. An individual’s general ability to exert self-control might be an important mechanistic variable that explains the relationship between robust self-confidence and athletic performance. As well as exploring the trait perspective of self-control, research has employed self-control manipulations and laboratory performance to examine state self-control. Considerable research suggests that performance on subsequent physical tasks is reduced following an initial task requiring self-control (e.g., Bray et al., 2011; Dorris et al., 2012; Englert & Bertrams, 2012). Recent lines of inquiry have revealed that initial self-control exertion impairs subsequent gross motor skill endurance performance (e.g., Englert & Wolff, 2015; Wagstaff, 2014), but it remains unknown whether previous exertion of self-control impairs subsequent endurance performance when self-regulation is potentially automatic. Furthermore, limited research exists to suggest that the effects of initial self-control exertion may become more pronounced over an extended period of time (Englert & Wolff, 2015). Further research is necessary to extend this finding.

Building on this work, potential moderators that may influence the extent to which initial self-control exertion impairs subsequent performance have been proposed, including glucose supplementation (e.g., Gailliot et al., 2007), as well as the duration of the primary self-control task, within the sequential-task paradigm (e.g., Hagger et al., 2010). However, controversy exists surrounding the role of glucose in counteracting self-control depletion (e.g., Lange & Eggert, 2014), and the extant research has yet to explicitly examine task duration as a moderator (Lee et al., 2016). Therefore, it seems prudent to further examine these lines of enquiry. Last, the exploration of possible alternative mechanisms that may explain why previous exertion of self-control impairs subsequent performance on physical tasks is a necessary area of research (Englert, 2016). The current thesis aims to achieve these goals.
**Study One (Chapter Two).** The first experimental study explored whether an individual’s general ability to exert self-control might be an important mechanistic variable that explains the relationship between robust self-confidence and athletic performance.

**Study Two (Chapter Three).** As the thesis developed, attention shifted to the state perspective of self-control. Utilising a dual task paradigm, Study Two explored whether exerting self-control reduces endurance performance in well-trained individuals and the potential for glucose administration to moderate any decrements in performance due to prior self-control exertion. Furthermore, Study Two examined whether any observed effects of self-control exertion and/or glucose supplementation are variable over different stages of endurance performance.

**Study Three (Chapter Four).** As an extension to Study Two, Study Three further examined whether initial self-control exertion impairs subsequent self-regulatory efforts during a well-practiced endurance task and whether this effect differs over time. The primary aim of Study Three was to explore whether initial task duration, within the sequential-task paradigm, can moderate any decrements in performance due to prior self-control exertion.

**Study Four (Chapter Five).** Following the examination of moderators, the final study sought to explain performance decrements following self-control exertion. Study Four examined whether exerting self-control reduces performance on a subsequent physical task that requires self-control, and whether any observed performance decrements can be explained by an individual’s perceptions of pain.

**General Discussion (Chapter Six).** Following these four experimental chapters, Chapter Six provides a summary and discussion of the thesis, its major findings, and the practical implications of these findings. Moreover, the limitations of the current thesis and future directions for prospective research are discussed.
Chapter Two
Study One

Self-control as an explanatory mechanism for the relationship between robust confidence and athletic performance.
Abstract

Successful athletes have identified robust self-confidence as an important characteristic of successful performance, but no research has empirically tested this proposal until now. In addition, this study explored the potential mediating role of self-control in the relationship between robust self-confidence and athletic performance. One hundred and fifty seven triathletes self-reported the robustness of their self-confidence and trait self-control prior to completing a competitive triathlon. Performance was assessed using participants’ race time. Structural equation modelling revealed that robust self-confidence was positively associated with self-control, which, in turn was positively associated with subsequent athletic performance. This same process was also supported when change in performance from the previous season was explored as the dependent variable. The results outline a potentially important mechanism why resilient athletes progress and perform successfully.

Keywords: Self-regulation, self-belief, triathletes
Introduction

Sport requires individuals to face a multitude of stressors, perform in highly demanding circumstances, and adjust to setbacks in the pursuit of sporting excellence (MacNamara et al., 2010; Sarkar & Fletcher, 2014). A number of psychological factors may be necessary for sporting success; in particular, self-confidence (i.e., the degree of certainty one possesses about his/her ability to be successful in sport; Vealey, 1986), may be important because it underpins resilience, stress management, and sporting achievement (Fletcher & Sarkar, 2012; Galli & Vealey, 2008; Gucciardi et al., 2011). It has been suggested, however, that solely possessing sport confidence may not be enough to perform successfully. Athletes need to hold robust confidence and maintain belief in one’s ability in the face of difficult experiences and possible setbacks (Bull et al., 2005; Vealey & Chase, 2008).

Robust self-confidence has been defined as a set of enduring, yet malleable positive beliefs that protect against the ongoing psychological and environmental challenges associated with competitive sport (Thomas et al., 2011). Athletes perceived to be the most resilient against setbacks have identified robust self-confidence as an important characteristic (Jones et al., 2007) and described an ‘unshakable self-belief” as fundamental for success (Sarkar & Fletcher, 2014). Those with fragile self-confidence may not remain focused and dedicated, while those with robust confidence tend to stay focused even when performance is poor (Faghir et al., 2013).

Furthermore, a strong sense of confidence has been associated with goal attainment, increased effort and persistence, and effective competition focus (Hays et al., 2009). Seemingly, therefore, an individual with robust self-confidence may have a greater general capacity to exert self-control in sport settings. Researchers have speculated that confidence may be related to good self-control (DeBono & Muraven, 2013) but this hypothesis has not received empirical attention, despite potentially providing insight into the relationship between robust self-confidence and athletic performance. Nonetheless, research exploring self-control and self-efficacy have argued that self-efficacy is negatively affected by self-control strength depletion, and that this motivational mechanism mediates the effect of depletion on physical performance (Chow, Hui, & Lau, 2015; Graham & Bray, 2015). Although not examining trait self-control per se, the findings imply that self-control may be a critical psychological construct when exploring the relationship between robust self-confidence and athletic performance.

In most sports, individuals are required to control their cognitive, emotional, and motor processes for superior athletic performance (Englert & Bertrams, 2012). Individual
differences in self-control ability (i.e., deliberate, effortful form of self-regulation; Baumeister et al., 2007) have been associated with several desirable outcomes, such as increased control of thoughts and emotions, and inhibition of impulses (Baumeister et al., 1998; Schmeichel & Zell, 2007). Given its beneficial effects for human functioning, the capacity for self-control seems a fruitful avenue to explore within the realm of athletic performance. Much of the existing literature has investigated the role of situational self-control strength (state self-control) on sport performance. Increased self-control can reduce the negative effects of state anxiety and improve performance under pressure (Englert & Bertrams, 2012), increase capacity to focus attention (Furley et al., 2013), and improve ability to overcome fatigue and override the urge to quit (Englert & Wolff, 2015; Wagstaff, 2014).

Research considering the role of dispositional (trait) self-control on sport performance has received limited attention. Dispositional self-control can be defined as the general capacity to alter one’s responses to achieve a desired state or outcome that otherwise would not arise naturally (e.g., Bauer & Baumeister, 2011; Baumeister & Vohs, 2007). Recently, Toering and Jordet (2015) reported that trait self-control was positively associated with practice quantity, as well as soccer performance in a sample of professional players.

Based on the literature reviewed above, it could be argued that an individual’s general ability to exert self-control might be an important variable that explains the relationship between robust self-confidence and athletic performance. Specifically, an indirect model was hypothesised in which robust self-confidence is positively associated with self-control, which in turn is positively associated with subsequent athletic performance. Alternative hypotheses were also tested (see Results section), however, it was proposed that athletes who demonstrate resilient self-beliefs may have a general propensity to control and focus their thoughts, emotions, and attention resulting in superior athletic performance. Understanding this process will advance our understanding of optimal performance development.

**Method**

**Participants and Procedures**

Participants comprised 157 athletes (103 male, 54 female) aged 18-61 years old ($M$ age $= 35$ years, $SD = 10$ years) who competed in a sprint distance triathlon (i.e., 750m swim, 20km cycle, and 5km run) between May 2014 and August 2015. The participants had, on average, 9 years ($SD = 10$ years) competitive experience in their sport and spent 9 hours ($SD = 4$ hours) per week training.

Following approval from a university ethics committee, each participant signed an informed consent form after the study was explained in full and it was clarified that
involvement was anonymous and voluntary. Participants were instructed to record their personal best race time (in minutes) from the previous year’s competitive season. Next, participants completed an inventory measuring robust confidence and trait self-control (see below), either by paper format or an online questionnaire; questions took approximately ten minutes to complete. Participants’ subsequent performance time in a sprint distance triathlon was then recorded by the researcher.

**Measures**

**Performance.** Performance was assessed using participants’ time (in minutes) obtained from the official records provided by the race organisers.

**Robust self-confidence.** Athletes’ robustness of self-confidence was assessed using the eight item Trait Robustness of Sports-Confidence Inventory (TROSCI; Beattie, Hardy, Savage, Woodman, & Callow, 2011). An example item was “If I perform poorly, my confidence is not badly affected”. Participants were asked to think about their confidence and how their performance may affect their confidence generally on a nine-point scale anchored by 1 (strongly disagree) to 9 (strongly agree). The scale authors reported that these items loaded onto the latent factor satisfactorily and the construct had good convergent validity with theoretically related variables (Beattie et al., 2011).

**Self-control.** The measure of self-control contained the recommended eight items from the Brief Self-Control Scale (Maloney, Grawitch, & Barber, 2012). However, an administration error led to one item being unsuitable to use (“Sometimes I can’t stop myself from doing something, even if I know it’s wrong). Athletes indicated how much each of the statements reflected how they usually act on a five-point scale ranging from 1 (not at all) to 5 (very much). Five items were reverse scored as they reflected lack of self-control (e.g., “I wish I had more self-discipline”). The items have demonstrated acceptable internal consistency and predictive validity in previous research (Maloney et al., 2012; see Appendix One for questionnaire pack)

**Results**

**Preliminary Analyses**

Cronbach’s alpha coefficients were \( \alpha = .84 \) (robust self-confidence) and .82 (self-control). Means, standard deviations and bivariate correlations are presented in Table 2.1. These are provided for information only as they do not relate to study hypotheses.

Confirmatory factor analyses (CFA) with Mplus 7.11 software (Muthén & Muthén, 1998-2013) were carried out to determine the factor structure of robust self-confidence and self-control. A combination of fit indices were used to evaluate the degree of model fit,
Table 2.1

Descriptive Statistics and Bivariate Correlations for all Variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>SD</th>
<th>1</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Robust self-confidence</td>
<td>4.59</td>
<td>1.64</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2. Self-control</td>
<td>3.05</td>
<td>.48</td>
<td>-.16*</td>
<td>-</td>
</tr>
<tr>
<td>3. Performance (minutes)</td>
<td>81.0</td>
<td>13.0</td>
<td>-.07</td>
<td>.13</td>
</tr>
</tbody>
</table>

Note. *p < .05; **p < .01
including the Satorra-Bentler chi square statistic (S-B$\chi^2$), the standardised root mean square residual (SRMR), the robust comparative fit index (CFI), and the robust root mean square error of approximation (RMSEA). Relatively stringent criteria proposes that excellent fit of a hypothesised model to the data is indicated when the SRMR fit index is close to or below 0.8, the RMSEA is close to or below .06, and the CFI is close to or above .95 (Hu & Bentler, 1999). The S-B$\chi^2$ is reported although it should be noted that this statistic is sensitive to sample size (Cheung & Rensvold, 2002).

The self-control scale showed acceptable factor structure: S-B$\chi^2$ (21) = 310.83, $p < .001$; SRMR = .05; CFI = .95; RMSEA = .08 (90% confidence interval [CI] = .04 – .12). The scale assessing robust self-confidence showed some degree of misfit to the data: S-B$\chi^2$ (28) = 381.95, $p < .001$; SRMR = .06; CFI = .89; RMSEA = .11 (CI = .08 – .15).

Examination of the standardised loadings and standardised residuals revealed one problematic item (“A bad result in competition has a very negative effect on my self-confidence”); hence, this item was removed from the analysis. The revised seven item version showed acceptable factor structure: S-B$\chi^2$ (21) = 293.54, $p < .001$; SRMR = .05; CFI = .96; RMSEA = .07 (CI = .01 – .11).

**Primary Analysis**

First, potential covariates and their relationships with participants’ performance were tested. Participants’ best time in the previous season, gender, sport experience and number of hours trained per week were included as predictors of performance. Although the model fit the data well: S-B$\chi^2$ (4) = 41.29, $p < .001$; SRMR = .00; CFI = 1.00; RMSEA = .00 (CI = .00 – .00), only previous best time significantly predicted performance ($\beta = .76$, $p < .001$). In fact, it is likely that inclusion of previous best performance in the model accounted for the other covariates, that is, males, experienced athletes, and athletes who train longer, perform better.

Next three models were tested: a) a direct effects model, in which the mediator (i.e., self-control) was not included, b) an indirect model, in which an indirect association between robust self-confidence and performance via self-control was hypothesised, and c) a combined model, in which both direct and indirect effects were modelled. Each model was tested using the robust maximum likelihood estimation method, with items as indicators of their respective latent factor and performance entered as an observed variable. Following the analysis of these models, each model was repeated adjusting for previous best performance. By doing so, this reconceptualised the performance outcome variable as intra-individual.
Table 2.2
Fit Indices for All Structural Models

<table>
<thead>
<tr>
<th>Outcome variable</th>
<th>Model</th>
<th>Fit Indices</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>S-Bχ²</td>
</tr>
<tr>
<td>Performance</td>
<td>Direct effects model</td>
<td>327.29*</td>
</tr>
<tr>
<td></td>
<td>Indirect model</td>
<td>786.30*</td>
</tr>
<tr>
<td></td>
<td>Combined model</td>
<td>786.30*</td>
</tr>
<tr>
<td>Performance</td>
<td>Direct effects model</td>
<td>383.68*</td>
</tr>
<tr>
<td>change from</td>
<td>Indirect model</td>
<td>904.60*</td>
</tr>
<tr>
<td>previous best</td>
<td>Combined model</td>
<td>904.60*</td>
</tr>
</tbody>
</table>

Note. S-Bχ² = Satorra-Bentler Chi Square Statistic; SRMR = Standardised Root Mean Square Residual; CFI = Robust Comparative Fit Index; RMSEA (90% CI) = Robust Root Mean Square Error of Approximation (90% Confidence Interval); * p < .001
change from previous best to current performance. Thirteen of the sample did not report their previous season’s best, therefore, this latter analysis was based on 144 participants.

As can be seen in Table 2.2, model fit indices demonstrated that the fit of the hypothesised direct effects model was satisfactory, however, robust self-confidence did not predict performance ($\beta = -0.10, p = 0.24$). It is important to highlight that the traditional requirement for a significant direct effect to infer mediation (e.g., Baron & Kenny, 1986) is no longer valid. Evidence for indirect processes can be obtained even if the direct or total effect is not significant (Ntoumanis & Appleton, 2015; Rucker, Preacher, Tormala, & Petty, 2011). The indirect model also fit the data well and significant associations were observed between robust self-confidence and self-control ($\beta = 0.23, p = 0.02$), and self-control and performance ($\beta = -0.18, p = 0.05$; note that the negative coefficient refers to the relationship with time, therefore, greater self-control was associated with quicker times). The combined model fit the data well, however, the direct effect of self-confidence on performance was not significant ($\beta = -0.06, p = 0.45$).

When adjusting these models to control for participants’ previous season’s best, the substantive conclusions remained the same. Robust self-confidence did not predict intra-individual change in performance in direct effects ($\beta = -0.06, p = 0.24$) or combined ($\beta = -0.02, p = 0.62$) models. In the indirect model, however, robust self-confidence significantly predicted self-control ($\beta = 0.24, p = 0.01$), which, in turn, significantly predicted change in performance ($\beta = -0.14, p = 0.02$). To test the indirect effect, bootstrapping procedures using 1000 samples to construct 95 percent confidence intervals (95% CIs) for the unstandardised parameter estimate were employed (Preacher & Hayes, 2008). The indirect effect was small ($b = -0.25$) but significant (95% CIs = -0.68 -0.01).

**Discussion**

In this study, previous performance research was extended by examining whether the robustness of athletes’ confidence and general capacity to exert self-control might be important considerations when investigating ecologically valid athletic performance. Consonant with the predictions, the results supported an indirect model in which robust self-confidence was positively associated with self-control, which in turn was positively associated with subsequent athletic performance. These processes are discussed in detail below.

Qualitative interviews with athletes suggest that possessing an unshakeable, robust self-confidence is a fundamental aspect of superior athletic performance (e.g., Bull et al., 2005; Sarkar & Fletcher, 2014; Thomas et al., 2011). However, the analysis found no direct
effect of robust self-confidence on athletic performance. Instead, the results demonstrated that an individual’s trait self-control may be a critical explanatory variable that needs to be considered when investigating the relationship between robust self-confidence and athletic performance. This may shed light on the cognitive, behavioural, and affective processes that resilient athletes utilise following the ubiquitous setbacks and stressors associated with competitive sport. For example, the results imply that athletes with resilient self-beliefs may have a relative superior propensity to control and focus their thoughts, emotions, and attention (Baumeister et al., 1998; Schmeichel & Zell, 2007).

The findings further imply that this increased general capacity for self-control is positively associated with subsequent superior athletic performance. The present research measured athletes’ general ability to exert self-control, which adds a new dimension to the current literature suggesting that increased state self-control can improve performance (e.g., Englert & Wolff, 2015; Wagstaff, 2014). Both types of self-control may lead to superior performance, but through different mechanisms. State self-control may facilitate athletes’ performance through optimal attention and emotion regulation (Furley et al., 2013), anxiety control (Englert & Bertrams, 2012), and the tolerance of pain (Schmeichel & Zell, 2007). Dispositional self-control may enhance athletes’ performance through its effect on practice quantity and quality (Baker & Young, 2014; Toering & Jordet, 2015), as well as an increased focus on long term goals (Hofmann, Baumeister, Förster, & Vohs, 2012). Future research may wish to explicitly test these contrasting mechanisms associated with state and trait self-control.

The findings of the present study are not only relevant to athletic performance, but the adjusted models focused on athletic improvement. Athletes with increased levels of robust self-confidence had higher self-control, which was associated with greater performance improvement from the previous season. Athletes accumulate many deliberate practice hours in order to improve and maintain athletic performance but this type of practice is not always enjoyable and requires effort and concentration (Baker et al., 2009). Dispositional self-control may facilitate athletic improvement through its effect on sustained motivation to engage in deliberate practice over time (Toering & Jordet, 2015). Further, in order for athletes to continually strive to reach optimal levels of performance, they must demonstrate sustained determination to succeed and perseverance in the face of failure (Baker & Coté, 2003). Therefore, self-control may facilitate athletic improvement through enabling athletes to successfully tolerate difficult periods that may arise throughout their career, including performance slumps, set-backs, and pressure (Jordet, 2016). Although the methodology
utilised in the present study provides an insight into the concepts associated with performance improvement, longitudinal research assessing multiple performances would be beneficial to confirm our findings.

