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Working on a cognitive task does not influence performance in a physical fitness test

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A B S T R A C T

Purpose: A limited number of studies have looked at the negative effect that cognitive fatigue has on physical performance.
Methods and results: Two studies were conducted to assess the impact of a cognitive task on performance in an externally paced running task. In study 1, 12 trained athletes completed a standardized shuttle run, once after a cognitively fatiguing task (unmatched stroop for 10 min) and once after an easy cognitive task (matched stroop for 10 min). Performance in the shuttle run test did not differ between the two conditions, and, surprisingly, perceived effort was significantly higher in the control condition. In study 2, the control condition was modified and the easy cognitive task replaced by watching a video. 11 trained athletes completed both sessions, however, there were again no differences in either performance or in perceived effort.
Conclusion: Both studies failed to reveal an impact of cognitive fatigue on subsequent physical performance. These findings contribute to the growing body of literature in this area, showing that the relationship between cognitive and physical task completion is not straightforward, and that other important factors still remain for investigation.

Throughout an individual's day, a variety of tasks are performed. It is of interest to understand how these tasks and their nature influence each other; such as understanding how work in a cognitive task influences performance of a physical task. While we know that cognitive fatigue[1] negatively influences subsequent cognitive task performance (Ackerman, Kanfer, Shapiro, Newton, & Beier, 2010), the question is whether there is a centrally shared resource, which both cognitive and physical tasks rely on. A number of studies have established that physical activity influences cognitive performance. The nature of the effects depends on task intensity (for a review, see McMorris, Sproule, Turner, & Hale, 2011). Looking at the other direction, however, – how cognitive fatigue influences physical performance – it is evident that little research has been devoted to this question so far.

One of the few but growing studies that has looked at the effect of a preceding cognitive task on physical performance was conducted by Marcora, Staiano, and Manning (2009). They looked at the effect of a 90 min cognitive task on performance in a cycling time trial at 80% intensity. This was compared to performance after 90 min of watching a TV documentary. The cognitive task they used was the AX-continuous performance test (AX-CPT) in which a series of four letters are presented on a computer screen and participants must respond with the right button for target trials (first letter A and last letter X) and with the left button for non-target trials (all other sequences). They found that perception of effort during cycling was elevated in the fatigue condition, which was accompanied by earlier withdrawal from the physical task. This result shows that a prior lengthy cognitive task influences perception of effort as well as physical task performance measured as time on task.

Building on Marcora et al.'s findings, MacMahon, Schücker, Strauss and Hagemann (2014) conducted a study on the effects of cognitive fatigue on physical performance, using a self-paced task. Using the same task as Marcora et al. to induce cognitive fatigue, they found that cognitively fatigued runners ran slower over a

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[1] We agree with Ackerman and Kanfer (2009) that the term "cognitive fatigue" is more precise in describing the concept than "mental fatigue" and will use this term throughout this paper. We refer here to fatigue evoked through work on a cognitively demanding task, therefore the term "cognitive fatigue" is more precise than the broader term "mental fatigue" (Ackerman & Kanfer, 2009).

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3000 m time trial compared with running in a non-fatigued control condition (watching a TV documentary). While overall running times were slower, level of perceived exertion was equal for both runs.

With a similar goal of delving in to the relationship between cognitive and physical task performance, and specifically understanding the mechanisms for the effect of cognitive fatigue on physical performance, Pageaux, Marcora, and Lepers (2013) focused on whether prolonged mental exertion (again using the AX-CPT paradigm) influences endurance performance (isometric contraction of knee extensors) by changes in neuromuscular function. In contrast to their hypothesis, cognitive fatigue did not lead to any impairment in neuromuscular function but again led to increased perception of effort and worse endurance performance (earlier withdrawal from the physical task). Thus, the authors exclude neuromuscular changes as a mediating factor in the inferior physical performance after cognitive fatigue, and underline the role of altered perception of effort. Brownsberger, Edwards, Crowther, and Cottrell (2013) provide support for this work, given that they found reduced power output at the same levels of perceived effort in a cycling task following pre exercise cognitive activity (Brownsberger et al., 2013). Finally, a recent study also showed similar effects, with 30 min of the stroop task leading to higher levels of perceived exertion and a reduction in average speed for a 5 k running time trial on a treadmill (Pageaux, Lepers, Dietz, & Marcora, 2014).

According to Marcora (2010), perception of effort is one of the factors that influences self-regulation of physical performance. It is thus important to regard perception of effort in relation to physical power output: Whereas in some studies the physical task used power output as the constant, resulting in elevated ratings of perceived exertion (RPE) due to cognitive fatigue (Marcora et al., 2009; Pageaux et al., 2013), in other studies RPE was held constant, resulting in lesser physical output (Brownsberger et al., 2013; MacMahon, Schücker, Hagemann, & Strauss, 2014; Martin Ginis & Bray, 2010). These two different patterns of findings can be simply seen as two indicators of the same effect, pointing to the importance of taking into account both physical output and as well as the perceived effort. However, up to now, the underlying mechanisms for the pattern of results, especially with regard to how cognitive fatigue leads to increased perception of effort, are not fully understood.

