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Integrating theories of self-control and motivation to advance endurance performance

Word count: 6424 excluding references

28 Abstract

29 Self-control is a burgeoning research topic within sport and motivational psychology.
30 Following efforts to define and contextualize self-control, characteristics of self-control are
31 considered that have important implications for sport performance. We describe and evaluate
32 various theoretical perspectives on self-control, including limited resources, shifting
33 priorities, and opportunity-costs. The research described includes sport-specific research but
34 also studies that focus on general motivational principles that look beyond sport-specific
35 phenomena. We propose that attentional, rather than limited resource, explanations of self-
36 control have more value for athletic performance. Moreover, we integrate self-control ideas
37 with descriptions of motivational phenomena to derive novel hypotheses concerning how
38 self-control can be optimized during sport performance. We explain how minimizing desire-
39 goal conflicts by fusing self-control processes and performance goals can delay aversive
40 consequences of self-control that may impede performance. We also suggest that autonomous
41 performance goals are an important motivational input that enhances the effectiveness of self-
42 control processes by a) reducing the salience of the desire to reduce performance-related
43 discomfort, b) increasing attentional resources towards optimal performance, and c)
44 optimizing monitoring and modification of self-control processes. These extensions to
45 knowledge help map out empirical agenda which may drive theoretical advances and deepen
46 understanding of how to improve self-control during performance.

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48 Keywords: ego-depletion, motivation, self-regulation, goal conflict, self-determination

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53 Integrating theories of self-control and motivation to advance endurance performance
54 The ability to resist feelings of discomfort and the urge to quit are critical elements of
55 successful sport performance, particularly for athletes who engage in prolonged physiological
56 efforts at high intensity. Succumbing to the urge to relieve the distress, even by minuscule
57 amounts, can be the difference between winning and losing. Indeed, the ability to override
58 natural tendencies may be a key individual difference that separates elite performers from
59 others (Martin et al., 2016; Tajet-Foxell & Rose, 1995). Despite the importance of this
60 characteristic, it is not well understood; hence, the psychological processes involved have not
61 been appropriately described. We propose that integrating models of self-control and
62 motivation represent a potential solution to this shortcoming. This article begins by defining
63 self-control, outlining the processes involved and contextualizing it within the broader self-
64 regulation construct. We then evaluate whether self-control typically reduces over time and
65 why this decline may occur. The strength model of self-control (Baumeister, Vohs, & Tice,
66 2007), which has also been termed the limited-resource model of self-control (Mead, Alquist,
67 & Baumeister, 2010) is included in discussions. This particular model has been reviewed in
68 sport and exercise psychology previously (Englert, 2016; Hagger, Wood, Stiff, &
69 Chatzisarantis, 2010), hence, a broader perspective is adopted to shed light on alternative
70 models that have evolved in recent years, including shifting priorities (Milyavskaya &
71 Inzlicht, 2018), opportunity costs (Kurzban, Duckworth, Kable, & Meyers, 2013) and
72 psychobiological models (Pageaux, Marcora, Rozand, & Lepers, 2015). These models are
73 then reconciled with motivation-based theories, including structural (Kruglanski et al., in
74 press) and self-determination (Ryan & Deci, 2017) perspectives. This integration allows us to
75 derive new ideas on how to optimise endurance performance through adaptive self-control
76 and motivation.

77 **Defining self-control**

78 Trait and state self-control have been associated with a wide range of adaptive
79 behaviours across multiple life domains (e.g., Baumeister et al., 2007; de Ridder, Lensvelt-
80 Mulders, Finkenauer, Stok, & Baumeister, 2012). Nonetheless, there are unique facets of trait
81 and state self-control that make it difficult to draw broad conclusions befitting both levels of
82 analysis, hence, the two concepts should not be used interchangeably (Allom, Panetta,
83 Mullan, & Hagger, 2016). For instance, individuals reporting high trait self-control may be
84 worse at using self-control on specific occasions because they are less practiced in avoiding
85 temptation (Imhoff, Schmidt, & Gerstenberg, 2013). Moreover, reported trait self-control has
86 no association with responses on two commonly employed situational measures of
87 behavioural self-control (Saunders, Milyavskaya, Etz, Randles, & Inzlicht, 2018). In
88 endurance activities, situational self-control is likely a more proximal influence on
89 performance, compared to dispositional self-control. Hence, the sole focus of this text is
90 situational self-control.

91 Self-control refers to ‘the capacity to resist a temptation that is in conflict with a
92 desired, long-term goal, in order to protect this valued goal’ (Fishbach & Woolley, 2018,
93 p167). Thus, self-control requires three components: a *desire*, a *higher order goal* and
94 conflict between the two (i.e., *desire-goal conflict*; Kotabe & Hofmann, 2015). Individuals
95 can experience conflict between two distal valued goals (e.g., a student-athlete deciding
96 between an important training session and an exam revision tutorial) or two proximal desires
97 (e.g., eat an unhealthy cake or consume an alcoholic drink after training), but it is only when
98 a desire conflicts with a distal goal that the significant cognitive disruption associated with
99 self-control occurs (Kotabe & Hofmann, 2015). Colloquial definitions of self-control also
100 imply a conflict between a temptation and a distal goal, rather than goal-goal or desire-desire
101 conflicts.