Taken together, findings convey that an individual’s general ability to exert self-control represents an explanatory mechanism for the relationship between robust self-confidence and subsequent superior athletic performance. It should be noted that the effect size of the indirect effect was small ($b = -.25$), however, given that the margins between winning and losing can be measured to several decimal places, this small increase in robust self-confidence could potentially have significant benefits on performance outcomes. From an applied perspective, it seems recommendable for practitioners to develop athletes’ self-control and levels of robust self-confidence to help withstand the problems and set-backs that can arise in sport (Toering & Jordet, 2015). Research has suggested that it may be possible to develop interventions in one facet of self-control (e.g., affect regulation) and benefit from this in another facet of self-control (e.g., quality of practice; Baumeister, Gailliot, DeWall, & Oaten, 2006). In addition to this, research has tentatively suggested that successful performances, coaching, quality preparation, and numerous psychological skills (e.g., positive self-talk, imagery, rationalisation) may help to develop and sustain robust self-confidence (Thomas et al., 2011). Finally, the inclusion of controlled, yet stressful scenarios during training could help athletes increase their self-control skills and resilience to prepare them for competition (Collins & MacNamara, 2012; Toering & Jordet, 2015).

**Limitations and Future Directions**

There were limitations to this study that need to be identified. Firstly, participants represented recreational competitive athletes. Every race may not be a priority for recreational athletes; therefore, individuals’ goals and expectations may vary. Some fundamental issues relating to the sport of triathlon also need consideration. Each triathlon venue may include unique features (e.g., different terrain and varying levels of elevation) that could influence performance to some degree. Although the fact that these findings were observed despite this ‘noise’ in the measurement may be perceived as a strength of the study.

Some possible future directions also arise from this study. Researchers should seek to systematically establish how robust self-confidence is developed and maintained in more detail. In addition, an individual’s capacity to exert self-control may contribute to superior athletic performance through several processes that have been speculated above (e.g., motivational- versus attention- based processes). Research is required to explore which aspects of self-control contribute to the development of superior athletic performance.
Conclusions

The present study aimed to understand the importance of self-control in the relationship between robust self-confidence and athletic performance. The results imply that there is no direct effect of robust self-confidence on athletic performance, but indirect effects through an individual’s general capacity to exert self-control exist.
Chapter Three
Study Two

Abstract
Completion of a task requiring self-control may negatively impact on subsequent self-regulatory efforts. This study explored a) whether this effect occurs during a well-practiced endurance task, b) the potential for glucose supplementation to moderate this effect, and c) whether this effect differed over time. Fourteen trained cyclists completed four simulated 16 km time trials on an electromagnetically braked cycle ergometer. Prior to each time trial, participants completed a congruent Stroop task or an incongruent Stroop task that required self-control. They also received either a glucose-based drink or placebo. Participants’ performance time and heart rate were recorded throughout the time trials. Multilevel growth curve analysis revealed a significant three-way interaction between self-control, glucose, and time ($b = -0.91; p = 0.02$). When participants did not exert self-control (congruent Stroop) or consume glucose (placebo drink) they were slowest during the early stages of the time trial but quickest over the full distance. No differences were found in heart rate across the four conditions. Findings suggest that prior self-control exertion may interfere with self-regulatory pacing strategies (i.e., optimal power output) during subsequent endurance performance. Moreover, the debate revolving around depletion of self-control must consider that any observed effects may be dependent on the timing of performance inspection.

Keywords: Growth models, cycling, self-regulation, ego depletion
**Introduction**

Self-control alludes to any effort to amend one’s own inner states or responses, including actions, feelings, thoughts, and task performances (Baumeister et al., 2007). This process facilitates desirable behaviour by helping to resist inappropriate impulses and continuing with appropriate behaviour. Some researchers suggest that this capacity to exert self-control is limited and becomes diminished when an individual regulates his or her behaviours, a state known as ego depletion (Baumeister et al., 2007). Consequently, the individual will have a reduced capacity to perform any subsequent behaviour that requires self-control. This ‘limited resource’ perspective has received both meta-analytic support (Hagger et al., 2010) and fervent challenge (e.g., Kurzban, 2016). Other researchers propose that self-control exertion is accompanied by shifts in motivation, emotion, and attention, and discount the limited resource explanation (Inzlicht & Schmeichel, 2012). When participants are confronted with a second self-control task, participants may be less motivated to comply with task-relevant goals (unless they receive incentives to do so).

Irrespective of the different explanations, considerable evidence exists that performance on subsequent physical tasks is reduced following an initial task requiring self-control. For example, individuals who were asked to regulate their emotions while watching an upsetting movie were unable to sustain an isometric handgrip squeeze for as long as individuals who watched the movie but engaged in no emotion regulation (Muraven et al., 1998). Although squeezing a handgrip primarily requires muscular strength, overcoming fatigue and overriding the urge to quit are acts of self-regulation. The ability for cognitive or emotion regulation to impair subsequent handgrip performance has been corroborated (e.g., Bray et al., 2011). Building on this work, researchers have attempted to enhance the ecological validity of the evidence so that conclusions regarding more complex human performance can be drawn. A variety of tasks requiring self-control (e.g., counting backwards from 1000 in multiples of seven while holding a spirit level, transcribing a neutral text whilst omitting the letters ‘e’ and ‘n’, completing an incongruent Stroop task, supressing emotions during an upsetting movie) have been associated with reduced performance in press-up tasks, basketball free-throw tasks, and cycling performance (Dorris et al., 2012; Englert & Bertrams, 2102; Englert & Wolff, 2015; Martin Ginis & Bray, 2011; Wagstaff, 2014).

Collectively, the studies above provide valuable insight into self-regulatory processes and athletic performance. However, it is currently unknown whether previous exertion of self-control impairs subsequent endurance performance when self-regulation is potentially automatic. In expert populations, the persistent pursuit of the same cognitive goal results in
the automatisation of cognitive processes (Williams, Huang, & Bargh, 2009). When this occurs self-regulatory resources may not be required to the same extent as conscious self-regulation (Schmeichel & Baumeister, 2004). From a limited resource perspective, an initial exertion of self-control would have no effect on subsequent physical performance because conscious self-control would not be required. On the other hand, successful endurance performance involves considerable levels of discomfort and overcoming these demands may exacerbate the need for conscious self-regulation. This latter hypothesis implies that engaging in an initial task requiring self-control may impair subsequent endurance performance because the self-regulation required to maintain effort and resist discomfort is salient.

As well as exploring the salience of self-control during well-practiced human performance, the present study aims to examine whether glucose can attenuate any decrements in performance due to prior self-control exertion. Tasks requiring controlled, effortful self-control demand increased cerebral functioning, possibly causing a concomitant rise in the requirement for blood glucose in the brain (Gailliot et al., 2007). Glucose in the blood is often measured under the assumption that equilibrium exists between glucose in the blood and the brain (Lund-Anderson, 1979). Glucose ingested immediately before and/or during exercise is rapidly digested, absorbed, and available for oxidation (Jeukendrup et al., 1999). Hence, glucose drinks may be a viable means of increasing the amount of glucose available for self-regulatory tasks, providing that one allows time for the glucose to reach the blood stream. Indeed, replenishing glucose with a drink containing sugar has been shown to restore performance during cognitive tasks that require self-control (e.g., DeWall et al., 2008; Gailliot et al., 2007; Wang & Dvorak, 2010). In a meta-analysis, the effect of experimental glucose supplementation on the depletion effect was deemed to be large and homogeneous ($d = 0.75$; Hagger et al., 2010).

Although the evidence seems compelling, the idea that the exertion of cognitive effort leads to significant reductions in glucose has proven controversial. The aforementioned effects have not been replicated with more accurate measurements of blood glucose (Molden et al., 2012), and results of the early studies (Gailliot et al., 2007) are not supported by re-analysis of the initial data (Kurzban, 2010; Schimmack, 2012). The role of glucose in counteracting self-control depletion has also come under robust criticism. In a recent study that employed a selective attention task (delay discounting) as the self-control manipulation and dependent measure, glucose administration did not moderate the depleting effect (Lange & Eggert, 2014). Similar results were also observed following an emotionally upsetting video (versus an emotionally neutral video; Dvorak & Simons, 2009), as well as a go/no-go...
paradigm (versus an infrequent no-go paradigm; Lange et al., 2014). It is possible that the exhaustion of self-control resources is moderated by glucose consumption only when dissimilar tasks are utilised as experimental manipulation and dependent variable measure (DeWitte, Bruyneel, & Geyskens, 2009). Athletic endurance performance represents an interesting context to pursue this research agenda given the critical role played by glucose drinks in optimising athletic performance (e.g., Jeukendrup, 2010). Sports drinks are so popular that their value is estimated to reach $2 billion by 2016 in the United States alone (International Markets Bureau, 2010). It is significant, therefore, to investigate the moderating role of glucose supplementation on self-control exertion and subsequent athletic endurance performance. Understanding potential psychological effects of glucose supplementation on endurance performance (as opposed to well-researched physiological processes) would advance our understanding of human behaviour during conditions of fatigue (e.g., Hagger & Chatzisarantis, 2012; Molden et al., 2012).

Extending the literature described above, the aims of the current research were to determine a) whether exerting self-control reduces endurance performance and increases heart rate in well-trained individuals, b) the potential for glucose administration to attenuate any decrements in performance due to prior self-control exertion, and c) whether any observed effects are variable over different stages of endurance performance. Heart rate was examined to rule out a potential physiological explanation for changes in performance, in line with literature on cognitive fatigue (Marcora et al., 2009). The latter aim of the study is particularly important as only one study has appropriately considered the timing of performance inspection (e.g., Englert & Wolf, 2015). In other words, do any effects of self-control exertion and/or glucose administration persist or change over the course of a subsequent endurance task?

In the present experiment, the initial task to manipulate self-control requirements was a congruent versus incongruent Stroop task carried out for four minutes. This task has been shown to require self-control (McEwan et al., 2013) and has been successfully employed for the same length of time in previous research (i.e., four minutes; Hagger et al., 2010). To measure athletic performance, a 16 km laboratory-based cycling time trial was utilised. A time trial requires numerous self-regulation behaviours including sustained effort despite considerable levels of discomfort, as well as regulating one's attention and emotions throughout periods of physical stress. Further, a time trial protocol may have greater ecological validity than time to exhaustion protocols often used in previous research (e.g., Carter, Jeukendrup, & Jones, 2005), because performance and physiological responses are
similar compared to outdoor time trials (Currell & Jeukendrup, 2008). Finally, a 16 km distance is familiar and well-practiced by cyclists; therefore, it may reduce the need for conscious self-regulation (Schmeichel & Baumeister, 2004).

Based on the broad self-control literature (e.g., Bray et al., 2011; Englert & Wolff, 2015; Wagstaff, 2014) it was hypothesised that engaging in a cognitively demanding task previously shown to require self-control (i.e., an incongruent Stroop task) would result in poorer performance on a 16 km cycling time trial, compared to a cognitively simple task (i.e., a congruent Stroop task). No significant differences in heart rate during the cycling task were expected. Furthermore, it was hypothesised that glucose drink supplementation would attenuate any reductions in performance due to self-control exertion, compared to a placebo drink (DeWall et al., 2008, Wang & Dvorak, 2010). Finally, it was hypothesised that any moderating impact of glucose would be observable towards the end of the time trial.

**Method**

**Participants**

Fourteen endurance trained cyclists (4 female, 10 male) aged 20-52 years old took part in the study. Inclusion criteria required that participants had experience in competitive cycling-based events (e.g., triathlon, road cycling), and were currently training for a cycling event. All participants were healthy, as assessed by a university approved general health questionnaire. Due to the choice of analytic strategy (see Data Analysis below), conventional criteria regarding sufficient sample sizes in single level designs are irrelevant. Indeed, growth models typically offer greater statistical power than traditional methods applied to the same data (B. O. Muthén & Curran, 1997) because the relevant unit of measurement are the repeated observations, not the participant (in this study, the 675 measurements throughout the time trials; Singer & Willett, 2003). What constitutes an adequate sample size for longitudinal growth model is debatable (Curran, Obeidat, & Losardo, 2010), however, modelling of artificial data revealed that estimated power to detect a small-moderate interaction effect (Effect Size = .30) with five measurement points (there was 15 in the current study) and 675 total observations would be > .90 (B. O. Muthén & Curran, 1997). In view of this, the sample size in the current study is deemed acceptable.

**Procedures**

Following approval from a university ethics committee, each participant gave written informed consent after the study was explained in full and it was clarified that involvement was anonymous and voluntary (see Appendix Two).
Preliminary fitness test. At least one week before the experimental trials began participants completed an incremental-effort cycle test to volitional exhaustion to determine individuals’ maximal power output (Wmax). This test was completed on an electromagnetically braked cycle ergometer (Lode Excalibur Sport, Groningen, The Netherlands) with adjustable saddle height and handle bar position. Following a self-selected warm up, participants began cycling at 95 W for three minutes, followed by incremental steps of 35 W every three minutes until exhaustion. Heart rate was monitored throughout by a radiotelemetry heart rate monitor (Polar Vantage NV, Kempele, Finland). Wmax was calculated from the final completed work rate plus the fraction of time spent in the final non-completed work rate, multiplied by 35 W. Eighty-five percent Wmax was subsequently used in all cycling time trials. During this test only, verbal encouragement was given to the participants by the same investigator. These procedures have been advocated and frequently employed in athletic endurance research (e.g., Jeukendrup, Hopkins, Aragon-Vargas, & Hulston, 2008).

Experimental protocol. Participants were instructed to keep a record of their food intake and activity patterns on the day before the first time trial and to replicate the same diet and exercise activities 24 hours before all subsequent trials (see Appendix Four). They were also asked to refrain from strenuous exercise and avoid alcohol and caffeine intake 24 hours before the start of each trial.

Each participant took part in four experimental sessions. On arrival in the laboratory, participants completed a questionnaire to control for the influence of daily stress (see Appendix Three). The questionnaire involved the seven stem questions from the Daily Inventory of Stressful Events Questionnaire (Almeida, Wethington, & Kessler, 2002). Participants were instructed to indicate whether any of a number of stressful events had occurred today by circling either ‘yes’ or ‘no’ (e.g., “An argument or disagreement with someone”). The items have demonstrated acceptable internal consistency and predictive validity in previous research (Almeida et al., 2002).

Participants were then fitted with the heart rate monitor and the cycle ergometer was adjusted to a comfortable position as requested by the participant. Participants began a standardised warm-up consisting of 10 minutes at 50% Wmax, followed by five minutes at 60% Wmax. Immediately following the warm-up participants were required to complete either a self-control or non-self-control experimental manipulation. A modified Stroop task was used as the experimental manipulation in this study. This task has been utilised as a means of depleting individuals’ self-control strength in many laboratory studies of self-
control (e.g., Hagger et al., 2010). In this task, participants are presented with colour words and required to read aloud the colour of the print ink and ignore the text for each word presented. However, when participants encounter a word presented in red ink, they are required to override the general instructions and read aloud the printed word. In the self-control condition, the print ink colour and printed text were mismatched. For example, the word ‘blue’ printed in yellow – the correct verbal response in this case would be yellow. However, when the word ‘blue’ is presented in red ink, the correct verbal response would be blue. Previous studies have repeatedly shown that this task is cognitively challenging and require self-control because individuals have to volitionally override their primary impulse of naming the word instead of the font colour (e.g., McEwan et al., 2013). In the non-self-control condition, the words were matched (e.g., the word ‘blue’ is printed in blue ink, ‘red’ is printed in red ink) and verbally communicating the colour of the ink does not require self-control (Baumeister et al., 2007). Participants performed the Stroop task on a computer for four minutes whilst sitting in a quiet room, words were serially presented on the screen with a 1,500 ms interval. Participants were instructed to respond as accurately as possible.

The glucose experimental manipulation took place immediately after the Stroop task. Participants ingested an initial bolus of 300 ml of a 3.9% glucose-electrolyte solution (Powerade) or a placebo solution (Powerade; zero glucose) containing flavourings, sweeteners, and electrolytes. The two drinks were similar in taste, texture, colour, and electrolyte content. Participants were briefed that the glucose/placebo solution was a commercially available sports drink.

Immediately after the drink consumption, participants commenced a simulated 16 km cycle time trial. In these time trials, participants completed a predetermined amount of work as fast as possible. The amount of work to be performed was calculated by assuming that participants could cycle at 85% of their Wmax for 25 min, which is comparable to 16 km personal bests of cyclists on the road (Jeukendrup et al., 2008). The ergometer was set in the pedalling-dependent mode (i.e., power varies with cadence) so as to replicate as accurately as possible a time trial in a field setting. A further 200 ml drink was consumed when half the workload had been completed, ensuring that glucose was available in the blood stream throughout the later part of the time trial. Outcome variables were heart rate and time, which were recorded after every 10% of the time trial had been completed, as well as 92.5%, 95%, and 97.5% completion. Participants received no encouragement or information except a signal that they had 20% and 10% of the time trial remaining. Music and external distracting material was eliminated during all exercise trials. All exercise trials were completed under
normal and standard environmental conditions (19-21°C dry bulb temperature and 50-60% humidity). Standing floor fans, always in the same position and fan speed, were available to participants to minimise thermal stress.

In sum, participants completed four simulated 16 km time trials under four experimental conditions: self-control/glucose, self-control/placebo, non-self-control/glucose, and non-self-control/placebo. Conditions were counterbalanced. Trials were separated by seven days and always performed at the same time of day to prevent any circadian variance.

**Data analysis**

Study hypotheses were investigated using multilevel growth models employing MLwiN 2.26 software (Rasbash, Steele, Browne, & Goldstein, 2012). Growth models examine variability in intra-individual patterns of change over time (Singer & Willett, 2003), therefore, they are particularly suited to measuring differences in time-trial performance. This type of analysis provides greater flexibility compared to traditional analysis of variance, in particular allowing for missing data points, unequally spaced time points, time-varying covariates, and non-normally distributed repeated measures (Curran et al., 2010). Multilevel modelling enabled the construction of separate, but associated equations to model time-varying (e.g., performance and heart rate) and time-invariant variables (e.g., experimental condition), which leads to superior estimation of parameters and statistical significance (Hox, 2010; Singer & Willet, 2003). Two levels of analysis were specified. Level 1 constituted the repeated observations throughout the time trials, which comprised Level 2 in the analysis (see Quene & Bergh, 2004 for a similar design). The 14 participants could have constituted a third level, however, this would represent an insufficient number of higher level units. The sample size at Level 1 was 675 data points because some trials had missing data, however, multilevel modelling does not require complete data sets (Hox, 2010) and deletion of participants with incomplete data has been strongly argued against (Newman, 2009).