One concept that is linked to cognitive activity is the process of self-regulation (Hofmann, Schmeichel, & Baddeley, 2012). Self-regulation refers to the act of exerting control over one's behaviors, such as, for example forcing oneself to get out of bed early in the morning to do exercise.[2] Gailliot and Baumeister (2007) describe it as "… the capacity to override one's impulses and automatic or habitual responses [… *which* …] includes controlling thoughts, emotions, desires, and behavior …" (p. 303). Most importantly, in the strength energy model of self-regulation, it is viewed as a global, but limited capacity that can be depleted by engaging in tasks requiring self-control (e.g. Baumeister, Bratslavsky, Muraven, & Tice, 1998; Hagger, Wood, Stiff, & Chatzisarantis, 2010b). Baumeister (e.g. Baumeister, 2003; Baumeister, Vohs, & Tice, 2007) uses the metaphor of a muscle that becomes fatigued after prolonged periods of exercise. In the same way as a muscle fatigues and operates less effectively, individuals become cognitively fatigued after engaging in tasks requiring self-control which will affect performance in subsequent self-control tasks. Thus, relating cognitive fatigue to the concept of self-regulation offers an explanation and points to a more specific mechanism for how cognitive fatigue influences physical performance: Both tasks, cognitive as well as physical, rely on the same resource (self-regulation).

Indeed, there is abundant evidence that depletion of self-regulation in one task influences performance in a second task also requiring self-regulation (e.g. Gailliot et al., 2007; Vohs & Heatherton, 2000). Most research has looked at two cognitive tasks, however, of particular relevance in the context of the present study is work wherein a cognitive task requiring self-regulation precedes exercise performance. In this line of work, there are a number of studies which show that handgrip-task performance is limited after engaging in a cognitive task requiring self-control (see e.g. meta-analysis by Hagger, Wood, Stiff, & Chatzisarantis, 2010a). In their meta-analysis Hagger et al. (2010a) report an averaged effect size of $d^+ = .64$ (based on $k = 18$ reported effect sizes for handgrip as the dependent task). One of the most recent studies using the handgrip task showed impaired maximum force production after engaging in a self-regulatory task (Bray, Graham, Martin Ginis, & Hicks, 2012).

The handgrip task is a very simple physical task, however, and lacks ecological validity to transfer findings to more complex sports. To our knowledge, only a few studies have looked at the effect of self-regulatory depletion on more complex, meaningful physical activities (Dorris, Power, & Kenefick, 2012; Martin Ginis & Bray, 2010; McEwan, Martin Ginis, & Bray, 2013). Among these, Martin Ginis and Bray (2010) results are striking: Participants who worked for only 3 min and 40 s on a modified stroop task generated lower levels of work output on a subsequent 10 min cycling task, keeping a fixed predetermined level of perceived exertion. Therefore, the preceding self-regulatory task altered their effort perception; they felt equal levels of physical strain despite lower work output. Dorris et al. (2012) reveal a similar pattern of results in their study: Competitive rowers, hockey and rugby players completed fewer press-ups (rowers) or sit-ups (hockey and rugby) after working on a difficult compared with an easy cognitive task. Added to these findings, self-regulatory depletion also caused decrements in accuracy as well as less consistency in dart throwing performance, with participants who were inexperienced in this task (McEwan et al., 2013).

To summarize, self-regulation is believed to be a fixed resource, which can be seen as an integral component of cognitive as well as physical performance. When this cognitive resource is depleted, it has a negative impact on subsequent task performance (either cognitive or physical tasks). Even though the cognitive fatigue manipulation in Marcora et al. (2009) and MacMahon et al. (2014) was not presented as a self-regulatory task, the AX-CPT task does include the element of response inhibition, an activity relying on self-regulatory resources.

Given this background, the present study examined the effect of cognitive fatigue induced by a self-regulation depletion task, on a continuous, complex running task where the running speed is controlled externally and increased step by step but withdrawal from the task self-determined (as opposed to a self-paced task where runners are free to select their own speed and have to complete a given time or distance). This task is a frequently employed physical fitness test where pace is continuously increased until exhaustion. For the depletion task, instead of using a cognitive task that combines elements of time on task as well as self-regulation (90 min AX-CPT), in this study we used a relatively shorter task (10 min) relying mainly on the process of self-regulation for response inhibition (stroop task). In line with the self-regulation model, we hypothesized that running at an externally controlled pace would be accompanied by an increase in perceived effort and decline in performance (earlier withdrawal from the physical task) in cognitively fatigued participants,

[2] We follow Hagger et al. (2010b) in using the terms self-regulation and self-control interchangeably.