102 Evolutionary accounts describe how humans are necessarily motivated to avoid
103 painful and effortful experiences (Kool, McGuire, Rosen, & Botvinick, 2010; Mees &
104 Schmitt, 2008), therefore, this definition of self-control can be applied to sustained athletic
105 performance, despite the empirical basis of this definition being rooted in mainstream
106 psychology. The urge to relieve the multifaceted distress associated with endurance
107 performance, such as respiratory discomfort (Smoliga, Mohseni, Berwager, & Hegedus,
108 2016), sensations associated with lactic acid accumulation (Rotto & Kaufman, 1988) or
109 thermal discomfort (Schlader, Simmons, Stannard & Mündel, 2011), by lessening work effort
110 represents an immediately satisfying proximal desire. The desire to exercise at intensities that
111 lead to positive, rather than negative, affect is considerable (Ekkekakis, Backhouse, Gray, &
112 Lind, 2008). In contrast, producing optimal athletic performance represents the valued distal
113 goal.

114 Desire-goal conflict can be predicted by the relative strengths of the desire and the
115 higher order goal, and the degree of incompatibility between the two (Kotabe & Hofmann,
116 2015). For example, relieving perceptions of discomfort associated with intense aerobic
117 activity versus maintaining optimal performance are clearly incompatible. However, for most
118 athletes, pursuing a gold medal in an Olympic final would be a stronger higher order goal
119 compared to merely obtaining useful performance data in training. As such, the desire-goal
120 conflict is likely to be lower in the former scenario than the latter. On the other hand, desire-
121 goal conflict would increase as the perceived distress associated with performance effort
122 increases. When the cost of maintaining performance is sufficiently great to override benefits
123 of persisting, maximal exertion is abandoned (Botvinick & Braver, 2015). The size of this
124 cost rises as the number and magnitude of the different systems recruited increases.
125 Unfortunately for athletes, elite sport performance places more demands on the brain and
126 associated systems than most other activities (Walsh, 2014). The costs associated with

127 maintenance of optimal performance are, therefore, enormous. In everyday life, the negative
128 affect associated with the costs of resisting a temptation in favour of a valued goal would lead
129 to negative reinforcement and motivation to avoid a similar state. Indeed, affective states
130 during exercise are a significant influence on future engagement (Rhodes & Kates, 2015).
131 However, during endurance performance it is necessary for athletes to repeatedly override
132 this motivational response to succeed.

133 Although the example of overcoming performance-related discomfort in favour of
134 optimal performance is used throughout this text, any athletic scenario in which an immediate
135 temptation is contrasted with a distal goal can be applied. For example, athletes who are
136 tempted to accept performance enhancing substances, to miss training for a party, or to
137 contravene nutritional advice, will all require self-control to maintain pursuit of the distal
138 goal of successful and legal athletic performance.

139 Reflecting broad cybernetic principles in which a disturbance from a reference state is
140 identified and an output function is subsequently initiated (Carver & Scheier, 1982), two
141 stages of successful self-control are proposed to exist (Fishbach & Converse, 2010; Fishbach
142 & Woolley, 2018). The first involves the identification of a goal-desire conflict which
143 activates the behavioural inhibition system to initiate a negative affective state (Kurzban et
144 al., 2013). In endurance performance, this would be the realisation that the desire to relieve
145 performance related discomfort is conflicting with optimal performance. Second, this
146 experience galvanizes an individual to inhibit responses or modify behaviour to counteract
147 the temptation, resolve the conflict, and use the experience to inform subsequent protective
148 behaviour (Gray & McNaughton, 2000; Lazarus 1993; Tooby, Cosmides, Sell, Lieberman, &
149 Sznycer, 2008). For example, endurance athletes use a variety of self-regulatory strategies
150 during competition, such as relaxation, mindfulness, and disassociation to modify responses
151 to exertion (Brick, MacIntyre, & Campbell, 2015). The two stages are distinct and are

152 regulated by different areas of the brain, namely the anterior cingulate cortex and dorsolateral
153 prefrontal cortex, respectively (Botvinick, Braver, Barch, Carter, & Cohen, 2001;
154 MacDonald, Cohen, Stenger, & Carter, 2007). Although there is some debate (Fujita, 2011),
155 these self-control processes are generally understood to occur consciously, as opposed to
156 broader definitions of self-regulation which include both automatic and conscious processes
157 (Baumeister et al., 2007; Milyavskaya & Inzlicht, 2018).

158 Attempts to categorize different types of self-control have been undertaken, including
159 a review of self-control measures which revealed four dimensions of self-control (Whiteside
160 & Lynam, 2001). Urgency is the inability to resist strong impulses, lack of premeditation
161 refers to acting before thinking, lack of perseverance reflects the inability to attend to
162 uninteresting or difficult tasks, and sensation seeking is a tendency towards exhilarating and
163 risky activities. Psychometric and neuro-scientific evidence points to considerable conceptual
164 overlap among the first three dimensions and they align with the definition of self-control
165 provided. The same evidence points to sensation seeking representing a distinct phenomenon
166 and is not considered in this text (Duckworth & Kern, 2011; Steinberg, 2008).