Prior to including predictor variables in the models, intercept only models were constructed to establish the proportion of variance at both levels of analysis for performance (model 1a) and heart rate (model 1b). Building on these models, a series of predictor variables were included to test the study hypotheses. First, linear time was included as a variable to model change in the outcome variable over the course of the time trial. Time was centred at the end of the time trial (i.e., the end of the time trial was labelled zero, with decreasing values towards the beginning of the time trial). The two binary coded main effects of the experimental conditions (i.e., self-control/non-self-control and placebo/glucose) were then included. Furthermore, a three-way interaction term (and associated lower order terms)
between time, self-control, and glucose was included to explore how the effects of experimental condition changed over the course of the trial. Participants levels of daily stress were controlled for in the models which were group mean centered to represent participants’ relative daily stress. These models are referred to as 2a (performance) and 2b (heart rate).

**Results**

**Preliminary analysis**

Table 3.1 displays means and standard deviations for performance (time) and heart rate for each experimental condition. Intraclass correlation coefficients (ICCs) were calculated from model 1a and 1b (shown in Table 3.2). The ICC for performance was 0.00 indicating that 100% of the variance in performance was attributable to the within-person level. The ICC for heart rate was 0.76 indicating that 24% of the variance in heart rate was attributable to the within-person level.

**Primary analysis**

As shown in Table 3.2, model 2a revealed a significant main effect for time, as well as significant interaction effects for self-control and time, and glucose and time. However, these were superseded by a significant three-way interaction between self-control, glucose, and time (\(b = -0.91; p = 0.02\)). Simple slopes analysis applied to multilevel models (Preacher, Curran, & Bauer, 2006) was subsequently conducted to interpret this interaction. After 10% of the trial had been completed (Figure 3.1), there were only small differences in performance time across experimental conditions (as would be expected after only ~3 minutes). However, participants were slowest when they did not exert self-control (congruent Stroop) or consume glucose (placebo drink). Participants were fastest when they did not exert self-control (congruent Stroop) but consumed glucose. At the midpoint of the trial (Figure 3.2) participants were now fastest when they did not exert self-control or consume glucose (i.e., the opposite trend, compared to the beginning of the trial). Negligible differences in performance were found in the other three experimental conditions. This trend was repeated at the end of the trial (Figure 3.3), with considerably faster performance when participants did not exert self-control or consume glucose, compared to the other three conditions.

Model 2b revealed no significant main effects or interaction effects. In other words, experimental condition did not influence heart rate at any point in the time trial.

**Discussion**

The present study explored the effects of exerting self-control on a subsequent endurance task requiring self-regulation in well-trained endurance athletes. The findings demonstrate that the effects of exerting self-control on subsequent endurance performance are
Table 3.1

*Final Performance Time and Heart Rate for each Experimental Condition*

<table>
<thead>
<tr>
<th>Experimental Condition</th>
<th>Time (seconds)</th>
<th>Heart Rate (beats per minute)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>Self-control/Glucose</td>
<td>1691</td>
<td>198</td>
</tr>
<tr>
<td>Self-control/Placebo</td>
<td>1706</td>
<td>222</td>
</tr>
<tr>
<td>Non-self-control/Glucose</td>
<td>1717</td>
<td>217</td>
</tr>
<tr>
<td>Non-self-control/Placebo</td>
<td>1652</td>
<td>185</td>
</tr>
</tbody>
</table>
Table 3.2

Final Models Describing Changes in Study Variables during the Time Trial

<table>
<thead>
<tr>
<th>Predictor Variable</th>
<th>Model 1a</th>
<th>Model 1b</th>
<th>Model 2a</th>
<th>Model 2b</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed effects</td>
<td>1060.11(20.35)**</td>
<td>163.31(2.17)**</td>
<td>1661.42(36.60)**</td>
<td>173.71(4.02)**</td>
</tr>
<tr>
<td>Intercept</td>
<td>-</td>
<td>-</td>
<td>16.44(0.18)**</td>
<td>0.22(0.01)**</td>
</tr>
<tr>
<td>Linear time</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Self-control</td>
<td>-</td>
<td>-</td>
<td>52.80(55.67)</td>
<td>-2.83(6.12)</td>
</tr>
<tr>
<td>Glucose</td>
<td>-</td>
<td>-</td>
<td>53.60(52.96)</td>
<td>-6.31(8.82)</td>
</tr>
<tr>
<td>Glucose × self-control</td>
<td>-</td>
<td>-</td>
<td>-68.09(79.89)</td>
<td>5.89(8.78)</td>
</tr>
<tr>
<td>Self-control × time</td>
<td>-</td>
<td>-</td>
<td>0.63(0.27)**</td>
<td>-0.03(0.02)</td>
</tr>
<tr>
<td>Glucose × time</td>
<td>-</td>
<td>-</td>
<td>0.73(0.25)**</td>
<td>0.02(0.02)</td>
</tr>
<tr>
<td>Self-control × glucose × time</td>
<td>-</td>
<td>-</td>
<td>-0.91(0.38)**</td>
<td>0.02(0.03)</td>
</tr>
<tr>
<td>Daily Stress</td>
<td>-</td>
<td>-</td>
<td>-4.97(32.73)</td>
<td>0.83(3.63)</td>
</tr>
</tbody>
</table>

Random effects

| Level 1 residual variance | 279582.75(15218.56)** | 64.244(3.62)** | 5414.97(305.10)** | 27.07(1.53)** |
| Level 2 residual variance | 0.00(0.00)            | 206.59(44.46)* | 16400.21(3533.61)* | 204.41(43.47)** |

Note. A dash indicates that the term was not included in the models. *p < .05. **p < .01. ‘a’ models include performance as the dependent variable and ‘b’ models include heart rate.
Figure 3.1

Three-way interaction effects for self-control and glucose conditions after 10 percent of the time trial had been completed.
Figure 3.2
*Three-way interaction effects for self-control and glucose conditions after 50 percent of the time trial had been completed.*
Figure 3.3

Three-way interaction effects for self-control and glucose conditions after 100 percent of the time trial had been completed.
dependent on the timing of performance inspection. Exerting self-control, consuming glucose, or a combination of both led to somewhat faster performance during the early stages of endurance cycling performance. By then end of the time trial this trend was reversed; participants completed the time trial in the fastest time when they did not exert self-control or consume glucose. Until now, it was unclear whether the continuous pursuit of the same, well-practiced cognitive goal in well-trained athletes would require sufficient levels of conscious self-regulation to be impaired by previous exertion of self-control.

In accordance with previous research (e.g., Bray et al., 2011; Englert & Wolff, 2015; Wagstaff, 2014), exertion of self-control significantly reduced subsequent performance in a task requiring self-control, in this case cycling time trial performance. However, this could only be concluded if one considers the entire time trial performance. In the early stages, participants went faster when they were previously required to exert self-control relative to the non-self-control/placebo condition. This performance difference could not be explained by changes in heart rate, which is consistent with the extant literature reporting no effect for cardiovascular responses on endurance performance following a cognitively demanding manipulation (Marcora et al., 2009).

This finding has significant implications for self-control theory. Self-control diminishes over time because exertion becomes increasingly aversive (Kool & Botvinick, 2014), however, enough time needs to elapse for motivational and attentional foci to be shifted from the distal goal (cycling as fast as possible) to the proximal tempting goal (relieving the physiological distress; Milyavskaya & Inzlicht, 2016). Examination of performance prior to any shifts taking place may lead to the erroneous conclusion that self-control exertion may actually increase performance, or at least no detrimental effects exist. Time may be particularly important when considering expert performance as initial efforts to self-regulate may be automatic and non-conscious (Schmeichel & Baumeister, 2004; Williams et al., 2009). Irrespective of theoretical stance, endurance tasks like the one employed in the present study would suit the exploration of prior self-control exertion with appropriate consideration of time. For example, researchers could establish when motivational priorities shift (Milyavskaya & Inzlicht, 2016), when self-regulation switches from automatic to conscious processes (Schmeichel & Baumeister, 2004), or when self-control resources become too scarce (Gailliot et al., 2007).

Furthermore, in terms of sport performance, the results imply that prior self-control exertion may interfere with self-regulatory pacing strategies (i.e., optimal power output) during subsequent endurance performance (Wagstaff, 2014). Engaging in an initial task that
did not require self-control led participants to adopt a pacing strategy that appeared to be more consistent over the course of the endurance task (i.e., optimal self-regulation). In contrast, initial self-control exertion may lead to the selection of a pacing intensity that is too high at the initial phase of endurance performance (i.e., suboptimal self-regulation), leading to reductions in intensity in the latter stages of the trial and decrements in overall endurance performance. It is possible that shifts in attention due to self-control exertion may interfere with self-regulation, but not in the expected way. In line with many theories of self-control, initial self-control exertion may lead to decreased self-control in a subsequent task, but this manifested in being unable or unwilling to self-regulate pacing, rather than a slower pace per se.

On the basis of some previous research (DeWall et al., 2008; Hagger et al., 2010; Wang & Dvorak, 2010), it was also hypothesised that glucose supplementation would moderate any effects of self-control exertion on subsequent performance. The results did not provide support for this hypothesis. In fact, ingesting glucose led participants to cycle at a slightly faster pace in the early stages but overall performance was slower, compared to the non-self-control/placebo condition. Glucose intake during tasks of this intensity and duration may be ineffective because any ergogenic effects on the central nervous system may be overridden by increased metabolic stress and afferent feedback (Jeukendrup et al., 2008). The lack of moderating effect of glucose concurs with the conclusions made by other researchers (e.g., Lange & Eggert, 2014). Indeed, the results suggest that, in this endurance performance-based paradigm, ingesting glucose may lead to similar interference with pacing strategies to that of self-control exertion described previously. This represents a thought-provoking idea as oral exposure to glucose has been associated with activation of areas of the brain (e.g., anterior cingulate cortex) responsible for behavioural responses to rewarding stimuli, such as glucose (Rolls, 2007). This same region of the brain has also been implicated in the management of self-control and performance monitoring (MacDonald, Cohen, Stenger, & Carter, 2007).

Limitations and Future Directions

Methodologically speaking, the experimenter read the instructions for each cognitive task from a pre-prepared text to reduce the variability in the delivery of the instructions (Dorris et al., 2012), and the experimenter was out of sight from the participant as they completed the time trial task. Nonetheless, future research should blind the experimenter from the purpose of the study. Moreover, this study represents the primary attempt to examine previous exertion of self-control and subsequent gross motor skill endurance
performance in well-trained athletes. Therefore, future research should attempt to replicate the findings in other endurance tasks (e.g., running) with expert populations to enhance the generalisability of the findings.

Further research should manipulate the length of the second task and examine the effects of previous self-control exertion on subsequent endurance performance. It could be that the effects of self-control exertion may become more pronounced over time in endurance tasks lasting considerably longer. Finally, it is possible that spending longer on the initial self-control task could consume more resources or decrease motivation, and have an increased deleterious effect on performance. Further research should manipulate initial task duration in a sequential-task paradigm and examine its effect on performance during the second task.

Conclusion

This study helps understand the relationship between previous self-control exertion and subsequent highly practiced endurance performance. The findings imply that pacing may explain why self-control exertion interferes with endurance performance. Finally, the debate regarding the exertion of self-control must consider that any observed effects may be dependent on the timing of performance inspection.
Chapter Four
Study Three

Manipulation of the initial self-control task, within the sequential-task paradigm, prior to endurance performance.
Abstract

Performing a task requiring self-control may impair subsequent self-regulatory efforts. This study explored a) whether this effect occurs during a well-practiced endurance task, b) the potential for initial task duration to moderate this effect, and c) whether this effect differed over time. Nine trained cyclists completed four simulated 16 km time trials on an electromagnetically braked cycle ergometer. Prior to each time trial, participants completed a congruent Stroop task or an incongruent Stroop task that required self-control, for either four minutes or 16 minutes. Participants’ performance time and heart rate were recorded throughout the time trials. Multilevel growth curve analysis revealed a significant three-way interaction between self-control, duration Stroop, and time ($b = -0.98; p < 0.001$). When participants exerted self-control (incongruent Stroop) for four minutes they were slowest during the early stages of the time trial, this effect was accentuated as the time trial progressed. No differences were found in heart rate across the four conditions. Findings suggest that spending longer on the initial self-control task does not have an increased deleterious effect on subsequent task performance. Moreover, the results imply that self-control exertion impairs subsequent performance in relatively small bouts, with evidence for conservation of resources during longer bouts of self-control exertion.

Keywords: Growth models, cycling, ego depletion, initial task duration
Introduction

Self-control is defined as individuals’ capacity to alter, modify, change or override impulses, desires, and habitual responses (Baumeister & Heatherton, 1996; Muraven & Baumeister, 2002). This controlled process facilitates desirable behaviour by helping to regulate urges, to juggle competing goals, and to sustain attention (Baumeister, et al., 2007). A popular approach to understanding self-control is the strength or ‘resource depletion’ model. Self-control is conceptualised as a limited resource which becomes depleted after a period of self-control exertion, resulting in performance decrements on a subsequent task requiring self-control (Baumeister et al., 2007). Although this ‘limited resource’ perspective has received empirical and meta-analytic support (e.g., Hagger et al., 2010), recently, however, it has received robust challenge (e.g., Kurzban, 2016). Other researchers have proposed that, following acts of cognitive effort, individuals experience a shift in motivational and attentional orientation that undermines subsequent acts that require self-control (Inzlicht & Schmeichel, 2016; Inzlicht, Schmeichel, & Macrae 2014).

Despite the different theoretical explanations, a considerable body of empirical evidence exists that performance on subsequent physical tasks is reduced following an initial task requiring self-control (e.g., Muraven & Shmueli, 2006; Tice et al., 2007). These studies have typically demonstrated the effects of initial self-control exertion using a simple physical measure such as squeezing a handgrip for as long as possible. Squeezing a handgrip becomes tiring and painful after some time; therefore, individuals are required to exert self-control in order to maintain effort to continue squeezing the handgrip (Bray et al., 2011). For instance, individuals who were asked to suppress any kind of emotional response during an upsetting video (i.e., self-control task) did not perform an isometric handgrip squeeze for as long as individuals who watched the video without any additional instructions (i.e., control condition; Muraven et al., 1998). Similar results, were also observed following an incongruent Stroop task (versus a congruent Stroop task; Bray et al., 2008; 2011).

Extending this work, researchers have attempted to improve the ecological validity of the evidence so that assumptions concerning more complex human performance can be drawn. The completion of a number of self-control tasks (e.g., counting backwards from 1000 in multiples of seven while holding a spirit level, transcribing a neutral text whilst omitting the letters ‘e’ and ‘n’, completing an incongruent Stroop task, suppressing emotions during an upsetting movie) have led to reductions in performance during press-up tasks, sit-up tasks, basketball free-throw tasks, dart-tossing tasks, and cycling performance (Dorris et al., 2012; Englert & Bertrams, 2102; Englert & Wolff, 2015; McEwan et al., 2013; Wagstaff, 2014).
Taken together, self-control seems to be beneficial in order to be able to achieve high levels of physical performance (Englert & Wolff, 2015).

Overall, the aforementioned studies offer a valuable insight into self-regulatory processes and athletic performance. But, it remains unclear whether previous exertion of self-control can negatively influence subsequent endurance performance when self-regulation is potentially automatic. In expert populations, the frequent pursuit of the same cognitive goal can result in the automatisation of cognitive processes commonly associated with the self-regulation of that behaviour (Schneider & Chein, 2003; Yarrow et al., 2009). With repeated practice, individuals can learn to persist automatically (Chartrand & Bargh, 2002). Therefore, athletes who regularly push themselves during training sessions and competition may themselves have learned to persist nonconsciously (Dorris et al., 2012; Yarrow et al., 2009). When this automatic behaviour occurs, self-regulatory processes may not be necessary to the same degree as conscious self-regulation (Schmeichel & Baumeister, 2004). Accordingly, from a ‘limited resource’ perspective, an initial exertion of self-control would have no effect on subsequent endurance performance because behaviour would be automatic, and self-regulatory resources may not be required to the same extent as conscious self-regulation (Schmeichel & Baumeister, 2004). However, successful endurance performance involves substantial levels of discomfort and overcoming these demands may intensify the requirement for conscious self-regulation. This latter hypothesis suggests that performing an initial task requiring self-control may negatively affect subsequent endurance performance because the self-regulation necessary to sustain effort and resist discomfort is salient.

In addition to examining the salience of self-control during well-practiced human endurance performance, the primary aim of the present study is to explore whether initial task duration can moderate any decrements in performance due to prior self-control exertion. Many of the primary self-control tasks that have been employed previously are relatively brief in duration (typically less than 10 minutes; Hagger et al., 2010; Vohs, Baumeister, Schmeichel, Twenge, Nelson, & Tice, 2008). Also, the majority of research has only examined one time period; research is yet to manipulate initial task duration within the sequential-task paradigm and examine its effect on performance during the second task (Hagger et al., 2010). It is currently unknown whether spending longer on the initial self-control task, could have an increased deleterious effect on subsequent performance. It is possible that spending longer on the initial self-control task would consume more resources, leading to exacerbated performance decrements on a subsequent task, also requiring self-control (Baumeister et al., 2007). On the other hand, spending longer on the primary self-
control task may actually heighten an individual’s desire to conserve the limited resource (Baumeister & Vohs, 2007; Muraven et al., 2006). This is because individuals may attempt to retain some of their self-control resources in anticipation of future exertion on the second self-control task (Baumeister & Heatherton, 1996; Muraven & Baumeister, 2000). Individuals may try to minimise the amount of self-control strength they deplete by being selective in their self-control efforts (Muraven et al., 2006). Consequently, by limiting how much effort is exerted, it may be unlikely that an individual will be sufficiently depleted to show increased performance effects on the subsequent task (Lee et al., 2016).

Building on the literature discussed above, the aims of the current research were to explore a) whether exerting self-control reduces endurance performance and increases heart rate in well-trained individuals, b) the potential for initial task duration to moderate any decrements in performance due to prior self-control exertion, and c) whether any observed effects are variable over different stages of endurance performance. Heart rate was explored to eliminate potential physiological explanations for performance changes, in accordance with literature on cognitive fatigue (Marcora et al., 2009). The first and latter aims of the current research were primarily conducted to extend the findings of Study Two in this thesis.

