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It wears me out just imagining it! Mental imagery leads to muscle fatigue and diminished performance of isometric exercise

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ABSTRACT

The purpose of this study was to investigate the aftereffects of self-generated mental imagery of an effortful task on physical self-control endurance and muscle fatigue. Participants performed two isometric handgrip endurance trials (50% of maximum contraction) separated by either an imagery manipulation or a quiet rest period. The imagery group showed greater negative changes in endurance performance from trial 1 to trial 2 ($p = .003$, $d = 0.87$) and increased muscle activation at baseline ($p = .01$, $d = 0.73$) and at 25% ($p = .03$, $d = 0.61$) of the second endurance trial compared to controls. We conclude that imagined performance of an effortful task depletes self-control strength and contributes to muscle fatigue.

1. Introduction

The ability to simulate physical, emotional and cognitive sensations using mental imagery is a fascinating phenomenon and powerful tool that allows us to manipulate many different types of experiences. While some of these experiences may be very straightforward, easy to image, and relaxing (e.g., sipping a cocktail on a tropical beach) others can be more complex; requiring investment of working memory and cognitive effort that can leave one feeling drained (e.g., packing up a house on moving day) (Moran, Guillot, MacIntyre, & Collet, 2012). Considering the latter example, even though no physical action may occur, the experience of imagined events may tax our cognitive, emotional, and physical resources. This hindering of energy resources is akin to the depletion of self-control strength described in the strength model of self-regulation (Baumeister, 2002).

Self-regulation or self-control refers to the ability to exert control over one's behaviors, thoughts, or emotions (Muraven & Baumeister, 2000). The strength model of self-control posits that when people engage in acts requiring self-control they deplete a limited central nervous system (CNS) resource that detracts from their ability to utilize self-control resources for subsequent acts. A meta-analysis by Hagger, Wood, Stiff, and Chatzisarantis (2010) has shown that depletion of self-control strength occurs across similar (e.g., cognitive–cognitive, Cohen's $d = 0.59$) and dissimilar domains (e.g., emotional–physical, $d = 0.63$).

Many different tasks have been used to deplete self-control strength and assess the aftereffects of strength depletion. One task that has been frequently used to deplete self-control resources is the "white bear" task (Wegner, Schneider, Carter, & White, 1987), which requires participants to initially form the mental image of a white bear and then suppress (inhibit) that image for a period of time (e.g., 5 min). Based on data from 19 studies reviewed in a meta-analysis by Hagger et al. (2010), participants who suppressed the image of a white bear performed worse on subsequent tasks involving physical, cognitive, and emotional self-control with an average effect size of $d = 0.65$.

Although ample research supports the notion that suppressing images depletes self-control strength, a relevant question is whether the process of forming mental images depletes self-control strength in a similar way. A study by Ackerman, Goldstein, Shapiro and Bargh (2009) supports the notion that forming images depletes self-control strength. In two studies, participants were instructed to read a story and take the perspective of a character in the story that was exerting self-control. Their findings revealed that participants who had imagined exerting self-control "in the character's shoes" subsequently performed worse on tasks requiring self-control compared to participants who simply read the same story. These findings suggest that self-control strength is vulnerable to both real and imagined depletion. However, it is unclear whether controlling images of oneself performing an activity requiring self-control can deplete self-control resources in a similar manner to that which occurs when imagining someone else.

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To test this question, Graham and Bray (2012) had participants perform two self-control tasks (endurance handgrip performance) that were separated by a guided imagery session, a listening task, or a quiet rest period. Contrary to expectations, findings showed no differences between conditions in endurance performance following the imagery manipulation. However, those authors noted that different types of imagery (i.e., scripted versus self-generated) and imagined tasks may require varying levels of self-control resources. For instance, in their study participants were exposed to a guided imagery script describing a moderately-intense aerobic workout session. When interpreting their findings, those authors questioned whether imagining oneself engaging in moderately-intense exercise requires self-control and suggested that imaging tasks that involve a greater amount of self-control strength to perform, such as intense, fatiguing, endurance exercise, may cause greater depletion of self-control strength. Thus, investigation of the effects of performing mental imagery on self-control strength depletion through the use of self-generated imagery of a challenging physical endurance task is required.

The investigation of whether mental imagery depletes self-control resources is important for practitioners as it is not uncommon for sport scientists and rehabilitation practitioners to prescribe the use of mental or motor imagery to aid in the learning or performance of tasks that require the exertion of physical effort (e.g., Cumming & Williams, 2012; Mulder, 2007). Understanding the effects of imagery on self-control strength and performance is also an important undertaking for empirical reasons as the proposed positive effects of imagery on physical task performance are not universal. For example, a meta-analysis showed the effects of imagery on physical endurance tasks are small and inconsistent (Driskell, Copper, & Moran, 1994). In addition, under some conditions, imagery has even produced negative effects on subsequent performances (e.g., Beilock, Afremow, Rabe, & Carr, 2001; Beilock & Gonzo, 2008; Woolfolk, Parish, & Murphy, 1985). Considering the mixture of conflicting findings, it is not surprising that specific theorizing or exploration of mechanisms explaining why imagery may hinder subsequent physical performances under certain conditions is elusive. Research that focuses on internal biological factors during and after imagery could assist in understanding why these negative performance aftereffects occur.