167 **Does self-control diminish over time?**

168 There is an impressive weight of evidence to suggest that individuals do not reliably
169 sustain self-control over time. This idea forms the basis of the strength model of self-control
170 (Baumeister et al., 2007). The theory's major postulate is that, after initial acts of self-control,
171 an individual's capacity to exert further self-control becomes diminished (Baumeister et al.,
172 2007; Hagger et al., 2010). This attenuation of self-control resource has been termed 'ego-
173 depletion' by advocates of the strength model (Baumeister, Bratslavsky, Muraven, & Tice,
174 1998) and replenishment of self-control occurs with rest (Tyler & Burns, 2008). Evidence for
175 the ego-depletion effect has typically employed a sequential-task paradigm consisting of an
176 initial experimental task in which self-control exertion is manipulated, followed by an

177 unrelated second task requiring self-control. A meta-analysis of 198 experiments reported
178 that, in conditions where self-control is needed during the first task (compared to no or
179 limited self-control required), self-control is diminished during the second task (Hagger et al.,
180 2010). Overcoming the urge to quit or reduce effort during prolonged or intense exercise
181 requires self-control; therefore, the sequential-task protocol has been employed in exercise
182 settings. Following a cognitive task requiring self-control to override response tendencies,
183 participants performed worse during indoor cycling and running tasks, compared to when
184 they completed a cognitively simple congruent Stroop task (Englert & Wolff, 2015;
185 MacMahon, Schücker, Hagemann, & Strauss, 2014; Pageaux, Lepers, Dietz, & Marcora,
186 2014). Reduced cycling performance has also been induced when participants first watched
187 an upsetting video and were instructed to suppress their emotional responses (i.e., self-control
188 condition), compared to when participants were given no guidance regarding emotion
189 regulation (i.e., control condition; Wagstaff, 2014).

190 Despite popularity and support for this tenet of the strength model, it has encountered
191 major challenges. A meta-analysis using different study inclusion criteria to those of Hagger
192 and colleagues (2010) and additional statistical techniques to correct for small-study effects
193 led to the conclusion that ‘self-control in general does not decrease as a function of previous
194 use’ (Carter, Kofler, Forster, & McCullough, 2015, p18). A multi-lab replication also failed
195 to evidence the hypothesized reduction in self-control (Hagger et al., 2016), which has led to
196 a series of commentaries, analyses, and debates (e.g., Baumeister & Vohs, 2016; Dang, 2017;
197 Hagger & Chatzisarantis, 2016; Sripada, Kessler, & Jonides, 2016;). A further re-analysis
198 suggests that it may be too early to conclude whether the effect is an experimental or
199 statistical artefact (Blázquez, Botella, & Suero, 2017).

200 In addition to the debate around the existence of self-control decline, numerous
201 studies have identified simple ways to sustain self-control, including incentives (Mischel &

202 Patterson, 1976; Muraven & Slessareva, 2003), providing choice (Moller, Deci & Ryan,
203 2006), watching an enjoyable TV show (Derrick, 2012), and meditating (Friese, Messner &
204 Schaffner, 2012). Individuals' prior beliefs about self-control also attenuate self-control
205 reductions (Clarkson, Hirt, Jia, & Alexander, 2010; Job, Dweck, & Walton, 2010) and ego-
206 depletion effects may be culturally grounded (Savani & Job, 2017). It is this fragility which
207 has made the ego-depletion effect so difficult to replicate, leading to the phenomenon
208 unwittingly taking centre stage in conversations about the 'replication crisis' in psychology
209 (Open Science Collaboration, 2015). It is, therefore, questionable whether any added value
210 would be gained from exploring the existence of the ego-depletion effect further. Instead,
211 embracing this instability and identifying the conditions leading to the ego-depletion
212 phenomenon to express itself is empirically valuable (see Iso-Ahola, 2017). For example, a
213 tipping-point of between four and six minutes of self-control exertion may be necessary for
214 reductions in self-control on a subsequent muscular endurance task to occur (Brown & Bray;
215 2017). Further increases in initial self-control use did not lead to changes in magnitude of the
216 depletion effect. Alternatively, it has been suggested that typical self-control tasks may not be
217 prolonged enough to induce subjective feelings of mental fatigue (Pageaux, Marcora, &
218 Lepers, 2013) and cognitive tasks lasting 30 minutes or longer have been suggested to induce
219 more reliable performance decrements on endurance tasks (Van Custer, Marcora, De Pauw,
220 Bailey, Meeusen, & Roelands, 2017).

221 The beginning of this article outlined the importance of effective self-control for
222 successful performance. However, self-control decline and the considerable cognitive costs
223 associated with self-control attempts counterintuitively imply that athletes who rely on it for
224 successful performance will likely fail. During self-control, increasing cognitive demand is a
225 signal that the value of the alternative temptation (e.g., relieving performance distress) is
226 beginning to outweigh the goal-oriented task (Kool et al., 2010). The more time spent

227 exerting self-control, the greater the aversive experience (Kool & Botvinick, 2014). Despite
228 evolutionary benefits (see Kurzban et al., 2013) this consequence does not help athletes
229 maintain maximal performance effort. Hence, we contend that forestalling self-control
230 processes can enhance endurance performance. In our example, the athlete is fighting the
231 urge to reduce painful experiences (e.g., dyspnoea, afferent signals from lactic acid
232 accumulation). However, psychophysiological sensations of pain may not necessarily
233 coincide with a negative affective state (Price, 2000). Only when the sensations associated
234 with increasing aerobic effort conflict with the goal of successful performance (i.e., a desire-
235 goal conflict exists) will negative affect occur and self-control be initiated.