In the present experiment, the sequential-task paradigm was employed to systematically manipulate the duration of the initial task. The primary task to manipulate self-control requirements was a congruent versus incongruent Stroop task. This task is a well-established self-control task and has been successfully applied in previous research (e.g., Englert & Wolff, 2015; McEwan et al., 2013). To manipulate initial task duration, the Stroop task was employed for four minutes (short duration) versus 16 minutes (long duration). These durations were utilised as previous research has employed this task for the same length of time (i.e., four minutes; Hagger et al., 2010). Furthermore, 16 minutes reflects a 400% increase in duration, thus reflecting a suitable variance for differences to be observed. To measure athletic performance, a 16 km laboratory-based cycling time trial was utilised. A time trial requires numerous self-regulation behaviours including sustained effort despite considerable levels of discomfort, as well as regulating ones attention and emotions throughout periods of physical stress. Moreover, a time trial protocol may have greater ecological validity than time to exhaustion protocols often used in previous research (e.g., Carter et al., 2005), because performance and physiological responses are similar compared to outdoor time trials (Currell & Jeukendrup, 2008). A 16 km distance is also familiar and well-practiced by cyclists; therefore, it may reduce the need for conscious self-regulation (Schmeichel & Baumeister, 2004).
Method

Participants

The sample consisted of nine endurance trained cyclists (4 female, 5 male) aged 23-28 years old. Inclusion criteria required that participants had experience in competitive cycling-based events (e.g., triathlon, road cycling), and were currently training for a cycling event. Due to my choice of analytic strategy (see Data Analysis below), conventional criteria regarding sufficient sample sizes in single level designs are irrelevant. The relevant unit of measurement in this study is the repeated observations throughout each time trial.

Procedures

Following approval from a university ethics committee, each participant signed an informed consent form after the study was explained in full and it was clarified that involvement was anonymous and voluntary (see Appendix Five). Furthermore, all participants were healthy, as assessed by a university approved general health questionnaire.

Preliminary fitness test. Participants completed an incremental-effort cycle test to volitional exhaustion to determine individuals’ maximal power output (Wmax). This test was carried out on an electromagnetically braked cycle ergometer (Lode Excalibur Sport, Groningen, The Netherlands) with adjustable saddle height and handle bar position. Furthermore, this test was performed at least one week before the experimental trials began. Following a self-selected warm up, participants began cycling at 95 W for three minutes, followed by incremental steps of 35 W every three minutes until exhaustion. Heart rate was monitored throughout by a radiotelemetry heart rate monitor (Polar Vantage NV, Kempele, Finland). Participants Wmax was calculated from the final completed work rate plus the fraction of time spent in the final non-completed work rate, multiplied by 35 W. Eighty-five percent Wmax was subsequently used in all cycling time trials. During this test only, verbal encouragement was given to the participants by the same investigator. These procedures have been advocated and frequently employed in athletic endurance research (e.g., Jeukendrup et al., 2008).

Experimental protocol. Participants were instructed to keep a record of their food intake and activity patterns on the day before the first time trial and to replicate the same diet and exercise activities 24 hours before all subsequent trials. They were also asked to abstain from strenuous exercise and avoid alcohol and caffeine intake 24 hours before the start of each trial (see Appendix Four).

Each participant took part in four experimental sessions. On arrival in the laboratory, participants completed a questionnaire to control for the influence of daily stress (see
Appendix Three). The questionnaire included the seven stem questions from the Daily Inventory of Stressful Events Questionnaire (Almeida et al., 2002). Participants were instructed to indicate whether any of a number of stressful events had occurred today by circling either ‘yes’ or ‘no’ (e.g., “An argument or disagreement with someone”). The items have demonstrated acceptable internal consistency and predictive validity in previous research (Almeida et al., 2002).

Participants were then fitted with the heart rate monitor and the cycle ergometer was adjusted to a comfortable position as requested by the participant. Participants began a standardised warm-up consisting of 10 minutes at 50% Wmax, followed by five minutes at 60% Wmax. Immediately following the warm-up participants were required to complete either a self-control or non-self-control experimental manipulation. In the self-control condition, participants were presented with a non-congruent Stroop task with the names of colours printed in a different colour (e.g., the word ‘blue’ printed in yellow). The aim was to verbally communicate the colour of the ink, not the word (e.g., ‘yellow’ not ‘blue’). However, when a word is presented in red ink, individuals are required to override the general instructions and read aloud the printed word. Previous research has advocated that this task is cognitively challenging and requires self-control (e.g., Englert & Wolff, 2015; McEwan et al., 2013). In the non-self-control condition, the colour of the ink and the word were matched (i.e., congruent) and verbally communicating the colour of the ink does not require self-control (Baumeister et al., 2007). Participants completed the Stroop task on a computer in a quiet room; words were serially presented on the screen with a 1,500 ms interval. Participants were instructed to respond as accurately as possible. Following the experimental manipulation participants completed a manipulation check which assessed their perceived effort. Participant’s rated their mental exertion during the Stroop task using Borg’s single-item CR-10 scale (Borg, 1998; 0 = extremely weak; 10 = absolute maximum), with higher scores indicating more perceived mental exertion (see Appendix Six). Participants performed the self-control or non-self-control experimental manipulation for either four minutes (short duration) or 16 minutes (long duration).

Following the experimental manipulation, participants consumed an initial bolus of 300 ml of a placebo glucose-free solution (Powerade; zero glucose) containing flavourings, sweeteners, and electrolytes. The drink was administered to conceal the overall objectives of the research.

Immediately following drink consumption, participants commenced a simulated 16 km cycle time trial. In these time trials, participants completed a predetermined amount of
work as fast as possible. The amount of work to be performed was calculated by assuming that participants could cycle at 85% of their Wmax for 25 min, which is comparable to 16 km personal bests of cyclists on the road (Jeukendrup et al., 2008). The ergometer was set in the pedalling-dependent mode (i.e., power varies with cadence) so as to replicate as accurately as possible a time trial in a field setting. A further 200 ml drink was consumed when half the workload had been completed. Outcome variables included heart rate and time, which were recorded after every 10% of the time trial had been completed, as well as 92.5%, 95%, and 97.5% completion. Participants received no encouragement or information except a signal that they had 20% and 10% of the time trial remaining. All exercise trials were completed under normal and standard environmental conditions (19-21°C dry bulb temperature and 50-60% humidity). Standing floor fans, always in the same position and fan speed, were available to participants to minimise thermal stress. Music and external distracting material was excluded during all trials.

In sum, participants completed four simulated 16 km time trials under four experimental conditions: self-control/short duration, self-control/long duration, non-self-control/short duration, non-self-control/long duration. Conditions were counterbalanced. Trials were separated by 48 hours and were always performed at the same time of day to prevent any circadian variance.

**Data analysis**

The data analysis procedure that was employed in Study Two of this thesis was utilised for the current study (please see page 48). The sample size at Level 1 was 491 data points because some trials had missing data. Furthermore, in the present study, the two binary coded main effects of the experimental conditions were self-control/non-self-control and long Stroop/short Stroop. Finally, the three-way interaction term included time, self-control, and Stroop duration.

**Results**

**Preliminary analysis**

Table 4.1 displays means and standard deviations for performance (time) and heart rate for each experimental condition. Intraclass correlation coefficients (ICCs) were calculated from model 1a and 1b (shown in Table 4.2). The ICC for performance was 0.00 indicating that 100% of the variance in performance was attributable to the within-person level. The ICC for heart rate was 0.50 indicating that 50% of the variance in heart rate was attributable to the within-person level.
### Table 4.1

*Final Performance Time and Heart Rate for each Experimental Condition*

<table>
<thead>
<tr>
<th>Experimental Condition</th>
<th>Time (seconds)</th>
<th>Heart Rate (beats per minute)</th>
<th>Mental Exertion</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>M</td>
</tr>
<tr>
<td>Self-control/Short duration</td>
<td>1838</td>
<td>307</td>
<td>178</td>
</tr>
<tr>
<td>Self-control/Long duration</td>
<td>1759</td>
<td>151</td>
<td>177</td>
</tr>
<tr>
<td>Non-self-control/Short duration</td>
<td>1730</td>
<td>152</td>
<td>179</td>
</tr>
<tr>
<td>Non-self-control/Long duration</td>
<td>1806</td>
<td>237</td>
<td>173</td>
</tr>
</tbody>
</table>
A repeated measures (ANOVA) was conducted to check differences in mental exertion across conditions. There was a significant main effect of self-control manipulation on ratings of perceived mental exertion ($F(1,7) = 13.60, p = .01, \eta^2 = .66$), with perceived mental exertion being significantly higher after participants completed the self-control conditions ($M = 4.28, SD = .37$) relative to the non-self-control conditions ($M = 1.66, SD = .70$). Furthermore, there was a significant main effect of Stroop task duration on ratings of perceived mental exertion ($F(1,7) = 8.88, p = .02, \eta^2 = .56$). Participants reported significantly higher perceived mental exertion following the long duration Stroop tasks ($M = 3.81, SD = .62$) compared to the short duration Stroop tasks ($M = 2.13, SD = .39$). There was no significant interaction for time*condition $F(1,7) = 0.80, p = .40, \eta^2 = .10$. These results imply that the incongruent Stroop task required greater mental effort compared to the congruent Stroop task, and that the long duration Stroop task required more mental effort relative to the short duration Stroop task.

**Primary analysis**

As displayed in Table 4.2, model 2a revealed a significant main effect for time, as well as a significant interaction effect for self-control and time. However, these were superseded by a significant three-way interaction between self-control, duration Stroop, and time ($b = -0.98; p < .001$). Simple slopes analysis applied to multilevel models (Preacher et al., 2006) was subsequently applied to interpret this interaction. After 10% of the trial had been completed (Figure 4.1), there were only small differences in performance time across experimental conditions (as would be expected after ~3 minutes of time trialling). However, participants were slowest when they completed the short duration, incongruent Stroop. This trend was accentuated as the time-trial progressed. Therefore, at the end of the trial (Figure 4.2), participants were slowest when they completed the short, self-control condition.

Model 2b revealed no significant main effects or interaction effects. In other words, experimental condition did not influence heart rate at any point in the time trial.

**Discussion**

The present study examined the effects of exerting self-control on a subsequent endurance task requiring self-regulation in well-trained endurance athletes. Previous research was extended by demonstrating that participants performed the cycling time trial task in the slowest time when they exerted self-control for a short duration. An extended time required to exert self-control did not lead to exacerbated performance decrements on the subsequent
**Table 4.2**

*Final Models Describing Changes in Study Variables during the Time Trial*

<table>
<thead>
<tr>
<th>Predictor Variable</th>
<th>Model 1a</th>
<th>Model 1b</th>
<th>Model 2a</th>
<th>Model 2b</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fixed effects</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intercept</td>
<td>1122.39(25.55)**</td>
<td>166.81(1.88)**</td>
<td>1739.10(45.49)**</td>
<td>177.54(3.46)**</td>
</tr>
<tr>
<td>Linear time</td>
<td>-</td>
<td>-</td>
<td>17.34(0.17)**</td>
<td>0.23(0.02)**</td>
</tr>
<tr>
<td>Self-control</td>
<td>-</td>
<td>-</td>
<td>132.33(71.15)</td>
<td>-0.98(5.67)</td>
</tr>
<tr>
<td>Duration Stroop</td>
<td>-</td>
<td>-</td>
<td>7.82(67.55)</td>
<td>-0.15(5.14)</td>
</tr>
<tr>
<td>Duration Stroop × self-control</td>
<td>-</td>
<td>-</td>
<td>-109.30(96.64)</td>
<td>1.19(7.52)</td>
</tr>
<tr>
<td>Self-control × time</td>
<td>-</td>
<td>-</td>
<td>1.09(0.25)**</td>
<td>0.03(0.03)</td>
</tr>
<tr>
<td>Duration Stroop × time</td>
<td>-</td>
<td>-</td>
<td>0.05(0.26)</td>
<td>0.04(0.03)</td>
</tr>
<tr>
<td>Self-control × duration Stroop × time</td>
<td>-</td>
<td>-</td>
<td>-0.98(0.37)**</td>
<td>-0.03(0.04)</td>
</tr>
<tr>
<td>Daily Stress</td>
<td>-</td>
<td>-</td>
<td>66.73(79.93)</td>
<td>-1.49(6.10)</td>
</tr>
<tr>
<td><strong>Random effects</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Level 1 residual variance</td>
<td>315918.00(20875.51)**</td>
<td>105.49(7.07)**</td>
<td>3547.19(236.90)**</td>
<td>38.87(2.65)**</td>
</tr>
<tr>
<td>Level 2 residual variance</td>
<td>304.804(5481.02)</td>
<td>106.09(28.30)**</td>
<td>17304.79(4394.15)**</td>
<td>96.84(25.26)**</td>
</tr>
</tbody>
</table>

*Note.* A dash indicates that the term was not included in the models. *p < .05. **p < .01. ‘a’ models include performance as the dependent variable and ‘b’ models include heart rate.
Figure 4.1

*Three-way interaction effects for self-control and duration Stroop conditions after 10 percent of the time trial had been completed.*
Figure 4.2

Three-way interaction effects for self-control and duration Stroop conditions after 100 percent of the time trial had been completed.
endurance task. Until now, it was unclear whether spending longer on the initial self-control task would moderate the deleterious effect on performance.

In accordance with previous research (e.g., Bray et al., 2011; Englert & Wolff, 2015; Wagstaff, 2014) a relatively brief (four minutes) exertion of self-control significantly reduced subsequent performance during an endurance task requiring self-control, in this case cycling time trial performance. The results demonstrate that in the early stages of the time trial, differences in performance across experimental conditions were minimal. Nonetheless, participants went slowest when they were previously required to exert self-control for a short duration. This difference in performance became exaggerated over time to the extent that individuals completed the cycling task 108 seconds slower, on average, when they completed a short self-control task relative to the short non-self-control task. This performance difference could not be explained by changes in heart rate, which is consistent with the extant literature reporting no effect for cardiovascular responses on endurance performance following a cognitively demanding manipulation (Marcora et al., 2009).

This finding has significant theoretical implications. In expert populations, initial efforts to self-regulate during the cycling task may be automatic and non-conscious (Schmeichel & Baumeister, 2004; Williams, 2009). As the cycling task progressed, discomfort levels may have intensified, therefore, overcoming these demands may exacerbate the need for conscious self-regulation. It is possible, that the examination of performance before self-regulation switches from automatic to conscious may perhaps lead to the inaccurate conclusion that self-control exertion does not lead to significant decrements in performance on the second task. Similarly, from a ‘shifting priorities’ perspective, self-control wanes over time because exertion becomes progressively aversive (Kool & Botvinick, 2014). However, enough time needs to elapse for motivational and attentional foci to be shifted from the distal goal (i.e., cycling as fast as possible) to the proximal tempting goal (i.e., relieving the physiological distress; Milyavskaya & Inzlicht, 2016). Consequently, if performance was to be examined prior to any shifts taking place, then it may lead to the similar erroneous conclusion that self-control exertion does not significantly impair subsequent performance.

Moreover, the findings significantly extend the extant literature by implying that spending longer on the initial self-control task did not lead to exacerbated performance decrements on a subsequent endurance task. In fact, participants completed the cycling task 79 seconds faster, on average, when they completed a long self-control task relative to the short self-control task. This finding appears to be aligned with the conservation hypothesis of
self-control resources (Muraven et al., 2006). That is, individuals may attempt to retain some of their self-control resources in anticipation of future exertion on the second self-control task (Baumeister & Heatherton, 1996; Baumeister & Muraven, 2000). Therefore, it is possible that during the long duration Stroop task requiring self-control, participants were more motivated to conserve self-control strength, relative to the short self-control task. This is because they were mindful of the fact that they were required to successfully perform the subsequent self-regulatory endurance task. Individuals may have been selective in their self-control efforts and disengaged from the initial self-control task (Lee et al., 2016). Consequently, participants may not have exerted sufficient effort to deplete their self-control resources to lead to increased performance effects on the subsequent endurance task (Chatzisarantis & Hagger, 2015a), relative to the short self-control task.

However, it is important to highlight that in the current study self-control efforts on the primary self-control task were not examined. Future research should explore whether spending longer on the initial self-control task results in a reduction in performance on the task itself (Hagger et al., 2010). The identification of a decline in performance on the primary task would enable researchers to ascertain a participants’ level of exertion, as well as provide an indication of resource depletion (Hagger et al., 2010), which may represent a better test of the conservation hypothesis. Nevertheless, this finding has significant implications for the designing and assessment of future experiments exploring self-control exertion and subsequent performance within the sequential-task paradigm. It is possible that the differences in the size of the depletion effect across studies may well be a result of variations in the duration of the initial task (Lee et al., 2016). It is important that this effect is replicated in a more diverse range of experimental studies. Such research may help to identify the most suitable duration required for the first task of the sequential-task paradigm to reliably lead to performance decrements on subsequent task performance (Lee et al., 2016).

Limitations and Future Directions

Despite yielding some important findings, there are some study limitations worth noting. Although steps were taken to avoid experimenter bias (e.g., the experimenter read the instructions for each cognitive task from a pre-prepared text to reduce the variability in the delivery of the instructions), future research should blind the experimenter from condition assignment. Moreover, the long duration Stroop task may have led to different levels of motivation to perform the task itself. Future research can attempt to ensure participants invest identical effort levels on the first task by providing participants with an incentive to engage in the first task (Lee et al., 2016). Finally, the self-control manipulation may have led to
different levels of motivation to perform the subsequent endurance task (e.g., Inzlicht & Schmeichel, 2012). Future studies should additionally assess participants’ motivation following the self-control task.

**Conclusion**

The study presented here offers an insight into the potentially debilitating role of previous self-control exertion on subsequent highly practiced endurance performance. Findings indicate that spending longer on the initial self-control task, within the sequential-task paradigm, does not appear to have an increased deleterious effect on subsequent endurance performance, relative to completing a short duration self-control task. The results imply that self-control exertion impairs subsequent endurance performance in relatively small bouts, with evidence for conservation of resources during longer bouts of self-control exertion.
Chapter Five
Study Four

Prior self-control exertion and perceptions of pain during a physically demanding task.
Abstract

Completion of a task requiring self-control has been associated with impaired performance on subsequent physical tasks also requiring self-control, but it remains unknown why this occurs. This study explored whether self-control exertion reduces performance during a physical task and whether any observed performance decrements could be explained by changes in perceptions of pain. Sixty three individuals completed two wall-sits until voluntary exhaustion. Prior to each wall-sit, participants completed an easy Stroop task or a difficult Stroop task that required self-control. Throughout the wall-sit, participants’ perception of pain was recorded as well as time to exhaustion. When participants completed the difficult Stroop task, they quit the wall-sit sooner and perceived greater pain, compared to when they completed the easy Stroop task. The findings suggest that perceptions of pain may explain why self-control exertion interferes with subsequent performance on a physical task.