Although several theories have been proposed to account for the effects of mental imagery on physical performance, two distinct perspectives are evident in the literature: central and peripheral (cf. Mulder, 2007). The central perspective of imagery suggests that engaging in imagery of physical tasks leads to activation of neurons in various structures of the CNS (e.g., primary motor cortex, premotor cortex, basal ganglia, cerebellum, parietal cortex, and the prefrontal cortex) that are responsible for the execution of the movement (Jeannerod, 2001; Mulder, 2007). In other words, imagery creates a central organization of a motor program and the associated activation of neurons within various areas of the brain responsible for priming the execution of the motor command is what is thought to lead to increased performance and learning through repeated imagery use. According to this perspective, muscle activity (EMG) should not occur during imagery as such activation should be suppressed upstream of the neuromuscular junction and any evidence of muscle activation is attributable to random activation as a consequence of incomplete motor command inhibition (Jeannerod, 1994, 2001).

Theories advocating the peripheral perspective stem from the psycho-neuromuscular theory (e.g., Carpenter, 1894; Jacobson, 1932), which suggests that performing imagery of a particular movement causes central organization of a motor program as well as activation of motor units in the muscles involved in the actual movement execution, but at a lower magnitude than what the movement would involve. Several studies have supported the peripheral perspective, showing an increase in muscle activity (EMG amplitude) during the imagery session (e.g., Bakker, Boschker, & Chung, 1996; Jacobson, 1932). However, several studies have failed to show muscle activation during imagery (e.g., Mulder, Zijlstra, & De Vries, 2005; Mulder, Zijlstra, Zijlstra, & Hochstenbach, 2004). Thus, support for the peripheral perspective of imagery remains controversial.

The primary objective of the present study was to investigate the effects of self-generated mental imagery of an effortful task on physical self-control endurance. Based on the discussion above and previous findings by Ackerman et al. (2009), it was hypothesized that engaging in an imagery task involving self-controlled effort regulation would lead to diminished performance on a subsequent self-control task. The second objective was to evaluate the peripheral perspective of imagery as well as how its predictions specifically relate to self-control depletion. We pursued this objective by recording muscle activation (EMG amplitude) throughout an experiment involving two test trials of an isometric muscular endurance task separated by a session of mental imagery of oneself performing the same endurance task. Examining muscle activation during the test trials allowed us to assess trial-to-trial changes in amplitude to determine variations in muscle fatigue following imagery or a quiet rest control task. EMG recordings also allowed us to determine if greater muscle activation was present when participants were engaging in imagery vs. quiet rest and could thus account for variations in self-control depletion or fatigue that might occur across trials.

2. Method

2.1. Participants and design

Participants were 50 university students (18 men and 32 women) with a mean age of 20.90 (SD = 3.05) years. The study utilized a single-blind, randomized experimental design with two levels of independent variable (imagery and quiet rest control) and three dependent measures: changes in physical self-control (endurance time), muscle activation during imagery or quiet rest, and changes in muscle activation (proportional EMG amplitude scores) across two endurance trials of submaximal isometric handgrip squeezing.

2.2. Measures

2.2.1. Physical self-control

Physical self-control was represented by the difference in the amount of time (seconds) participants were able to endure holding a 50% maximum voluntary contraction (MVC) of an isometric handgrip squeeze across two trials. Participants performed a maximum endurance isometric flexion of their dominant hand at 50% of their maximum voluntary contraction (MVC) using an isometric handgrip dynamometer (model MLT003/D; ADInstruments, Colorado Springs, CO) with graphic computer interface (PowerLab 4/25T; ADInstruments, Colorado Springs, CO).

Prior to the first endurance trial, participants performed three, four-second 100% MVCs on the dynamometer; each separated by 1 min of rest. The average force recording obtained from a one-second window at the peak of each MVC trial was analyzed to determine peak force generation. The peak force value obtained from the MVC yielding the greatest force was then halved to determine the 50% MVC target value for the endurance trials.

To perform the endurance contraction, participants squeezed the handgrip dynamometer and were provided visual feedback on a 17 in. computer monitor in the form of a force tracing (i.e., a real-time graphed line indicating how much force was being generated). The target force level (50% MVC) was shown as a static line on the screen. Participants were instructed to maintain a handgrip squeeze for as long as possible that kept the force tracing line at, or slightly above, the target level while resisting the temptation to quit.

Throughout the trials, if the force tracing fell below the 50% MVC, participants were instructed by the experimenter to "squeeze harder so the line stays above the marker on the screen". The trial ended when participants voluntarily stopped gripping the dynamometer or when the line-tracing fell below the criterion force value for longer than two seconds. Force generation values (Newtons) were recorded continuously throughout both trials.

The number of seconds participants maintained an isometric handgrip squeeze at ≥50% MVC (time to failure; TTF) was used as the physical self-control performance dependent variable. TTF was determined off-line, during data-analysis, using the Chart 5™ graphing software application that allowed identification of the start