236 To provide greater clarity, consider two endurance athletes. The first athlete values
237 successful performance but experiences trepidation of the amount of effort required and pain
238 to overcome. In this example, there is a desire (to avoid the pain), which conflicts with a goal
239 (successful performance). This desire-goal conflict initiates the self-control process, and the
240 costly and aversive experience of self-control begins to accumulate. A second athlete values
241 successful performance equally well, however, this athlete considers the performance-related
242 discomfort as an important and necessary element of goal pursuit. By fusing the activity of
243 overcoming discomfort with the goal of successful performance, the discomfort becomes
244 instrumental to the goal, not in conflict with it (c.f., Kruglanski et al., in press). Consequently,
245 initiation of self-control can be delayed, leading to decreased negative affect and cognitive
246 load, and subsequent enhanced endurance performance. Outside of sport, greater persistence
247 on a reading task occurred when the goal of a bonus payment was fused to the task, rather
248 than a distinct bonus and task or no payment control condition (Woolley & Fishbach, 2016).
249 This implies that, although exerting self-control to overcome performance-related discomfort
250 will be necessary at some point for successful performance, delaying self-control exertion by
251 reducing the discomfort-performance conflict will enhance performance. In practical terms,

252 perceiving the need to overcome performance-related discomfort as part of successful
253 performance, rather than as an obstruction to it, should achieve this delay.

254 Even with a highly integrated process and goal, at some point, the desire to remove
255 performance-related discomfort will conflict with successful performance and self-control
256 will be required. During these assumed latter stages of endurance performance, we suggest
257 that the focus should be on embracing this conflict, rather than suppressing it. The degree to
258 which the affective distress signal of a desire-goal conflict recruits self-control is moderated
259 by the individual's acceptance of the distress (Inzlicht & Legault, 2014; Kashdan &
260 Rottenberg, 2010). Without this aversive experience, goal conflicts would go unidentified and
261 resolution could not take place (Inzlicht & Legault, 2014). In sport, emotion is often viewed
262 as counterproductive to performance (Lee Sinden, 2010, 2012). In contrast, self-control
263 theorists propose that affective consequences of self-control are aversive, yet adaptive and
264 necessary element of successful task performance (Inzlicht & Legault, 2014). This response
265 is the signal that things could go awry and there is a need to initiate self-control. Only by
266 accepting the negative affect can one make appropriate decisions regarding behavioural,
267 emotional or cognitive corrections. A lack of acceptance will lead to immediately gratifying
268 defensive responses to the distress, which in the context of endurance performance is
269 expected to be a reduction of effort. Moreover, the aversive state related to goal conflict
270 releases nor-epinephrine, which is associated with heightened attention (Aston-Jones &
271 Cohen, 2005). The aversive state may, therefore, have some positive implications for
272 performance contexts where psycho-physiological arousal is beneficial.

273 This hypothesis has applicability to sport psychology research, where a psychological
274 skills training perspective advocates suppression of, rather than acceptance of, negative
275 internal states (Gardner & Moore, 2007). Doing so will lead to an inability to use affective
276 information to motivate subsequent action (Inzlicht & Legault, 2014). Instead, a mindful

277 awareness and non-judgmental acceptance can amplify conflict-related affect and effectively
278 mobilise self-control (Elkins-Brown, Teper, & Inzlicht, 2017). Professional ballet dancers
279 reported greater awareness of pain during a cold pressor test, compared to age matched
280 controls, but were more effective in exerting self-control (Tajet-Foxell & Rose, 1995).

281 To achieve this performance state, it is necessary to devise strategies for the latter
282 stages of endurance performance. Inzlicht and colleagues (2014) recommend focusing on
283 monitoring, attending to, and acceptance of goal conflict through mindfulness training and
284 implementation intention strategies. Mindfulness training empowers individuals to non-
285 judgementally attend to the present moment (Kabat-Zinn, 2003) and has gathered some
286 momentum within sport psychology (e.g., Gardner & Moore, 2012). This technique may be
287 effective by nurturing acknowledgement and acceptance of the experiential affect that signals
288 the need for self-control (Teper & Inzlicht, 2013; Teper, Segal, & Inzlicht, 2013). In addition,
289 mindful individuals have a greater sensitivity to the need for self-control and can monitor
290 goal conflict and self-control processes effectively (Elkins-Brown et al., 2017).

291 Implementation intention strategies are behavioural or cognitive plans in response to
292 anticipated situations (Gollwitzer & Oettingen, 2011). These plans likely improve self-control
293 by reducing the discrepancy between behaviour and distal goal. Mindfulness interventions
294 have shown promise in impacting upon athletic performance, but self-control has not been
295 considered as a mechanism for these effects, and the research lacks methodological rigor
296 (Sappington & Longshore, 2015). Implementation intentions have not been studied in
297 endurance performance contexts.