Keywords: self-regulation, ego depletion, pain tolerance, physical performance
Introduction

Self-control has been defined as the process of volitionally controlling and overriding predominant, habitual tendencies in order to achieve a specific goal (Baumeister et al., 1998). This process enables individuals to initiate and inhibit particular responses, attend to stimuli, and engage in purposeful, effortful, and goal-directed behaviours (Baumeister, Heatherton, & Tice, 1994). Evidence has implied that following the exertion of self-control on one task, individuals typically have an impaired ability to self-regulate when performing a subsequent second task, even if this task is drawn from a different domain (Hagger et al., 2010). For instance, in laboratory settings, following an act of self-control, individuals were less persistent in an anagram task (e.g., Muraven et al., 1998), experienced difficulties regulating their emotions whilst watching an emotionally-provoking video (e.g., Schmeichel., 2007), and made more errors when naming colour words in a Stroop task (e.g., Richeson & Shelton, 2003). Meta-analytic evidence has provided support for impaired performance on the second self-control task due to initial exertion of self-control (e.g., Hagger et al., 2010).

Considerable research has demonstrated that self-control exertion can impair performance on subsequent physical tasks also requiring self-control. One task that has frequently been administered to explore physical performance is squeezing an isometric handgrip for as long as possible (e.g., Muraven et al., 1998; Muraven & Shmueli, 2006; Tice et al., 2007). Although this task primarily requires muscular strength, overcoming fatigue and overriding the urge to quit become primarily an act of self-control and mental persistence (Muraven et al., 1998). To illustrate, following the completion of a task requiring self-control (incongruent Stroop task), individuals did not persist at an isometric handgrip task for as long compared to when they completed a task requiring no self-control (congruent Stroop task; Bray et al., 2008). Recently, research has employed callisthenic measures of physical action so that assumptions concerning more complex human performance can be formulated. For instance, following a cognitively demanding task (counting backwards from 1000 in 7’s whilst holding a spirit level), competitive athletes performed significantly worse on a sit-up task compared to when they completed a cognitively simple task (counting backwards from 1000 in 5’s; Dorris, Power, & Kenefick, 2012). The ability for self-control exertion to reduce subsequent physical performance has been substantiated during cycling tasks (e.g., Englert & Wolff, 2015; Wagstaff, 2014), dart throwing tasks (e.g., McEwan et al., 2013) and basketball free throw tasks (Englert & Bertrams., 2012; Englert et al., 2015a). Clearly, self-control seems to be crucial in order to be able to achieve high levels of physical performance that require prolonged effort or attention. What is unknown and, therefore, the focus of the
present study is why this occurs. Understanding the causal explanations would provide a
more complete model of self-control.

A number of theories have been proposed to explain self-regulatory failures following
previous exertion of self-control. Some researchers have suggested that self-control is a
limited resource; therefore, prior acts of self-control can lead to a temporary loss of self-
control strength in subsequent acts (Baumeister et al., 1998). Other researchers have proposed
that, following acts of self-control, individuals experience a shift in motivational and
attentional orientation that undermines subsequent acts that require cognitive effort (Inzlicht
& Schmeichel, 2012). Many of the physical or athletic tasks that have been utilised
previously are unpleasant and induce considerable levels of discomfort (e.g., Bray et al.,
2011; Dorris et al., 2012; Englert & Wolff, 2015). Combining this fact with a ‘shifting
priorities’ perspective (Inzlicht & Schmeichel, 2016), self-control exertion may lead to greater
attention on perceptions of pain during a subsequent endurance task. This may lead to an
increased focus on the proximal goal ( quitting or reducing effort to relieve the pain), relative
to the distal goal (persisting on the task to maximise performance), resulting in reduced
performance (Wooley & Fishbach, in press). The completion of self-control tasks has led to
significantly higher perceptions of effort and self-regulatory fatigue during subsequent acts of
self-control (e.g., Hagger et al., 2010; Martijn, Tenbult, Merckelbach, & Dreezens, 2002),
providing support for the shifting priorities perspective. Furthermore, individuals with higher
levels of trait self-control persisted longer at a painful cold pressor test compared to those
participants with lower levels of trait self-control (Schmeichel & Zell, 2007). The cold
pressor test is a method of experimental pain induction, whereby participants are required to
submerge their hand in cold water for as long as possible. However, this does not explain
why a bout of self-control exertion reduces subsequent physical performance.

Extending the literature described above, the aims of the current research were to
determine whether exerting self-control a) reduces performance and b) increases perceptions
of pain on a subsequent, unrelated physical task that requires self-control. In addition, the
current study investigated whether any observed performance decrements as a result of self-
control exertion could be explained by an individual’s perceptions of pain. In the present
experiment, the self-control manipulation was a congruent versus incongruent Stroop task
performed for four minutes. Previous research has shown that this task requires self-control
(McEwan et al., 2013) and has been employed for the same length of time as in the present
study (i.e., four minutes; e.g., Gailliot et al., 2007). A wall-sit was employed to measure
physical performance, which entails leaning with one’s back against a wall with hips and
knees bent at 90 degrees. This procedure is increasingly painful and requires participants to resist the temptation to alleviate the pain by quitting the task, and instead to invest sustained effort to persist as long as possible. Based on the broad self-control literature (e.g., Bray et al., 2011; Dorris et al., 2012; Englert & Wolff, 2015; Inzlicht & Schmeichel, 2016) it was hypothesised that engaging in a cognitively demanding task previously shown to require self-control (i.e., an incongruent Stroop task) would result in poorer performance (hypothesis 1) and increased perceptions of pain (hypothesis 2) in a subsequent wall-sit task, compared to a cognitively simple task (i.e., a congruent Stroop task). In addition, it was expected that perceptions of pain would mediate the effects of the self-control manipulation on wall-sit performance (hypothesis 3).

Methods

Participants

The sample consisted of 63 recreationally active participants (21 male, 42 female) aged 18-34 years old (M age = 22 years, SD = 3 years). The participants spent, on average, four days (SD = 2 days) per week exercising, and 56 participants reported that they had completed a wall-sit previously. A power calculation (G*Power version 3.1; Faul, Erdfelder, Lang, & Buchner 2009) with power = .80 and α = .05, indicated a sample size of N = 52 would be sufficient to detect a medium effect size (.40).

Following approval from a university ethics committee, each participant signed an informed consent form after the study was explained in full and it was clarified that involvement was anonymous and voluntary (see Appendix Seven). Furthermore, all participants were healthy, as assessed by a university approved general health questionnaire.

Protocol

Each participant took part in two experimental sessions. On arrival in the laboratory, participants completed questionnaires to control for the influence of daily stress, as well as physical fatigue. Participants were then familiarised with the wall-sit procedure. Subjects were directed to stand with his/her back against a wall, feet shoulder width apart and knees and hips flexed at a 90 degree angle, with his/her hands resting against the wall. Specific exercise instructions were scripted so that they remained constant for each subject. Participants practiced the wall-sit once to ensure that they were familiar with and understood what was required.

Participants were then administered a computerised version of the Stroop task. Colour words were presented on a screen and participants were required to read aloud the colour of the print ink and ignore the text of each word presented. However, when participants
encounter a word presented in red ink, they are required to override the general instructions and read aloud the printed word. In the self-control condition, the print ink colour and printed text were mismatched. For example, if the word ‘yellow’ was printed in green, the correct verbal response would be green. However, if the word ‘orange’ was presented in red ink, the correct verbal response would be orange. In the non-self-control condition, the words were matched (e.g., the word ‘yellow’ was printed in yellow ink, ‘red’ was printed in red ink).

Previous studies have repeatedly demonstrated that the incongruent version of the Stroop task is cognitively challenging and requires self-control because individuals have to volitionally override their primary impulse of naming the word instead of the font colour (e.g., Englert & Wolff, 2015; McEwan et al., 2013). Participants sat in a quiet room and were instructed to respond as accurately as possible. The Stroop task was four minutes in duration and words were presented on the screen at 1,500 ms intervals. Prior to the actual test, participants completed a practice session lasting 30 seconds to acquaint with the task. Following the experimental manipulation of self-control, participants completed a manipulation check which assessed their perceived mental exertion during the Stroop task (see measures section).

Participants then performed the wall-sit. Subjects were instructed to hold the position for as long as possible, until exhaustion. Throughout the wall-sit, participants’ perception of pain was recorded (see measures section). In sum, participants completed two seated wall-sits under two experimental conditions: prior self-control and non-self-control. Sessions were counterbalanced and separated by 24 hours.

**Measures**

**Daily stress.** Daily stress was assessed using the seven stem questions from the Daily Inventory of Stressful Events Questionnaire (Almeida et al., 2002; see Appendix Three). Participants were instructed to indicate whether any of a number of stressful events had occurred today by circling either ‘yes’ or ‘no’ (e.g., “An argument or disagreement with someone”). The item scores have demonstrated acceptable internal consistency and predictive validity in previous research (Almeida et al., 2002).

**Perceptions of physical fatigue.** Physical fatigue was measured using the fatigue subscale from the Profile of Mood States (POMS; McNair, Lorr, & Droppleman, 1992; i.e., “I feel physically worn out” and “I feel physically exhausted”). Participants were instructed to consider the degree to which they were currently experiencing the items on a five-point scale anchored by 1 (*not at all true*) to 5 (*very true*). These items were selected from the POMS as they had the highest factor loadings in previous research and acceptable reliability (e.g., Beedie, Terry, & Lane, 2000; see Appendix Eight).
Mental exertion. As a manipulation check participants’ rated their mental exertion during the Stroop task using Borg’s single-item CR-10 scale (Borg, 1998; 0 = extremely weak; 10 = absolute maximum; see Appendix Six).

Perceptions of pain. Participants completed the short-form McGill pain questionnaire (SF-MPQ; Melzack, 1987), in order to determine current pain perception. First, participants reported the degree to which they were currently experiencing various sensations on a four-point scale anchored by 0 (none) to 3 (severe). Four items each from the sensory (“Throbbing”, “hot-burning”, “cramping”, “aching”) and affective (“Tiring-exhausting”, “sickening”, “fearful”, “punishing-cruel”) subscales were used. The investigator presented the participants with a printed copy of each item and they were instructed to verbally communicate their answer (see Appendix Ten). In addition to this, participants completed the Visual Analog scale from the SF-MPQ; a 10-centimeter line, where one end represented no pain and the other end represented the worst pain (see Appendix Nine). Participants were asked to make a mark on the line that represented his/her current pain intensity. The SF-MPQ has been used previously in studies of pain as a relatively quick assessment tool to examine pain levels during physical activities (e.g., Osborne & Gatt, 2010; Paparizos, Tripp, Sullivan, & Rubenstein, 2005).

Participants completed a subscale of pain measurement at 15 second intervals for the entire duration of the wall-sit task. For instance, participants completed the four items from the sensory subscale after 10 seconds, the four items from the affective subscale after 25 seconds, and the VAS after 40 seconds. This same order was subsequently repeated throughout the wall-sit. Intervals of 15 seconds were employed to allow participants enough time to answer the items from each subscale and a period of rest before the following subscale was presented.

Task performance. Performance was assessed using the time (in seconds) participants stopped the wall-sit task.

Results

Preliminary Analysis

The Statistical Package for Social Sciences (SPSS; Version 22.0) was used for all statistical analyses. Table 5.1 displays descriptive statistics for each variable across each experimental condition. Paired samples t-tests revealed that participants did not differ in their prior levels of daily stress $t(61) = -.88, p = .24, r = .01$, or ratings of physical fatigue $t(61) = -.34, p = .74, r = .04$, across experimental conditions. The manipulation check revealed that participants reported higher mental exertion following the incongruent Stroop task ($M = 5.15$, $SD = 1.81$).
Table 5.1
Descriptive Statistics for all Variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Experimental condition</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Self-control</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Non-self-control</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>Mental exertion</td>
<td>5.15</td>
<td>1.83</td>
<td></td>
</tr>
<tr>
<td>Physical fatigue</td>
<td>2.02</td>
<td>.86</td>
<td></td>
</tr>
<tr>
<td>Daily stress</td>
<td>6.45</td>
<td>1.05</td>
<td></td>
</tr>
<tr>
<td>Wall-sit performance time (secs)</td>
<td>130.16</td>
<td>70.01</td>
<td></td>
</tr>
<tr>
<td>Sensory pain scores</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Start of wall-sit task</td>
<td>.83</td>
<td>.57</td>
<td></td>
</tr>
<tr>
<td>End of wall-sit task</td>
<td>2.21</td>
<td>.58</td>
<td></td>
</tr>
<tr>
<td>Affective pain scores</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Start of wall-sit task</td>
<td>.50</td>
<td>.48</td>
<td></td>
</tr>
<tr>
<td>End of wall-sit task</td>
<td>.97</td>
<td>.59</td>
<td></td>
</tr>
<tr>
<td>VAS pain scores</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Start of wall-sit task</td>
<td>3.83</td>
<td>1.88</td>
<td></td>
</tr>
<tr>
<td>End of wall-sit task</td>
<td>6.68</td>
<td>2.13</td>
<td></td>
</tr>
</tbody>
</table>
SE = 0.23) compared to the congruent Stroop task (M = 1.33, SE = .15), t(61) = 16.68, p < .001, r = .90.

**Primary Analyses**

A paired samples t-test was conducted to evaluate the impact of exerting self-control on wall-sit performance time (hypothesis 1). The results revealed that participants gave up quicker in the self-control experimental condition (M = 130.16, SE = 8.90), compared to the non-self-control condition (M = 147.31, SE = 9.27), t(61) = -2.79, p = .007, r = .30. These differences were statistically significant after a bonferroni correction for four t-tests (p < .013) was utilised and were of small effect size; Cohen’s d = .24.

Repeated measures multivariate analysis of variance (MANOVA) was used to test the effect of experimental condition on participants’ perception of pain during the wall-sit task (hypothesis 2). Although the study protocol required participants to complete multiple measures of sensory, affective, and VAS subscales, 57% of participants did not complete more than two complete set of measures before they quit the task. To maintain the maximum sample size, therefore, MANOVAs were conducted on all participants’ first and final set of pain scores before quitting the task. At the beginning of the wall-sit, differences in pain across the experimental conditions were bordering on conventional levels of statistical significance and a moderate effect size was observed: F(3, 58) = 2.44, p = .07, η² = .11. Follow-up univariate tests indicated that VAS scores at the beginning of the wall-sit task were significantly higher following the self-control experimental condition (M = 3.83, SE = .24) compared the non-self-control condition (M = 3.37, SE = .21), F(1,60) = 6.23, p = .02, η² = .09). Experimental condition had no effect on sensory scores (p = .20) or affective scores (p = .11).

Eighteen participants did not complete a second set of pain scores before quitting and it was considered inappropriate to re-use their first pain scores as their final pain scores. Therefore, a second MANOVA was conducted on results from the remaining 45 participants. Results revealed significant differences in final pain scores before quitting across experimental conditions and a large effect size: F(3, 42) = 2.77, p = .05, η² = .17. Follow-up univariate tests revealed that VAS scores at the end of the wall-sit task were significantly higher following the self-control experimental condition (M = 6.68, SE = .32), compared to the non-self-control condition (M = 6.19, SE = .36), F(1,44) = 8.38, p = .01, η² = .16). No differences were found for sensory scores (p = .40) or affective scores (p = .73) across experimental conditions.
Based on the MANOVA results, within-subject mediation analysis (Judd, Kenny, & McClelland, 2001) was employed to test whether the VAS pain scores \( (H) \) in the self-control \((I)\) and non-self-control \((2)\) experimental conditions at the start of the wall-sit task mediated the observed differences in wall-sit performance time \( (\hat{Y}) \). Although a MANOVA was previously conducted on pain scores at the beginning of the wall-sit task, a separate t-test on the VAS pain scores at the beginning of the wall-sit task was conducted. This t-test was carried out because univariate tests indicated that the VAS appeared to be driving the differences in perceptions of pain across experimental conditions. Results revealed that the mean VAS pain score in the self-control condition was significantly higher \( (M = 3.83) \) compared to the non-self-control condition \( (M = 3.37) \), this difference was significant, \( t(61) = 2.50, p = .02 \). Next, each performance time was regressed on the VAS pain measure from the same experimental condition. The results revealed that VAS pain scores were associated with worse performance times: \( \hat{Y}_1 = 130.16 + 3.83 H_1, t(60) = -4.49, p < .001 \) and \( \hat{Y}_2 = 147.31 + 3.37 H_2, t(62) = -5.10, p < .001 \). Finally, when the performance time difference \( (\hat{Y}_{Di}) \) was regressed on the sum \( (H_S) \) and difference \( (H_D) \) of VAS pain scores, the following results were observed: \( \hat{Y}_{Di} = -17.15 - 7.20 H_S + 0.47 H_D \). In this model, the VAS pain score difference was a significant predictor of the performance difference \( t(60) = -3.45, p < .001 \), but the VAS pain sum was not \( t(60) = .76, p = .45 \). The results suggest that differences in VAS pain scores at the beginning of the wall-sit task mediate the difference in performance time across experimental conditions.

Furthermore, mediation analysis was conducted to examine whether the VAS pain scores \( (H) \) in the self-control \((I)\) and non-self-control \((2)\) experimental conditions at the end of the wall-sit task mediate the observed differences in wall-sit performance time \( (\hat{Y}) \). A separate t-test on the VAS pain scores at the end of the wall-sit task revealed that the mean VAS pain score in the self-control condition was significantly higher \( (M = 6.68) \) compared to the non-self-control condition \( (M = 6.19) \), \( t(44) = 2.89, p = .01 \). Next, each performance time was regressed on the VAS pain measure from the same experimental condition. The results revealed that VAS pain scores at the end of the wall-sit task in the self-control experimental condition were significantly related to performance time, with high VAS pain scores associated with worse performance time \( (\hat{Y}_1 = 130.16 + 6.68 H_1, t(44) = 2.21, p = .03) \). However, VAS pain scores at the end of the wall-sit task in the non-self-control condition were not significantly related to performance time \( (\hat{Y}_2 = 147.31 + 6.19 H_2, t(44) = 1.82, p = .08) \). When the performance time difference \( (\hat{Y}_{Di}) \) was regressed on the VAS pain sum \( (H_S) \) and difference \( (H_D) \), the following results were observed: \( \hat{Y}_{Di} = -17.15 - 12.87 H_S + 0.50 H_D \). The results revealed that the VAS pain score difference was not a significant predictor of the
performance difference $t(44) = .10, p = .92$, or the VAS pain sum $t(44) = .67, p = .51$.

Therefore, differences in VAS pain scores at the end of the wall-sit task do not mediate the difference in performance time across experimental conditions.

**Discussion**

The present study explored the effects of exerting self-control on a subsequent physical task requiring self-control and examined whether any observed performance decrements could be explained by an individual’s perceptions of pain. Consonant with the predictions, participants quit a physically demanding ‘wall-sit’ task faster when they exerted self-control, relative to when they did not. This effect was attributable to participants’ elevated perceptions of pain following the exertion of self-control at the early stages of the task. The findings provide initial evidence that perceptions of pain may explain why the use of self-control interferes with subsequent performance on a physical task.