298 **Why does self-control fade?**

299 The strength model of self-control describes how self-control draws energy from an
300 internal resource that is consumable but limited (Baumeister et al., 1998). Congruent with this
301 limited resource perspective, an argument exists that individuals are motivated to conserve

302 self-control if future need is anticipated, which may be reflected in poorer self-control prior
303 to the anticipated future use (Muraven, Shmueli, & Burkley, 2006). However, the
304 identification of the resource that is depleted remains elusive. Glucose has been suggested as
305 a candidate resource and initial studies revealed that engaging in self-control reduced blood
306 glucose, which in turn was associated with impaired performance on subsequent measures of
307 self-control (Gailliot et al., 2007). In addition, imbibing a glucose-based drink has been
308 shown to attenuate the ego-depletion effect (DeWall, Baumeister, Gailliot, & Maner, 2008;
309 Gailliot et al., 2007). However, both these effects have been inconsistently observed (Lange
310 & Eggert, 2014; Lange, Seer, Rapior, Rose, & Eggert, 2014; Molden et al., 2012). In sport
311 research, reductions in endurance performance following mentally fatiguing tasks have been
312 shown to occur without reductions in blood glucose (Marcora, Staiano, & Manning, 2009).
313 Critically, there is an assumption that equilibrium exists between glucose in the blood and the
314 brain (Lund-Anderson, 1979). However, changes in blood glucose resulting from cognitive
315 effort are unlikely to be caused by increased brain glucose uptake (Messier, 2004) and brain
316 activation consumes little additional glucose compared to enduring basal requirements
317 (Raichle & Gusnard, 2002). Kurzban (2010) expands on these arguments to conclude that it is
318 highly unlikely that glucose is the resource on which self-control is based on.

319 Despite these metabolically-based refutations, glucose may still be associated with
320 self-control processes in other ways. Mouth rinsing then spitting glucose-based drinks can
321 ameliorate self-control reductions without any enhanced blood glucose availability (Hagger
322 & Chatzisarantis, 2013; Molden et al., 2012; Sanders, Shirk, Burgin, & Martin, 2013).
323 Indeed, the perceptual effects of self-control use and glucose ingestion may be similar given
324 that oral exposure to glucose activates similar areas of the brain (e.g., anterior cingulate
325 cortex; Chambers, Bridge, & Jones, 2009; Rolls, 2007) as the initiation of self-control
326 (MacDonald et al., 2007). This idea may explain why self-control exertion via an incongruent

327 Stroop task, ingestion of glucose, or a combination of both experimental manipulations led to
328 similar performance trends during 16 kilometre cycling time trials (Boat, Taylor, & Hulston,
329 2017).

330 In sum, it is unlikely that glucose is the central resource behind self-control processes.
331 But ruling out one candidate resource does not preclude the existence of another. Certainly, a
332 global element to self-control exists given that the two tasks comprising the sequential-task
333 paradigm are often unrelated, thus demonstrating cross-contextual effects. This global
334 characteristic is most easily observed in sport performance research where the first task is a
335 cognitive function (e.g., resisting a natural response tendency) and the second is physical
336 (e.g., endurance performance task). Nonetheless, the search for a biological foundation of
337 self-control continues. Some theories acknowledge capacity-based explanations for self-
338 control failure, but usually these refer to the non-motivational cognitive resources (e.g.,
339 executive function) that help resist temptation in the pursuit of the distal goal (Kotabe &
340 Hoffmann, 2015), rather than any biological resource.

341 In contrast to the limited resource argument, several theories of self-control, effort,
342 and attention can be reconciled under the core hypothesis that reductions in self-control
343 performance can be accounted for by a shift in attentional and perceptual foci. The shifting
344 priorities model of self-control (Inzlicht & Schmeichel, 2016; Milyavskaya & Inzlicht, 2018)
345 describes how attentional processes resolve the self-control dilemma by shifting the salience
346 of the immediate temptation or the valued distal goal. In other words, initial self-control use
347 leads to a shift in focus towards the temptation, hence reduced self-control in a subsequent
348 task. Similarly, modifications in perception of effort have been proposed to be the central
349 mechanism explaining how mental fatigue reduces endurance performance (Pageaux et al.,
350 2015). From a psychobiological perspective, mental fatigue stemming from prolonged
351 exertion of self-control induces neurochemical changes in the brain (e.g. adenosine

352 accumulation in the anterior cingulate cortex) that result in an incremental shift in perception
353 of effort required and, therefore, premature exhaustion during subsequent endurance
354 performance (Marcora, 2008). Self-control depletion and mental fatigue similarly require
355 consistent conscious effort that may stimulate negative feelings (Hagger et al., 2010), and
356 both may lead to an unwillingness to employ further effort and performance decrements
357 (Inzlicht & Schmiechel, 2012). Self-control and cognitive fatigue experiments typically vary
358 in the tasks that are utilised; mental fatigue tasks usually last considerably longer than the
359 tasks that are employed in self-control depletion research. For example, 90 minute tasks have
360 been used to induce cognitive fatigue (Marcora et al., 2009) whereas, tasks as short as four
361 minutes have been employed to induce self-control exertion (Boat et al., 2017). It is
362 important to note, however, that this distinction is based on the method to induce mental
363 fatigue or self-control, not on the construct itself. Overall, reduced self-control and mental
364 fatigue share much communality.

365 The attentional and perceptual shifts described above have a greater body of
366 supportive evidence from sport research, compared to the limited resource argument. For
367 instance, participants reported greater perceptions of pain and reduced persistence during a
368 postural endurance task following self-control exertion, compared to when they did not
369 initially exert self-control (Boat & Taylor, 2017). The idea that increased awareness of
370 somatic sensations can act as a motivational input eventually leading to the cessation of effort
371 has considerable overlap with Tenenbaum's (2001) social cognitive model of attentional
372 focus in sport. During high intensity exercise, athletes' attention is dominated by perceptions
373 of physiological effort and the ability to switch away from this experience is severely
374 diminished (Hutchinson & Tenenbaum, 2007). Visual and aural attention also shifts
375 following self-control exertion, leading to reduced performance in dart throwing and
376 basketball free throws, especially in high pressure situations (Englert, Bertrams, Furley, &

377 Oudejans, 2015; Englert, Zwemmer, Bertrams, & Oudejans, 2015). However, this attentional
378 shift was not replicated during a hypothetical basketball decision-making task (Furley,
379 Bertrams, Englert, & Delphia, 2013).

380 Evidence founded on psychobiological models draws similar conclusions. Cognitive
381 fatigue tasks, including a 90 minute AX-Continuous Performance Task (Carter, Braver,
382 Barch, Botvinick, Noll, & Cohen, 1998) and a 30 minute Stroop task, have been employed to
383 demonstrate that mental fatigue enhances perceptions of effort, which facilitates
384 disengagement during time-to-exhaustion endurance performance tasks (Pageaux et al., 2014;
385 Marcora et al., 2009). In these studies, there were negligible or no difference in heart rate
386 across conditions, suggesting that mental fatigue does not limit exercise tolerance through
387 cardiorespiratory mechanisms (Marcora et al., 2009; Van Custem et al., 2017). Overall, there
388 is strong theoretical and empirical evidence to suggest that shifting attentional focus is the
389 most plausible explanation for self-control reductions in sport contexts. Hence, it is necessary
390 to identify how attention can be shifted towards factors conducive to, rather than obstructive
391 of, self-control processes during endurance performance. In the following section, we argue
392 that a focus on motivation will help us achieve this goal.

393 Many theories of self-control describe motivational mechanisms to explain self-
394 control processes, including the shifting priorities model of self-control (Milyavskaya &
395 Inzlicht, 2018) and the opportunity-costs model (Kurzban et al., 2013). The strength model of
396 self-control somewhat differs in this respect by proposing a non-motivational mechanism
397 explaining self-control failure, but even this theory suggests motivation can moderate
398 reductions in self-control (Baumeister, 2016; Baumeister & Vohs, 2007). According to
399 motivational theories, the motivational basis behind the conflicting desire and goal influences
400 the attentional processes described above. In turn, attention can guide a subjective valuation
401 process in which distal and proximal choices are constantly evaluated (Berkman, Livingston,

402 Kahn, & Inzlicht, 2015) and individuals decide appropriate levels of task engagement based
403 on the prioritization of these choices (Kurzban et al., 2013). Motivational intensity theory
404 (Brehm & Self, 1989; Gendolla & Richter, 2010), the guiding framework shaping
405 psychobiological explanations of endurance performance (Marcora, 2008), also highlights the
406 conscious evaluation of required effort and task difficulty as a central decision in task
407 engagement (Wright et al., 2007; Wright, Stewart, & Barnett, 2008). In other words, an
408 endurance athlete will continually evaluate the pros and cons of reducing or sustaining effort
409 to achieve success. For example, the increasing pain sensations during sustained, high
410 intensity performance can lead an athlete to progressively focus on relieving the pain
411 (attentional priorities shift; Hutchinson & Tenenbaum, 2007), eventually weighing this goal
412 more heavily than the importance of winning. The dynamics between valued goals and
413 immediate gratification would have been adaptive for primordial ancestors (Beedie & Lane,
414 2012; Kurzban et al., 2013). In particular, the opportunity-cost model has strong roots in
415 evolutionary psychology of foraging organisms. Put simply, an organism is required to
416 constantly evaluate the opportunity costs of foraging in the same patch versus changing
417 location (Gallistel, 1990). Recent literature from shifting-priority theorists is consistent with
418 this evolutionary account. When individuals exploit known rewards only, it prevents
419 exploration and potential identification of larger and more efficiently obtained rewards
420 (Inzlicht, Schmeichel, & McRae, 2014).