In accordance with previous research (e.g., Bray et al., 2011; Dorris et al., 2012; Englert & Wolff, 2015; McEwan et al., 2013; Wagstaff, 2014), exertion of self-control significantly reduced subsequent performance in a physical task, in this case wall-sit persistence. When participants completed a difficult cognitive task, they did not perform a wall-sit task for as long, compared to when they completed a simple cognitive task. The results provide yet more evidence that when participants are required to perform two consecutive acts of self-control, diminished performance on the second task ensues (Hagger et al., 2010).

The results also imply that the exertion of self-control led to elevated perceptions of pain. This effect was witnessed at the beginning and end of the wall-sit task, with increasing effect sizes as the task progressed. Exertion of self-control seemed to act as a motivationally significant stimulus that brought about a state of elevated distress (Elkins-Brown, Teper, & Inzlicht, in press). This aversive state has been proposed not only to encourage individuals to attend to the presence of task goal conflict (persisting on the physical task versus quitting to relieve the pain), but also encourage participants to prepare for actions to reduce this distressing state (Inzlicht & Legault, 2014). Consequently, this led to increased focus on the proximal goal (quitting to relieve the pain), relative to the distal goal (persisting on the physical task; Inzlicht & Schmeichel, 2016), resulting in disengagement from the task earlier in order to relieve the physical distress.

Building upon the aforementioned finding, perceptions of pain in the early stages of the wall-sit task explained the difference in performance time across experimental conditions. Following the exertion of self-control, increased pain sensations may have led individuals to
focus on relieving the pain (attentional priorities shift), and consider it more important than achieving high levels of performance (motivational priorities shift; Inzlicht et al., 2014). This choice resulted in conscious attention being drawn to the dilemma (Baumeister & Bargh, 2014). Instead of ignoring the pain, an individual’s motivational orientation was shifted towards the immediately gratifying tempting goal; leading to performance declines (Inzlicht & Schmeichel, 2016). Importantly, perceptions of pain in the early stages of the physical task seemed to be driving the performance decrements, not perceptions of pain at the end of the task. It could be that perceptions of pain at the end of the task were somewhat expected, given that the wall sit task becomes increasingly painful. However, pain at the beginning of the task may have been somewhat of a shock to individuals, leading to a reduction in performance on the physical task.

It is important to highlight that the VAS scores appeared to be driving the observed differences in perceptions of pain, compared to the sensory and affective pain scores. This could be explained by two reasons. First, the VAS is deemed to be a highly responsive outcome measurement for monitoring changes in pain (Chaffee, Yakuboff, & Tanabe, 2011), whereas the sensory and affective scales are only 4-point scales. It may be beneficial for the VAS to be used in future similar work. Second, the VAS measurements had longer to manifest compared to the affective and sensory measurements. Future research may wish to assess pain more frequently; this would provide a valuable insight into how perceptions of pain may change over the course of a physical task following a self-control manipulation, and provide further insights into the processes demonstrated in the present research.

The mediation analysis implies that self-control can influence perceptions of pain; therefore, it may be beneficial to focus on self-control strength in order to reduce the negative effects of perceptions of pain during a physical performance task. Research has implied that regular self-control exertion can improve an individual’s ability to perform future acts of self-control (Baumeister et al., 2006). To illustrate, squeezing a handgrip twice a day, for as long as possible, each day over a two week period improved individual’s self-control performance in subsequent self-control acts (Bray, Graham, & Saville, 2015). Performing relaxation techniques can also attenuate self-control reductions (Friese et al., 2012; Tyler & Burns, 2008). Performing these techniques and strategies may well have a positive influence on the negative relationship between perceptions of pain and performance on a physical task.

**Limitations and Future Directions**

Despite yielding important findings, there are some study limitations worth noting. Numerous steps to eliminate any potential problems associated with bias were taken; for
instance, the experimenter read the instructions for all tasks from a pre-prepared text to reduce the variability in the delivery of the instructions (Dorris et al., 2012). However, a blind-researcher protocol was not employed; therefore, the possibility of experimenter bias impacting the results of this study cannot be ruled out. Additionally, participant’s mood was not assessed following the Stroop task designed to manipulate self-control. It could be argued that overriding a well-elaborated behaviour (i.e., reading the ink colour not the word) could be associated with negative emotional states (Tice & Bratslavsky, 2000). Therefore, it is possible that mood differences may well have been responsible for the current pattern of results. However, previous research has repeatedly shown that self-control manipulation does not affect mood (e.g., Englert & Bertrams, 2012; Muraven et al., 1998).

Some possible future directions also arise from this study. Future research should examine alternative explanatory mechanisms for performance decrements following initial self-control exertion. For instance, performing tasks requiring the exertion of self-control may potentially reduce the perceived importance of subsequent task goals relative to the expected effort required (Hagger et al., 2010). This may result in a reduction in motivation to perform subsequent tasks that are thought to be effortful and fatiguing (Inzlicht & Schmeichel, 2016). Moreover, future research may wish to ask participants retrospectively whether they were distracted during the physical task by their perceived levels of physical discomfort (Englert et al., 2015a). This would provide a valuable insight into whether a self-control manipulation leads to an increased focus on proximal goals relative to the distal goals during the physical task.

Conclusions

The present study provides further evidence that initial self-control exertion reduces performance on a physical-based task. Furthermore, the results make an important contribution to the self-control literature by highlighting perceptions of pain as an explanation why self-control exertion interferes with subsequent performance on a physical task.
Chapter 6
General Discussion
This thesis began by exploring the relationships between dispositional self-control, robust self-confidence, and superior athletic performance. Following this study, a change of focus to self-control manipulations and laboratory performance was employed to examine state self-control. Utilising a sequential-task paradigm, the thesis examined whether previous exertion of self-control impairs subsequent endurance performance, as well as potential moderators (glucose and duration of self-control effort) and mediators (pain) of this effect. This chapter presents a synthesis of the key findings of the four studies, and the associated practical implications. The limitations of the current thesis will also be discussed, in conjunction with potential directions for future research.

**Self-Control as an Explanatory Mechanism for the Relationship between Robust Confidence and Athletic Performance**

Study One explicitly considered whether the robustness of athletes’ confidence and general capacity to exert self-control might be important considerations when investigating ecologically valid athletic performance. The findings imply that an individual’s general ability to exert self-control represents a critical explanatory variable that needs to be considered when exploring the relationship between robust self-confidence and athletic performance. Athletes with resilient self-beliefs may have a relative superior propensity to control and focus their thoughts, emotions, and attention (Baumeister et al., 1998; Schmeichel & Zell, 2007). Furthermore, an increased general capacity for self-control was positively associated with superior athletic performance.

These findings add a new dimension to the extant literature suggesting that increased state self-control can improve performance (e.g., Englert & Wolff, 2015; Wagstaff, 2014). Trait and state self-control may lead to superior performance, but through different mechanisms. The extant literature has implied that state self-control may facilitate athlete’s performance through optimal attention and emotion regulation (e.g., Englert et al., 2015a; Englert et al., 2015b), anxiety control (Englert & Bertrams, 2012), and the tolerance of pain (Schmeichel & Zell, 2007). Although the examination of trait self-control is understudied, it could be that dispositional self-control may improve athletes’ performance through its effect on practice quantity and quality (Baker & Young, 2014; Toering & Jordet, 2015), an increased focus on long term goals (Hofmann et al., 2012), as well as sustained determination to succeed and perseverance in the face of failure (Baker & Coté, 2003). These mechanisms remain speculative at present, however, future wish may wish to explicitly explore potential mechanisms, this may provide a valuable insight into why better self-control can improve athletic performance.
In view of these results, a key implication would be for sport practitioners to develop athletes’ self-control and levels of robust self-confidence, to help withstand the obstacles and difficulties that can arise in sport. Having an awareness of the strategies and techniques that may help to facilitate these psychological factors would be beneficial. For example, research has acknowledged that it may be possible to develop interventions in one facet of self-control (e.g., affect regulation) and benefit from this in another facet of self-control (e.g., quality of practice; Baumeister, et al., 2006). Successful performances, quality preparation, and several psychological skills (e.g., positive self-talk, imagery, rationalisation) may help to develop and sustain robust self-confidence (Thomas et al., 2011). Finally, the implementation of controlled, yet stressful scenarios during training could help athletes increase their self-control skills and resilience to prepare them for competition (Collins & MacNamara, 2012; Toering & Jordet, 2015). Following Study One, attention shifted to focus on the state perspective of self-control, through the utilisation of self-control manipulations and laboratory performance.

**Initial Self-Control Exertion Impairs Physical Performance**

Studies Two, Three, and Four of this thesis consistently demonstrated that exerting self-control on one task significantly impaired subsequent performance in a physical task requiring self-control. The results provide further support for previous findings that self-control impairment via a cognitively demanding task impairs subsequent physical self-regulatory efforts (e.g., Bray et al., 2008, 2011; Dorris et al., 2012; Englert & Bertrams, 2012; Englert et al., 2015; Englert & Wolff, 2015; Furley et al., 2013; McEwan et al., 2013; Wagstaff, 2014). Recent meta-analytic evidence has questioned the existence and replicability of the depletion effect and strongly suggested that it is not a real phenomenon (Carter et al., 2015). However, the current thesis provides an empirical base for assumptions that self-control exertion leads to performance decrements on subsequent unrelated tasks requiring self-control.

This thesis extends current research by explicitly considering whether previous exertion of self-control impairs subsequent endurance performance when self-regulation is potentially automatic. In expert populations, the frequent pursuit of the same cognitive goal results in the automatisation of cognitive process typically associated with the conscious self-regulation of that behaviour (Williams et al., 2009). When this automatic behaviour occurs, self-regulatory processes may not be necessary to the same degree as conscious self-regulation (Schmeichel & Baumeister, 2004). Prior to these studies, it was unclear whether the performances of well-trained athletes would require enough in the way of conscious self-
regulation to be impaired by initial self-control exertion. Collectively, the findings from Studies Two and Three imply that self-control impairment can indeed debilitate endurance performance in expert populations. It appears that conscious self-regulation is vital to continued persistence at a well-practiced physical task. If it wasn’t, then initial self-control exertion would not have impaired performance on the subsequent endurance task (Dorris et al., 2012). Despite the automatisation of cognitive processes, participants still used their capacity for conscious self-regulation to persist at the endurance task. It is likely that as the endurance task progressed, an individual’s physical discomfort levels increased. This elevated distress may have provoked the need for conscious self-regulation (Inzlicht & Legault, 2014). Consequently, individuals became aware of the temptation to reduce effort to relieve the pain, and its contrast with the goal of optimal performance (Milyavskaya & Inzlicht, 2016). Therefore, self-control was required to inhibit the response tendency to reduce effort and relieve the feelings of discomfort, and to instead ‘dig deep’ and achieve high levels of performance (Gray & McNaughton, 2000). Taken together, the findings from Study Two and Three indicate that despite their highly practiced performances, an athlete’s ability to persist and perform successfully at physical tasks could be impaired by initial self-control exertion.

By being aware of the link between self-control exertion and subsequent well-practiced athletic performance, the current literature on self-control can be applied to ascertain the types of self-regulatory behaviour that can impair an athlete’s performance during training and competition. For instance, emotional regulation, intellectual responding, thought suppression, choice making, and concentration have all been shown to require self-control (Baumeister et al., 2007; Schmeichel & Baumeister, 2004). Although the findings from Study Two and Three do not conclude that all of the above can impair performance on a subsequent endurance task requiring self-regulation in athletes, they do imply that reduced performance at a self-regulatory task can be bought about in well-trained athletes by non-sporting behaviour. Any athletic scenario in which an immediate temptation is contrasted with a valued distal goal can be applied. For example, to ignore fans or to contravene nutritional advice, all contrast with the distal goal of successful athletic performance. It may be beneficial, therefore, for sport practitioners to make efforts to make athletes aware that self-regulation requirements originate from a number of sources such as thought-suppression, decision making, and concentration (cf., Baumeister et al., 2007). Future studies should set out to transfer these findings to real sport scenarios in order to expand the generalisability of the effects of self-control exertion found in experimental studies.
Self-Control Effects are Variable over Different Stages of Performance

A particular strength of the current thesis is the attention afforded to the examination of performance effects across different stages of performance. Study Two demonstrated that during the early stages of endurance cycling performance, exerting self-control led to somewhat faster performance. However, by the end of the performance task, individuals completed the endurance task in the fastest time when they did not exert self-control. Study Three extended the findings of Study Two. Exerting self-control led to somewhat slower times in the early stages of endurance cycling performance. This effect escalated throughout the duration of the task. Therefore, by the end of the performance task, individuals performed the fastest time when they did not exert self-control. These findings provide support for previous conclusions reported by Englert and Wolff (2015), and provide an empirical foundation for assumptions that the effects of exerting self-control are variable over different stages of subsequent performance.

Taken together, the findings from Studies Two and Three have significant implications for self-control theory. First, the timing of performance examination may be particularly important when considering expert performance. Efforts to self-regulate during the initial stages of performance may be automatic and non-conscious (Schmeichel & Baumesiter, 2004). However, performance may become increasingly uncomfortable and sustaining effort despite considerable levels of discomfort may exacerbate the need for conscious self-regulation. Although speculative at present, it is possible that if performance was to be examined before self-regulation switches from automatic to conscious then it may lead to the erroneous conclusion that self-control exertion may actually increase performance, or at least no detrimental effects exist. Similarly, from a ‘shifting priorities’ perspective, self-control may have weakened as the performance task progressed, this is because exertion becomes progressively aversive (Kool & Botvinick, 2014). However, enough time needs to elapse for motivational and attentional foci to be shifted from the distal goal (i.e., cycling as fast as possible) to the proximal tempting goal (i.e., relieving the physiological distress; Milyavskaya & Inzlicht, 2016). Consequently, the examination of performance prior to any shifts taking place may lead to the similar aforementioned conclusion.

In light of this finding, it is imperative that the theoretical debates surrounding the exertion of self-control must recognise that any observed performance effects may be dependent on the timing of performance examination. This finding may also explain why depletion effects have not always been observed (Cunningham & Baumeister, 2016). Certainly, this fundamental outcome of the thesis provides the impetus for future research to
ascertain when motivational priorities shift (Milyavskaya & Inzlicht, 2016), when self-regulation alters from automatic to conscious processes (Schmeichel & Baumeister, 2004), or when self-control resources become too scarce (Gailliot et al., 2007). Such knowledge would assist in providing further insight into the possible processes that underpin performance decrements following the exertion of self-control.

**Glucose Does Not Moderate Self-Control Ability**

A recent avenue of inquiry in the pursuit of mechanisms that govern performance decrements following initial self-control exertion has been the identification of physiological moderators. Most prominent is the proposed role of glucose (e.g., Gailliot et al., 2007). The findings from Study Two failed to replicate the previously reported conclusions supporting the idea that replenishing glucose with a drink containing glucose can restore performance during tasks requiring self-control (e.g., Baumeister et al., 1998; DeWall et al., 2008; Gailliot et al., 2007; Hagger et al., 2010; Wang & Dvorak, 2010). However, the findings are in line with an increasing body of evidence suggesting that glucose administration does not moderate any decrements in performance due to initial self-control exertion (e.g., Dvorak & Simmons, 2009; Lange & Eggert 2014; Lange et al., 2014). When combined with other lines of criticism (e.g., Kurzban, 2010; Lange & Eggert 2014; Lange et al., 2014), this finding provides evidence against the proposal that glucose reflects the limited fuel required to exert self-control. In view of the current state of the evidence, it seems that the effect of glucose supplementation on moderating the effects of initial self-control exertion is far from being an established research phenomenon.

Interestingly, Study Two also revealed that ingesting glucose may lead to similar interference with athletic endurance performance to that of self-control exertion described previously. Imbibing glucose led individuals to perform at a slightly faster pace during the early stages of endurance performance, but overall performance was slower, compared to consuming no glucose. The findings imply that, in an endurance-based paradigm, glucose supplementation may interfere with optimal power output (i.e., pacing). Ingesting glucose leads to the adoption of a pacing intensity that is too high at the initial phase of endurance performance, resulting in reductions in intensity during the latter stages of performance and decrement in overall performance. The fact that imbibing glucose and self-control exertion may act in similar ways represents a thought-provoking idea. Self-control is regulated by the anterior cingulate cortex region of the brain (MacDonald et al., 2007); similarly, this same area of the brain is responsible for behavioural responses to rewarding stimuli, such as glucose (Rolls, 2007).
Extended Self-Control Effort may lead to Conservation of Self-Control

Research has proposed that spending longer on the primary self-control task may consume more resources, resulting in increased effects on subsequent performance (Hagger et al., 2010). Until now, this hypothesis had not been explicitly examined. The third study of this thesis revealed that extended initial task duration, within the dual task paradigm, did not have an increased deleterious effect on subsequent task performance, which does not provide support for previous propositions. In fact, participants performed as well as when they were not required to exert self-control. This finding appears to be aligned with the conservation hypothesis of self-control resources (Muraven et al., 2006), whereby individuals attempt to retain some of their self-control in anticipation of future exertion on the second self-control task (Baumesiter & Heatherton, 1996; Muraven & Baumeister, 2000). Prolonged self-control exertion seemed to heighten an individual’s desire to conserve self-control, because they were mindful of the fact that they were required to perform an immediate self-regulatory task. Individuals may not have exerted sufficient effort to reduce their self-control resources to lead to increased performance effects (Chatzisarantis & Hagger, 2015a).

Task duration should therefore be an important consideration when designing and evaluating future experiments examining self-control exertion and subsequent performance within the sequential-task paradigm (Lee et al., 2016). It is possible that the variation in the size of the depletion effects across studies may well be attributable to differences in the duration of the initial task. It is important that this effect is replicated in a more diverse range of experimental studies. This will help to identify the most suitable duration required for the first task of the sequential-task paradigm to reliably lead to performance decrements on subsequent task performance, and may help to resolve the current ongoing debate concerning the size of the depletion effect (Lee et al., 2016).

Perceptions of Pain as an Explanation for Performance Decrements Following Initial Self-Control Exertion

Given the call for an increased focus on the actual mechanisms behind performance decrements following a primary self-control task (Englert, 2016), Study Four of this thesis explored whether any performance decrements on a physical task, following the exertion of self-control, could be explained by an individual’s perceptions of pain. Until now, this hypothesis had not been explicitly explored. The fourth study of this thesis revealed that the fundamental explanation for observed performance decrements was elevated perceptions of pain during the early stages of physical performance. Consistent with the ‘shifting priorities’ paradigm, exertion of self-control seemed to act as a motivationally significant stimulus that...
brought about a state of elevated distress (Elkins-Brown et al., in press). This aversive state has been projected not only to encourage individuals to attend to the presence of task goal conflict (persisting on the physical task versus quitting to relieve the pain), but also encourage participants to prepare for actions to reduce this distressing state (Inzlicht & Legault, 2014). Accordingly, this led to increased focus on the proximal goal (quitting to relieve the pain), relative to the distal goal (persisting on the physical task), resulting in disengagement from the task earlier in order to relieve the physical distress (Milyavskaya & Inzlicht, 2016). Study Four of this thesis makes a significant contribution to the self-control literature by highlighting perceptions of pain as an explanatory mechanism behind performance decrements on physical tasks following the exertion of self-control.

Taken together, the findings from Studies Two, Three, and Four, in tandem with previous research, might point to future practical implications. Research has revealed possible methods to reduce depletion effects. For example, relaxation techniques (e.g., mediation autogenic training; Greenspan & Feltz, 1989), as well as mindfulness mediation (Friese et al., 2012), following the completion of a self-control task (e.g., Tyler & Burns, 2008), have been recognised as valuable strategies. Applying relaxation methods can accelerate the revitalisation of self-control (Greenspan & Feltz, 1989). Although relaxation strategies are well recognised in sport and exercise psychology (e.g., Williams & Harris, 2001), relaxation has yet to be explored within the realm of self-control exertion and subsequent athletic performance (Englert, 2016). Future research may wish to test this assumed relationship.

Furthermore, an individual’s self-control capacity can be trained by employing specific training techniques (Baumeister et al., 2006). To illustrate, individuals who participated in a two-week self-control training programme performed significantly better in future self-control tasks compared to a control group that did not receive self-control training (e.g., Bray et al., 2015; Denson, Capper, Oaten, Friese, & Scholfield, 2011; Finkel, DeWall, Slotter, Oaten, & Foshee, 2009; Gailliot, Plant, Butz, & Baumeister, 2004). Within these studies, a varied spectrum of training methods to improve self-control have been utilised, for example squeezing a handgrip twice a day (Bray et al., 2015), use of non-dominant hand (Denson et al., 2011; Gailliot et al., 2004), and altering habitual manner of speaking (Gailliot et al., 2004). Recent meta-analytic evidence has provided support for the beneficial effects of self-control training on increasing an individual’s capacity to exert self-control (Allom, Mullan, & Hagger, 2016; Freisem, Frankenbach, & Loschelder, in submission). Applying specific self-control training techniques could, therefore, be an innovative approach to help
athletes effectively regulate themselves during difficult sporting situations. However, the effects of self-control training have proven controversial. Following a six-week training programme of either cognitive or behavioural self-control tasks, trained participants did not improve at overcoming their habits, or report exerting more self-control in everyday life, implying that training self-control through repeated practice does not result in generalised improvements in self-control (Miles, Sheeran, Baird, MacDonald, Webb, & Harris, in press). Given the variability in previously reported training effects, further empirical studies are warranted to establish the reliability of training programmes on improving self-control.

Moreover, interventions that either reinforce the value of distal goals, decrease the worth of indulging, or shift attention to highlight the value of self-control may also improve self-control (Milyavskaya & Inzlicht, 2016). For instance, reminding athletes throughout the day of their motivation for their valued goal may help them to resist competing temptations. This could be achieved through the receipt of text messages or the use of an app with motivational advice (Whittaker, McRobbie, Bullen, Borland, Rodgers, & Gu, 2012). Such techniques may heighten the value of self-control by reducing the effort required to exert self-control, and emphasise the motives in favour of the distal goal (Milyavskaya & Inzlicht, 2016). Similarly, making the proximal goal more inherently enjoyable (e.g., making healthy food taste nice), may enhance its value and lead to successful self-control (Wooley & Fishbach, in press). Taken together, the aforementioned practical implications remain speculative at present; however, the reviewed training interventions and behavioural strategies underscore fruitful avenues for future research within the realm of athletic performance.

**Strengths and Limitations, and Future Directions**

The present thesis has offered a number of findings which significantly advance the current literature. A strength of this thesis is the theoretical bases upon which the proposed relationships were hypothesised. This thesis began with the strength model of self-control as the dominant perspective, but as the thesis progressed, others became more prominent (e.g., the shifting priorities model of self-control). Currently, there remains an ongoing debate on the processes underlying performance decrements following the exertion of self-control. The strength model of self-control continues to be a well-utilised perspective when explaining performance decrements following the exertion of self-control. However, the findings of this thesis add evidence to the proposition that the observed deterioration in self-control over time may be a result of attentional and motivation shifts. In particular, the findings from Study Four appear to be consistent with the shifting priorities model of self-control (Milyavskaya &
Inzlicht, 2016; Inzlicht & Schmeichel, 2016). To illustrate, the exertion of self-control led to increased attention on the proximal tempting goal (i.e., perceptions of pain) during the subsequent second task, and individual’s considered it more important than the distal goal (i.e., achieving high levels of performance; Milyavskaya & Inzlicht, 2016). Therefore, an individual’s motivational orientation was shifted towards the immediately gratifying tempting goal leading to performance impairment. Although these findings appear to be consistent with the shifting priorities perspective, more work is needed to test the proposed mechanisms of this model.

For instance, there is limited direct evidence that depletion effects are mediated by shifts in motivation and attention (Baumeister, 2014). It is also important to highlight that motivation and attention were not directly assessed in this thesis. Future research should make efforts to explore whether the exertion of self-control leads to a reduction in motivation to perform subsequent task goals (Inzlicht & Schmeichel, 2012). Also, future studies should examine whether a self-control manipulation leads to increased focus on proximal goals relative to distal goals during the second self-control task, within the dual task paradigm (Milyavskaya & Inzlicht, 2016). This work will provide an invaluable insight into the actual mechanisms behind performance decrements following self-control exertion, and will provide an empirical basis for the assumptions that self-control failure is due to shifts in motivational orientation and attentional focus (Inzlicht & Schmeichel, 2016).

A further strength of this thesis is the use of a controlled, counterbalanced, and repeated measures design with manipulation checks that were utilised in Study Two, Three, and Four. The within-participant design can eliminate potential problems related to between-group designs, including homogeneity of groups, as well as individual differences (Hellier, 1998); it also provides an alternative to the between-group designs typically used in self-control research.

Moreover, the use of endurance sport performance as a self-control task in Study Two and Three is perceived to be a strength of the current thesis. In many sports, individuals are required to exhibit optimal pacing strategies during time-bound competitions. Therefore, these studies may well better represent sport performance than previous research employing calisthenic measures of physical action and handgrip performance (Wagstaff, 2014). Furthermore, the utilisation of a well-trained sample of athletes in Study Two and Three represents a further strength. By transferring the detrimental effects of initial self-control exertion to well-trained populations was valuable in order to expand the generalisability of the findings to expert athletic performance (Dorris et al., 2012). Nonetheless, future studies
should examine the effects of previous self-control exertion and subsequent whole-body endurance exercise in alternative endurance tasks (e.g., running) with expert populations. Utilising a broader range of endurance performance tasks may provide additional insights into the effects of initial self-control exertion and athletic performance, as well as enhance the generalisability of the findings.

Although both the self-control measure and the robust self-confidence assessment utilised in Study One were both dispositional measures, there may have been a conceptual disconnect between the focus of the self-confidence assessment (i.e., sport-related) and the self-control measure (i.e., ones general life; Bandura, 1997). It may have been advantageous for the self-control measure to be adapted to reflect self-control in the sport domain. Moreover, longitudinal research assessing multiple performances would provide researchers with a greater temporal insight in changes in performance over time, and would be beneficial to confirm the findings reported in Study One.

Study Two, Three, and Four of the present thesis utilised the Stroop task to experimentally manipulate self-control. It is important to acknowledge that the Stroop task is not sport specific, and is relatively artificial in nature (Englert, 2016). In this thesis, however, it was imperative to utilise a well-established self-control task in a controlled setting (e.g., Wallace & Baumeister, 2002). The Stroop task has been successfully used in sport psychology studies previously (e.g., Englert & Bertrams, 2014; McEwan et al., 2013). Nonetheless, future studies should apply sport specific measures to make findings more relevant to sport practitioners. Research has recently attempted to apply more sport-related self-control manipulation tasks. For instance, Englert and Betrams (2014) vicariously depleted their participants by instructing them to read stories about a soccer player who had to regulate himself throughout a soccer match. Following the story, the participants were instructed to take the perspective of the described soccer player. When visualising themselves in the shoes of the depleted athlete described in the story, participants performed significantly worse in a subsequent self-control task. In a similar study, Gröpel, Baumeister, and Beckmann (2014) instructed their participants to perform a straining, rigorous workout program for 15 minutes which required self-control. Although these studies have made efforts to employ sport relevant self-control manipulation tasks, future research may benefit from focusing on creating real world sport goal conflicts that need to be resolved during self-control manipulation tasks. The inclusion of more sports-related depletion tasks may create a more powerful argument for the relevance of initial self-control exertion and subsequent performance in sports (Enlgert, 2016).
Furthermore, in Studies Two, Three, and Four, performance on the initial self-control task was not assessed. It is possible that individuals may have varied in the extent to which they were motivated to engage in the primary self-control task and, therefore, the extent to which they exerted self-control (Lee et al., 2016). This may have led to significant variance in performance on the first task and affect subsequent task performance (Lee et al., 2016). The relatively brief duration of the Stroop task employed in Studies Two, Three, and Four, means that it is unlikely that there would have been an observable deterioration in performance on the initial self-control task itself in these studies (Hagger et al., 2010). The utilisation of a longer duration Stroop task in Study Three, however, may well have led to a decline in performance on the task itself. Although steps were taken to eliminate any potential differences associated with task motivation, future research should assess performance on the initial self-control task (Hagger et al., 2010). The identification of a decline in performance would be an advantageous measure of depletion and determining a participants’ level of exertion (Hagger et al., 2010), and may have been a better test of the conservation hypothesis in Study Three. Future research can attempt to ensure participants invest identical effort levels on the first task by providing participants with an incentive to engage in the first task (Lee et al., 2016).

Similarly, participant’s mood was not assessed following the primary self-control task. It is possible that overriding a well-elaborated behaviour (i.e., reading the ink colour not the word) could be associated with negative emotional states (Hagger et al., 2010). Therefore, engaging in a task requiring self-control may have induced negative affect, irrespective of whether the task itself involves affect regulation (Tice & Bratslavsky, 2000). Consequently, this may lead to an explanation in which performance decrements following self-control exertion is the result of coping with a negative state. However, previous research has repeatedly shown that self-control manipulation does not affect mood (e.g., Baumeister et al., 1998; Englert & Bertrams, 2012; Muraven et al., 1998; Wagstaff, 2014).

Summary

This thesis has offered evidence for the potential impact of self-control in facilitating superior athletic performance. When taken in their entirety, the results of Study one suggest that an individual’s general capacity to exert self-control may well be a potentially important mechanism why resilient athletes progress and perform successfully. Moreover, the results of Studies Two, Three, and Four collectively provide consistent evidence that self-control exertion impairs subsequent physical performance. Studies Two and Three enhance the extant literature by implying that self-control impairment can debilitate endurance performance.
when self-regulation is potentially automatic, but these effects are variable over different stages of performance. In addition, extended self-control effort may lead to the conservation of self-control, whilst glucose supplementation does not appear to moderate self-control ability. Finally, Study Four provides initial evidence that perceptions of pain may explain why self-control exertion interferes with subsequent performance on a physical task. The findings of the present research, therefore, have significant implications for self-control theory, and athletic performance.
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Appendices
Appendix 1
Questionnaire Pack (Study One)

Participant Information Sheet
Main Investigator: Ruth Boat,
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LE11 3TU,
R.Boat@lboro.ac.uk

Supervisor: Dr Ian Taylor,
Loughborough University,
Leicestershire, UK,
LE11 3TU,
I.M.Taylor@lboro.ac.uk
01509 223274.

What is the purpose of the study?
The study aims to investigate whether specific underlying psychological factors are important for performance development. Participants will be assessed on a selection of potential influences on performance development.

Who is doing this research and why?
The lead investigator is Ruth Boat, a doctoral candidate at Loughborough University. The supervisor of the project is Dr Ian Taylor, a lecturer in the School of Sport, Exercise, and Health Sciences at Loughborough University.

Are there any exclusion criteria?
Participants must be aged 18 or over, and must be planning to compete in a sprint triathlon between May 2014 and September 2015. Children under the age of 18 cannot participate.

Once I take part, can I change my mind?
Yes! After you have read this information and asked any questions you may have we will ask you to complete an Informed Consent Form, however if at any time you wish to withdraw from the study please just contact the main investigator. You can withdraw at any time, for any reason and you will not be asked to explain your reasons for withdrawing.

Will I be required to attend any sessions and where will these be?
No, you will be given a multisection questionnaire that you will be required to complete. This can be collected and completed during your open water swimming training session.

What will I be asked to do?
You will be handed a multisection questionnaire by the lead investigator. You will be required to complete the questionnaire at some point during swim training. You will hand back your questionnaire to the lead investigator immediately after completion.

How long will it take?
The completion of the questionnaire will take approximately 10 minutes.

Is there anything I need to do before I start completing the questionnaires?
Before beginning your questionnaire, you will be required to answer a selection of demographic questions. These will be included in your questionnaire pack.

Who should I send the questionnaire back to?
Once you have completed the questionnaire, you should hand it back to the main investigator (Ruth Boat).

**What personal information will be required from me?**
You will be asked a selection of demographic questions; these will include your name, age, gender, how many times you train per week, as well as your personal best performance time from your last competitive season.

**Are there any risks in participating?**
No!

**Will my taking part in this study be kept confidential?**
Yes! Your answers will remain confidential, and once your results have been logged on a password protected computer, completed questionnaires will be stored in a locked cupboard.

**What will happen to the results of the study?**
The results will be submitted to Loughborough University as part of a research project.

**What do I get for participating?**
If you wish, a report that summarises your responses to the questionnaires that you will complete in relation to the results of the study will be provided.

**I have some more questions who should I contact?**
The main investigator (details above).

**What if I am not happy with how the research was conducted?**
If you are not happy with how the research was conducted, please contact Mrs Zoe Stockdale, the Secretary for the University’s Ethics Approvals (Human Participants) Sub-Committee:

Mrs Z Stockdale, Research Office, Rutland Building, Loughborough University, Epinal Way, Loughborough, LE11 3TU. Tel: 01509 222423. Email: Z.C.Stockdale@lboro.ac.uk

The University also has a policy relating to Research Misconduct and Whistle Blowing which is available online at http://www.lboro.ac.uk/admin/committees/ethical/Whistleblowing(2).htm
INFORMED CONSENT FORM

The purpose and details of this study have been explained to me. I understand that this study is designed to further scientific knowledge and that all procedures have been approved by the Loughborough University Ethical Approvals (Human Participants) Sub-Committee.

I have read and understood the information sheet and this consent form.

I have had an opportunity to ask questions about my participation.

I understand that I am under no obligation to take part in the study.

I understand that I have the right to withdraw from this study at any stage for any reason, and that I will not be required to explain my reasons for withdrawing.

I understand that all the information I provide will be treated in strict confidence and will be kept anonymous and confidential to the researchers unless (under the statutory obligations of the agencies which the researchers are working with), it is judged that confidentiality will have to be breached for the safety of the participant or others.

I agree to participate in this study.

Your name

________________________________________

Your signature

________________________________________

Signature of investigator

________________________________________

Date

________________________________________
Full Name…………………………………………………………………………………………

Gender:   Male  □   Female  □

Date of Birth……../……../……..

Age………………………Years

Mobile Phone number………………………………………………………………………

E-mail address………………………………………………………………………………

Experience competing in this sport………………….Years…………….Months

Hours per week training…………….Hours

Do you compete for a club/university/national team*:   □ Yes   □ No
*Please circle as appropriate

Personal Best from last year’s competitive season:

       Sprint Distance.................Hours.................Minutes.................Seconds.

Using the scale provided, please indicate how much each of the following statements reflects how you *typically are*.

<table>
<thead>
<tr>
<th>Statement</th>
<th>Not at all</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Very much</th>
</tr>
</thead>
<tbody>
<tr>
<td>I am good at resisting temptation</td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>I have a hard time breaking bad habits</td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>I do certain things that are bad for me, if they are fun</td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>I wish I had more self-discipline</td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>People would say that I have iron self-discipline</td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Pleasure and fun sometimes keep me from getting my work done</td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Sometimes I stop myself from doing something, even if I know it’s wrong</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I often act without thinking through all the alternatives</td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>
Think about your confidence and how your performance may affect your confidence generally.

The statements below describe how you may feel generally about your confidence, answer each statement by circling the number that corresponds to how strongly you agree or disagree generally. Please try and respond to each item separately.

The terms competition refers to competitive events.

<table>
<thead>
<tr>
<th></th>
<th>Strongly Disagree</th>
<th>Neutral</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>A bad result in competition has a very negative effect on my self-confidence</td>
<td>1 2 3 4 5 6 7 8 9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>My self-confidence goes up and down a lot</td>
<td>1 2 3 4 5 6 7 8 9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Negative feedback from others does not affect my level of self-confidence</td>
<td>1 2 3 4 5 6 7 8 9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>If I perform poorly, my confidence is not badly affected</td>
<td>1 2 3 4 5 6 7 8 9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>My self-confidence is stable; it does not vary much at all</td>
<td>1 2 3 4 5 6 7 8 9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>My self-confidence is not generally affected by the outcome of competition</td>
<td>1 2 3 4 5 6 7 8 9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>If I make a mistake it has quite a large detrimental effect on my self-confidence</td>
<td>1 2 3 4 5 6 7 8 9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>My self-confidence remains stable regardless of fluctuations in fitness level</td>
<td>1 2 3 4 5 6 7 8 9</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

THANK YOU FOR PARTICIPATING

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Appendix 2
Participant Information Sheet and Informed Consent Form (Study Two)

The relationships among cognitive effort, different types of drink, and sports performance

Participant Information Sheet

What is the purpose of the study?
The study aims to investigate the relationship between cognitive and physical effort, and to explore if sports drinks can alter these relationships.

Who is doing this research and why?
The lead investigator is Ruth Boat, a doctoral candidate at Loughborough University. The supervisor of the project is Dr Ian Taylor, a lecturer in the School of Sport, Exercise, and Health Sciences at Loughborough University.

Are there any exclusion criteria?
Participants must be aged 18 or over, and engage in regular physical exercise. Children under the age of 18 cannot participate.

Once I take part, can I change my mind?
Yes! After you have read this information and asked any questions you may have we will ask you to complete an Informed Consent Form, however if at any time, before, during or after the sessions you wish to withdraw from the study please just contact the lead investigator. You can withdraw at any time, for any reason and you will not be asked to explain your reasons for withdrawing.

Will I be required to attend any sessions and where will these be?
Yes, you will be required to attend 5 laboratory sessions in total. All sessions will take place at Loughborough University, and each will last approximately 1 hour. All sessions will be arranged at a time that is most convenient for you.