421 There are myriad motivational inputs that can influence attention and decisional
422 processes, for example, most proximal temptations are instantly enjoyable or satisfying and
423 offer more certainty, relative to distal goals (Kahneman & Tversky, 1979). The relationship
424 between motivation and effective self-regulation has been scrutinised for several decades.
425 Tenets of self-determination theory (Ryan & Deci, 2017), a prevalent theory in sport and
426 exercise psychology research (see Taylor, 2015), offers several avenues for theoretical

427 integration. This amalgamation can assist in deriving several mechanistic hypotheses
428 explaining how motivation can enhance endurance performance. Broadly speaking, we
429 contend that internalizing and integrating successful performance will facilitate self-control in
430 several ways. According to self-determination theory, humans are fundamentally inclined
431 towards growth, which partly expresses itself as a tendency to internalise extrinsically driven
432 behaviour so that it becomes integrated with one's true sense of self (Ryan & Deci, 2017).
433 Internalised goals and motives are autonomous, freely chosen, of personal meaning, and
434 concordant with one's true sense of self. In contrast, motives and goals that have not been
435 internalised are deemed to be controlling, extrinsic in nature and point towards receiving
436 rewards or avoiding punishment (Kasser & Ryan, 1996; Ryan & Deci, 2017).

437 Conflict-based self-control failures typically occur if the temptation or desire becomes
438 too strong (Kotabe & Hoffman, 2015) but this failure can be avoided if successful endurance
439 performance is internalised and autonomously driven. In a series of studies, autonomous
440 motivation was associated with decreased attraction to proximal temptations (Milyavskaya,
441 Inzlicht, Hope, & Koestner, 2015). This finding explains why autonomous goals are easier to
442 pursue (Werner, Milyavskaya, Foxen-Craft, & Koestner, 2016) and are less fatiguing (Moller
443 et al., 2006; Muraven, 2008), relative to controlling goals. In other words, autonomously
444 motivated individuals do not rely on greater self-control to resist temptations; they perceive
445 temptations as less prominent, which make goal progress smoother. This hypothesis implies
446 that autonomously motivated athletes will see performance-related discomfort as a less
447 salient barrier to successful performance, relative to athletes energized by controlling
448 motivations. Over time, this process is more likely to become habit in autonomously
449 motivated individuals (Radel, Pelletier, Pjevac, & Cheval, 2017).

450 In addition to reducing the prominence of temptations, autonomous motivation acts as
451 a motivational input to increase the salient of the long-term goal (i.e., enhanced endurance

452 performance) preventing a shift in priority to the proximal temptation (Berkman et al., 2015).
453 Goals that are central to one's self-description are more chronically and easily activated when
454 the context requires it, relative to goals held distant from the self (Higgins, 1996; Markus,
455 1977). This ease of activation holds considerable influence over attentional and evaluative
456 processes (Ferguson & Bargh, 2004; Milyavskaya et al., 2015) and, therefore, can protect the
457 goal from competing temptations (Fishbach & Shah, 2006). As such, autonomously
458 motivated athletes who wholly identify with successful performance should not only perceive
459 the temptation to reduce effort as less salient, but also psychologically approach and dedicate
460 appropriate cognitive resources towards the valued goal of successful performance
461 (Ntoumanis et al., 2014).

462 The third explanation concerning why autonomous motivation can enhance endurance
463 performance reflects the tendency to recover from an error or setback. The constant effort
464 required to override aversive feelings associated with endurance performance means
465 occasional slips in self-regulation are unavoidable. Trait and situational autonomy leads to
466 greater sensitivity and responsiveness to these errors, which, in turn leads to superior self-
467 regulatory performance (Legault, & Inzlicht, 2013). In addition, appraisal of self-regulatory
468 strategies can occur following performances. Autonomously motivated individuals embrace
469 information that is relevant to the self and can acknowledge and accept personal deficiencies,
470 in comparison to individuals driven by controlling motives who perceive a greater threat
471 response (Hodgins, 2008; Hodgins & Knee, 2002; Weinstein, Deci, & Ryan, 2011). By
472 reflecting on barriers to optimal performance, autonomously motivated individuals can plan
473 strategies and responses that promote distal goal accomplishment. Specifically, autonomously
474 oriented individuals create if-then plans that specify when, where, and how people will
475 instigate responses if the goal is threatened (Carraro & Gaudreau, 2011). To this end,
476 autonomously motivated athletes should be able to identify, accept and rectify self-regulatory

477 errors, such as momentary lapses in optimal effort within a single performance context.
478 Moreover, autonomously motivated athletes are likely to reflect on self-regulation following
479 performances and create effective plans to override the temptation of relieving performance-
480 related discomfort when it occurs in the future. Both intra- and inter-performance processes
481 should yield better endurance performance.

482 Overall, this integration of self-determination theory and models of self-control
483 suggests that when performance is integrated with one's true sense of self (i.e., an
484 autonomous goal) the greater likelihood of optimal performance because a) the temptation to
485 reduce effort is less salient, b) the goal of optimal performance is attended to more
486 effectively, and c) self-regulatory errors are embraced and rectified more efficiently. It is
487 worth noting that this list of explanations may not be complete and there may be other
488 reasons why motivation influences self-control and subsequent athletic performance. For
489 example, controlled motivation, relative to autonomous motivation might lead to a greater
490 physiological stress response (Reeve & Tseng, 2011). This stress response may lead to
491 decreased self-regulatory performance due to decreased executive function (Starcke, Wiesen,
492 Trotzke, & Brand, 2016). Alternatively, enhanced cortisol response may initiate more
493 effective metabolic responses to exercise demands (Coker & Kjaer, 2005).