What will I be asked to do?
First, the main investigator will contact you regarding a time that is most convenient for you to attend your first laboratory session. During this first session, you will complete a Health Screen Questionnaire. If you successfully complete the Health Screen Questionnaire, you will be required to complete a short questionnaire containing some demographic questions and your resting heart rate, height, and weight will be measured. You will then complete an incremental cycle test to volitional exhaustion on a stationary cycle ergometer. On your second laboratory visit, you will complete a 10 mile time trial on a stationary cycle ergometer. This will be repeated on the 3 subsequent laboratory sessions; however, before
you start the 10 mile time trial, you will complete a 15 minute cognitive task on a computer and ingest 300ml of a commercially available sports drink.

**How long will it take?**
Each laboratory session will last approximately 1 hour. As you will be required to attend the laboratory on 5 different occasions, the total time demand will be approximately 5 hours.

**Is there anything I need to do before I attend the lab sessions?**
You will be instructed to refrain from strenuous exercise, and avoid alcohol and caffeine intake 24 hours prior to each trial. Further, you will be asked to repeat your daily routine (e.g., diet) prior to the sessions as closely as possible.

**What personal information will be required from me?**
You will be asked basic demographic questions during your first laboratory session; these will include your age, gender, sports you compete in, as well as how many times you train per week. Also, during your first session, you will be required to complete a Health Screen Questionnaire, as it is important that you are in good health and have had no significant health problems in the past. Furthermore, during your first session, your height, weight, and resting heart rate will also be measured. Finally, on each of the subsequent laboratory sessions, you will be asked to complete a repeat visit questionnaire, to ensure continued good health.

**Are there any risks in participating?**
Performing moderate or vigorous cycling exercise carries the following risks that we feel you should be made aware of, as well as some of the things we are doing to minimise these risks:

- **Sensations of fatigue and physical exhaustion** – this will be short-lived and will subside in a few minutes upon stopping exercise.
- **Fainting** – often related to physical exhaustion and then suddenly stopping, this will be mitigated by the inclusion of a cool-down period immediately after the cycling time trial is complete to gradually bring you back to normal.
- **Cardiovascular event (e.g., myocardial infarction or ‘heart attack’)** – this is a small risk, particularly for healthy individuals who are accustomed to physical activity. We will also make sure that you are warmed-up and cooled down appropriately around the exercise tests and will be monitoring your heart-rate and general disposition when exercising to minimise the risk of a cardiovascular event.

**Will my taking part in this study be kept confidential?**
Yes! Your answers will remain confidential and anonymous. Once your results have been logged on a password protected computer, completed questionnaires will be stored in a locked cupboard.

**What will happen to the results of the study?**
The results will be submitted to Loughborough University as part of a PhD thesis and published in psychology or sports science journals (no identifying details will be in any communication).

**What do I get for participating?**
If you wish, a report that will summarize your performance in the time trials in the context of the study will be provided.
I have some more questions who should I contact?
The lead investigator (details above).

What happens now?
Once you have had a chance to read this Participant Information Sheet we will contact you via email or phone (whichever you prefer) to see if you are still interested in taking part in the study. If you do not want to participate then that is fine and you do not have to give a reason for this. If you do wish to participate further, we will arrange for you to attend the laboratory for session 1. During session 1, you will be asked to complete the Health Screen Questionnaire, if you successfully complete the Health Screen Questionnaire you will be asked to complete an informed consent form to confirm that you are happy to participate in this study. You will be asked to keep a copy of this Participant Information Sheet and a copy of the signed consent form. You are then ready to take part in the study!

What if I am not happy with how the research was conducted?
If you are not happy with how the research was conducted, please contact Mrs Zoe Stockdale, the Secretary for the University’s Ethics Approvals (Human Participants) Sub-Committee:

Mrs Z Stockdale, Research Office, Rutland Building, Loughborough University, Epinal Way, Loughborough, LE11 3TU. Tel: 01509 222423. Email: Z.C.Stockdale@lboro.ac.uk

The University also has a policy relating to Research Misconduct and Whistle Blowing which is available online at http://www.lboro.ac.uk/admin/committees/ethical/Whistleblowing(2).htm
The relationships among sports drinks, cognitive effort, and physical performance
INFORMED CONSENT FORM
(to be completed after Participant Information Sheet has been read)

The purpose and details of this study have been explained to me. I understand that this study is designed to further scientific knowledge and that all procedures have been approved by the Loughborough University Ethical Approvals (Human Participants) Sub-Committee.

I have read and understood the information sheet and this consent form.

I have had an opportunity to ask questions about my participation.

I understand that I am under no obligation to take part in the study.

I understand that I have the right to withdraw from this study at any stage for any reason, and that I will not be required to explain my reasons for withdrawing.

I understand that all the information I provide will be treated in strict confidence and will be kept anonymous and confidential to the researchers unless (under the statutory obligations of the agencies which the researchers are working with), it is judged that confidentiality will have to be breached for the safety of the participant or others.

I agree to participate in this study.

Your name

Your signature

Signature of investigator

Date

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Appendix 3

Daily Inventory of Stressful Events Questionnaire (Study Two, Three, and Four)

Please indicate whether any of the following events have occurred today by circling the correct response:

<table>
<thead>
<tr>
<th>Event</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>An argument or disagreement with someone</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anything else that you could have argued about but decided to let it pass in order to avoid a disagreement</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anything at work or university that most people would consider stressful</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anything at home that most people would consider stressful</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Discrimination on the basis of such things as sexual orientation, race sex, or age</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anything happen to a close friend or relative that turned out to be stressful</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anything else that most people would consider stressful</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix 4
Diet and Exercise Diary (Study Two and Three)

Please record your food intake and activity patterns on the day before your 2nd visit to the laboratory.

*Please try to refrain from strenuous exercise, and avoid alcohol and caffeine intake 24 hours before each laboratory session.*

<table>
<thead>
<tr>
<th>Food Intake</th>
<th>Drink Intake</th>
<th>Activity Patterns</th>
</tr>
</thead>
</table>

Please try to replicate the same diet and exercise activities 24 hours before your remaining laboratory sessions.
Appendix 5
Participant Information Sheet and Informed Consent Form (Study Three)

The relationships among cognitive effort, different types of drink, and sports performance

Participant Information Sheet

What is the purpose of the study?
The study aims to investigate the relationship between cognitive and physical effort, and to explore if sports drinks can alter these relationships.

Who is doing this research and why?
The lead investigator is Ruth Boat, a doctoral candidate at Loughborough University. The supervisor of the project is Dr Ian Taylor, a lecturer in the School of Sport, Exercise, and Health Sciences at Loughborough University.

Are there any exclusion criteria?
Participants must be aged 18 or over, and engage in regular physical exercise. Children under the age of 18 cannot participate.

Once I take part, can I change my mind?
Yes! After you have read this information and asked any questions you may have we will ask you to complete an Informed Consent Form, however if at any time, before, during or after the sessions you wish to withdraw from the study please just contact the lead investigator. You can withdraw at any time, for any reason and you will not be asked to explain your reasons for withdrawing.

Will I be required to attend any sessions and where will these be?
Yes, you will be required to attend 5 laboratory sessions in total. All sessions will take place at Loughborough University, and each will last approximately 1 hour. All sessions will be arranged at a time that is most convenient for you.

What will I be asked to do?
First, the main investigator will contact you regarding a time that is most convenient for you to attend your first laboratory session. During this first session, you will complete a Health Screen Questionnaire. If you successfully complete the Health Screen Questionnaire, you will be required to complete a short questionnaire containing some demographic questions and your resting heart rate, height, and weight will be measured. You will then complete an incremental cycle test to volitional exhaustion on a stationary cycle ergometer. On your second laboratory visit, you will complete a 10 mile time trial on a stationary cycle ergometer. This will be repeated on the 3 subsequent laboratory sessions; however, before you start the 10 mile time trial, you will complete a 16 minute cognitive task on a computer and ingest 300ml of a commercially available sports drink.
How long will it take?
Each laboratory session will last approximately 1 hour. As you will be required to attend the laboratory on 5 different occasions, the total time demand will be approximately 5 hours.

Is there anything I need to do before I attend the lab sessions?
You will be instructed to refrain from strenuous exercise, and avoid alcohol and caffeine intake 24 hours prior to each trial. Further, you will be asked to repeat your daily routine (e.g., diet) prior to the sessions as closely as possible.

What personal information will be required from me?
You will be asked basic demographic questions during your first laboratory session; these will include your age, gender, sports you compete in, as well as how many times you train per week. Also, during your first session, you will be required to complete a Health Screen Questionnaire, as it is important that you are in good health and have had no significant health problems in the past. Furthermore, during your first session, your height, weight, and resting heart rate will also be measured. Finally, on each of the subsequent laboratory sessions, you will be asked to complete a repeat visit questionnaire, to ensure continued good health.

Are there any risks in participating?
Performing moderate or vigorous cycling exercise carries the following risks that we feel you should be made aware of, as well as some of the things we are doing to minimise these risks:

- Sensations of fatigue and physical exhaustion – this will be short-lived and will subside in a few minutes upon stopping exercise.
- Fainting – often related to physical exhaustion and then suddenly stopping, this will be mitigated by the inclusion of a cool-down period immediately after the cycling time trial is complete to gradually bring you back to normal.
- Cardiovascular event (e.g., myocardial infarction or ‘heart attack’) – this is a small risk, particularly for healthy individuals who are accustomed to physical activity. We will also make sure that you are warmed-up and cooled down appropriately around the exercise tests and will be monitoring your heart-rate and general disposition when exercising to minimise the risk of a cardiovascular event.

Will my taking part in this study be kept confidential?
All data will be handled in line with the Data Protection Act (1998). All data will be coded and logged on a password protected computer; completed questionnaires will be stored in a locked cupboard.

What will happen to the results of the study?
The results will be submitted to Loughborough University as part of a PhD thesis and published in psychology or sports science journals (no identifying details will be in any communication). You will be able to request that your data is withdrawn from the study up to 2 months from your participation in the study. After this time, it may not be possible for you to withdraw your data from the study as the data may have been aggregated or published. Further, your data will be retained for 10 years.

What do I get for participating?
If you wish, a report that will summarize your performance in the time trials in the context of the study will be provided.
I have some more questions who should I contact?
The lead investigator (details above).

What happens now?
Once you have had a chance to read this Participant Information Sheet we will contact you via email or phone (whichever you prefer) to see if you are still interested in taking part in the study. If you do not want to participate then that is fine and you do not have to give a reason for this. If you do wish to participate further, we will arrange for you to attend the laboratory for session 1. During session 1, you will be asked to complete the Health Screen Questionnaire, if you successfully complete the Health Screen Questionnaire you will be asked to complete an informed consent form to confirm that you are happy to participate in this study. You will be asked to keep a copy of this Participant Information Sheet and a copy of the signed consent form. You are then ready to take part in the study!

What if I am not happy with how the research was conducted?
If you are not happy with how the research was conducted, please contact Ms Jackie Green, the Secretary for the University’s Ethics Approvals (Human Participants) Sub-Committee:

Ms J Green, Research Office, Hazlerigg Building, Loughborough University, Epinal Way, Loughborough, LE11 3TU. Tel: 01509 222423. Email: J.A.Green@lboro.ac.uk

The University also has a policy relating to Research Misconduct and Whistle Blowing which is available online at http://www.lboro.ac.uk/committees/ethics-approvals-human-participants/additionalinformation/codesofpractice/.
The relationships among cognitive effort, different types of drink, and sports performance

INFORMED CONSENT FORM
(to be completed after Participant Information Sheet has been read)

The purpose and details of this study have been explained to me. I understand that this study is designed to further scientific knowledge and that all procedures have been approved by the Loughborough University Ethics Approvals (Human Participants) Sub-Committee.

I have read and understood the information sheet and this consent form.

I have had an opportunity to ask questions about my participation.

I understand that I am under no obligation to take part in the study.

I understand that I have the right to withdraw from this study at any stage for any reason, and that I will not be required to explain my reasons for withdrawing.

I understand that all the information I provide will be treated in strict confidence and will be kept anonymous and confidential to the researchers unless (under the statutory obligations of the agencies which the researchers are working with), it is judged that confidentiality will have to be breached for the safety of the participant or others.

I agree to participate in this study.

Your name

________________________________

Your signature

________________________________

Signature of investigator

________________________________

Date

________________________________
Appendix 6
Mental Exertion Questionnaire (Study Three and Four)

Please rate your mental exertion in the cognitive task. Please circle your answer.

<table>
<thead>
<tr>
<th>Number</th>
<th>Description</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Nothing at all</td>
<td></td>
</tr>
<tr>
<td>0.5</td>
<td>Extremely Weak</td>
<td>(Just Noticeable)</td>
</tr>
<tr>
<td>1</td>
<td>Very Weak</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Weak</td>
<td>(Light)</td>
</tr>
<tr>
<td>3</td>
<td>Moderate</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Strong</td>
<td>(Heavy)</td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Very Strong</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Extremely Strong</td>
<td>(Almost Max)</td>
</tr>
</tbody>
</table>
Appendix 7
Participant Information Sheet and Informed Consent Form (Study Four)

How do we perceive exertion during a physical performance task?
Participant Information Sheet

Investigator: Ruth Boat,
Loughborough University,
Leicestershire, UK,
LE11 3TU,
R.Boat@lboro.ac.uk

Dr Ian Taylor,
Loughborough University,
Leicestershire, UK,
LE11 3TU,
I.M.Taylor@lboro.ac.uk
01509 223274.

What is the purpose of the study?
The study aims to investigate potential influences on how we perceive exertion during a physical performance task.

Who is doing this research and why?
The lead investigator is Ruth Boat, a Doctoral candidate in the School of Sport, Exercise, and Health Sciences at Loughborough University.

Are there any exclusion criteria?
Participants must be aged 18 or over, and be recreationally active. Children under the age of 18 cannot participate.

Once I take part, can I change my mind?
Yes! After you have read this information and asked any questions you may have, we will ask you to complete an Informed Consent Form. However if at any time, before, during or after the sessions you wish to withdraw from the study please just contact the lead investigator. You can withdraw at any time, for any reason and you will not be asked to explain your reasons for withdrawing.

Will I be required to attend any sessions and where will these be?
Yes, you will be required to attend 2 laboratory sessions in total. Each session will take place at Loughborough University, and will last approximately 30 minutes. The sessions will be arranged at a time that is most convenient for you.

What will I be asked to do?
The main investigator will contact you regarding a time that is most convenient for you to attend the laboratory for your first session. During this first visit, you will complete a Health Screen Questionnaire. If you successfully complete the Health Screen Questionnaire, you will be required to complete a short questionnaire containing some demographic questions. You will then complete a 4 minute mental task on a computer. You will then be asked to perform a standing wall sit for as long as you can. At various stages throughout this physical task you will be asked to complete a short questionnaire about your perceptions of the task. The same procedure will be followed in your second laboratory visit.

How long will it take?

I.M. Taylor@lboro.ac.uk 01509 223274.
Each laboratory session will last approximately 30 minutes. As you will be required to attend the laboratory on 2 occasions, the total time demand will be approximately 1 hour.

**What type of clothing should I wear?**
Wear clothing you feel comfortable exercising in.

**What personal information will be required from me?**
You will be asked basic demographic questions during the laboratory session; these will include your age, gender, and your familiarity with the physical task. Also, during your first session, you will be required to complete a Health Screen Questionnaire, as it is important that you are in good health and have had no significant health problems in the past. Finally, on the second laboratory visit, you will be asked to complete a repeat visit questionnaire, to ensure continued good health.

**Are there any risks in participating?**
There are very few risks for taking part in this study. You may slightly ache afterwards from completing the standing wall sit.

**Will my taking part in this study be kept confidential?**
All data will be handled in line with the Data Protection Act (1998). All data will be coded and logged on a password protected computer; completed questionnaires will be stored in a locked cupboard.

**What will happen to the results of the study?**
The results will be submitted to Loughborough University as part of a research project and published in psychology or sports science journals (no identifying details will be in any communication). You will be able to request that your data is withdrawn from the study up to 2 months from your participation in the study. Reasons for this are after this time, the data from the study may have been aggregated or published, and therefore it will not be possible for you to withdraw your data from the study. Further, your data will be retained for 10 years.

**What do I get for participating?**
If you wish, a report that will summarize your responses in the laboratory sessions in the context of the study will be provided.

**I have some more questions who should I contact?**
The lead investigator (details above).

**What happens now?**
Once you have had a chance to read this Participant Information Sheet we will contact you via email or phone (whichever you prefer) to see if you are still interested in taking part in the study. If you do not want to participate then that is fine and you do not have to give a reason for this. If you do wish to participate further, we will arrange for you to attend the laboratory for your first session. During session 1, you will be asked to complete the Health Screen Questionnaire, if you successfully complete the Health Screen Questionnaire you will be asked to complete an informed consent form to confirm that you are happy to participate in this study. You will be asked to keep a copy of this Participant Information Sheet and a copy of the signed consent form. You are then ready to take part in the study!

**What if I am not happy with how the research was conducted?”
If you are not happy with how the research was conducted, please contact Ms Jackie Green, the Secretary for the University’s Ethics Approvals (Human Participants) Sub-Committee:

Ms J Green, Research Office, Hazlerigg Building, Loughborough University, Epinal Way, Loughborough, LE11 3TU. Tel: 01509 222423. Email: J.A.Green@lboro.ac.uk

The University also has a policy relating to Research Misconduct and Whistle Blowing which is available online at http://www.lboro.ac.uk/committees/ethics-approvals-human-participants/additionalinformation/codesofpractice/.
How do we perceive exertion during a physical performance task?
INFORMED CONSENT FORM
(to be completed after Participant Information Sheet has been read)

The purpose and details of this study have been explained to me. I understand that this study is designed to further scientific knowledge and that all procedures have been approved by the Loughborough University Ethics Approvals (Human Participants) Sub-Committee. Yes ☐ No ☐

I have read and understood the information sheet and this consent form. Yes ☐ No ☐

I have had an opportunity to ask questions about my participation. Yes ☐ No ☐

I understand that I am under no obligation to take part in the study. Yes ☐ No ☐

I understand that I have the right to withdraw from this study at any stage for any reason, and that I will not be required to explain my reasons for withdrawing. Yes ☐ No ☐

I understand that all the information I provide will be treated in strict confidence and will be kept anonymous and confidential to the researchers unless (under the statutory obligations of the agencies which the researchers are working with), it is judged that confidentiality will have to be breached for the safety of the participant or others. Yes ☐ No ☐

I agree to participate in this study. Yes ☐ No ☐

Your name __________________________________________

Your signature _________________________________________

Signature of investigator ________________________________

Date __________________________________________________
Appendix 8
Fatigue Questionnaire

Please rate how you feel at this moment in time, i.e., **right now**

<table>
<thead>
<tr>
<th>Statement</th>
<th>Not at all true</th>
<th>Somewhat true</th>
<th>Very true</th>
</tr>
</thead>
<tbody>
<tr>
<td>I feel physically worn out</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>I feel physically exhausted</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>
Appendix 9

Visual Analog Scale for Pain (Study Four)
Appendix 10

Example Pain Item (SF-MPQ: Study Four)

ACHING

0  1  2  3