494 **Summary and final thoughts**

495 By reviewing several prominent ideas behind self-control, we have attempted to
496 widen the theoretical scope of this important research topic. Collective consideration of the
497 various models will allow a broader depth of knowledge to develop in the race to improve
498 athletic performance. This is not to dismiss the idea of singular theoretical explanations, but
499 to shed light on complementary hypotheses, establish greater theoretical depth, and
500 encourage sport researchers to be at the forefront of research progress. One of the strongest
501 elements of the self-control literature is that it is almost entirely based on experimental

502 designs with random samples that point strongly to causal effects. Moreover, the dependent
503 variables are almost always behavioural (e.g., giving up on a task, responding slower to a
504 stimulus), as opposed to self-report variables common in sport psychology work. As such,
505 evidence contained within the self-control literature would almost entirely be categorised as
506 high quality.

507 Within the article we propose several extensions to current knowledge. These
508 proposals are based on the integration of self-control and motivational theory. First, we
509 integrate self-control definitions and structural motivational perspectives (Kruglanski et al., in
510 press) to hypothesise that a fusion of the process of overcoming performance-related
511 discomfort and performance goals will reduce the desire-goal conflict required for initiation
512 of self-control. This fusion will delay aversive and costly consequences that may impede
513 performance. This idea is followed by the suggestion that attentional processes, rather than
514 limited resources explain why self-control reduces over time, yet we also highlight that
515 glucose remains an interesting construct to study in self-control research, but not as a
516 resource that self-control is based upon. The final section is based on a mutual consideration
517 of several self-control theories that place motivation as a central mechanism and self-
518 determination theory. By focusing on autonomous goals and motivation as a key motivational
519 input in the self-control process, we can speculate on three mechanistic explanations of how
520 to improve self-control. Autonomous regulation during endurance performance can a) reduce
521 the salience of the desire to reduce performance-related discomfort, b) increase the attentional
522 resources dedicated to optimal performance goals, and c) help monitor and modify self-
523 control more effectively during performance and over time.

524 Examination of the ideas proposed can provide greater understanding of the
525 psychological processes before and during athletic performance, as well as greater theoretical
526 insight into the conditions required for self-control maintenance. It is a simple suggestion that

527 self-control and motivation research might dovetail well and provide new insight. However,
528 realizing these types of investigation requires collaboration across scientific fields as the
529 theories are couched in different scientific philosophies. The opportunity-cost model, for
530 example, embeds motivation within information-processing paradigms representing
531 fundamental computational decisions (e.g., Kurzban et al., 2013). In contrast, sport
532 psychologists with knowledge of self-determination theory generally conceptualize
533 motivation within broader phenomenological perspectives focusing on the sense of self (Ryan
534 & Deci, 2006).

535 Despite a history of self-regulation training within sport psychology (e.g., Hardy &
536 Nelson, 1988), there are surprisingly few field interventions or basic experiments that have
537 attempted to improve self-control in sport, particularly those that focus on behavioural
538 measures, rather than self-report. As alluded to at the beginning of this article, this distinction
539 is important because self-report and behavioural measures evaluate discrete facets of self-
540 control that should not be viewed as equivalent (Allom et al., 2016; Imhoff, Schmidt, &
541 Gerstenberg, 2013). Self-control training protocols have been examined extensively in non-
542 sport literature and shown to be somewhat effective but poorly understood (e.g., Friese,
543 Frankenbach, Job, & Loschelder, 2017). Many of these training protocols, such as repeatedly
544 squeezing a handgrip or using one's non-dominant hand for everyday tasks over several
545 weeks, seem to lack the ecological validity necessary to transfer into sport training contexts.
546 On the one hand this gap represents a worrying lack of knowledge, but on the other, it
547 represents a ripe opportunity for exploration and advancement.

548 We have deliberately placed this article at the interface of mainstream psychology and
549 sport performance research. For instance, considerable evidence has accumulated from sport
550 researchers demonstrating attentional (e.g., Boat & Taylor, 2017; Englert et al., 2015) and
551 perceptual shifts (Pageaux et al., 2014; Marcora et al., 2009) following self-control exertion,

552 as well as the self-control control fade more generally (MacMahon et al., 2014; Wagstaff,
553 2014). In contrast, little sport research has established moderators and boundary conditions of
554 self-control reductions or the affective costs associated with self-control. Some of the
555 hypotheses we have put forward are also based on mainstream psychology, rather than sport-
556 specific research. For example, the idea that fusing processes and performance goals will
557 delay the desire-goal conflict and improve endurance performance has not been empirically
558 tested, nor has the mechanisms explaining why autonomous motivation enhances self-control
559 during endurance performance. We acknowledge and embrace this fact, and in doing so, we
560 align with arguments put forward by scholarly bodies to progress motivation science (see
561 open letter from the Society for the Science of Motivation here
562 <http://www.thessm.org/MotivationalManifesto.pdf>). In brief, we aim to progress from
563 establishing sport-specific motivational phenomena addressing specific applied problems, to
564 general motivational rules or principles that that lie beyond surface expressions in sport.

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