The Effects of Depleted Self-Control Strength on Skill-Based Task Performance

Desmond McEwan, Kathleen A. Martin Ginis, and Steven R. Bray
McMaster University

The purpose of this study was to examine the effects of depleted self-control strength on skill-based sports task performance. Sixty-two participants completed the following: a baseline dart-tossing task (20 tosses), with measures of accuracy, reaction time, and myoelectrical activity of the arms taken throughout; a self-control depletion (experimental) or a nondepletion (control) manipulation; and a second round of dart tossing. As hypothesized, participants in the experimental condition had poorer mean accuracy at Round 2 than control condition participants, and a significant decline in accuracy from Round 1 to Round 2. Experimental condition participants also demonstrated poorer consistency in accuracy compared with control condition participants at Round 2 and a significant deterioration in consistency from Round 1 to Round 2. In addition, consistency in reaction time improved significantly for the control group but not for the experimental group. The results of this study provide evidence that ego depletion effects occur in the performance of a skill-based sports task.

**Keywords:** self-regulation, self-control, ego depletion, strength model, sports psychology, electromyography

Self-regulation, or self-control, refers to any effort by a human being to alter its own inner states or responses, including actions, thoughts, feelings, and task performances (Baumeister, Heatherton, & Tice, 1994). In order for individuals to overcome the force of their habitual or normal responses, they must draw on a limited resource known as self-control strength (Baumeister & Heatherton, 1996; Baumeister et al., 1994). According to the strength model of self-control (Baumeister, Vohs, & Tice, 2007), all behaviors requiring self-regulation draw upon this same central nervous system resource. This resource is drained or depleted when an individual regulates his or her behaviors; consequently, the individual will have a decreased capacity to perform any subsequent behavior that requires self-regulation. This failure to self-regulate due to a depletion of the self-control resource is commonly referred to as ego depletion (Baumeister, Bratslavsky, Muraven, & Tice, 1998). While the exact anatomical location of this resource is not conclusively known, preliminary evidence (e.g., Banfield, Wyland, Macrae, Munte, & Heatherton, 2004) suggests that it may be under executive control in the prefrontal cortex. This hypothesis arises from the finding that executive functioning is integral to key self-regulation processes, such as initiating and inhibiting particular responses, coordinating actions, attending to stimuli, and planning and engaging in purposeful, effortful, and goal-directed behaviors (Schmeichel & Baumeister, 2004).

Considerable research has demonstrated that ego depletion effects occur for a variety of behaviors, such as regulating one’s emotions, thoughts, attention, and—most pertinent to the current study—physical performances (Hagger, Wood, Stiff, & Chatzisarantis, 2010). Furthermore, because self-control appears to be a central resource, when self-control strength is depleted while self-regulating on one task (e.g., self-regulating one’s emotions), people typically have an impaired ability to self-regulate when performing a subsequent second task, even if that task is drawn from another domain (e.g., self-regulating one’s physical exertion; Baumeister et al., 1998). With regard to depletion effects on physical task performances, Muraven, Tice, and Baumeister (1998) found that participants who were instructed to suppress their emotional responses to an upsetting movie were unable to sustain an isometric handgrip squeeze for as long as those who were not initially told to engage in such self-regulation. These results have since been corroborated in several studies (e.g., Bray, Martin Ginis, Hicks, & Woodgate, 2008; Martin Ginis & Bray, 2010). Ego depletion effects have also been shown for skill-based (non-sport) tasks such as in the board game Operation, which tests participants’ hand–eye coordination and fine motor skills (Vohs et al., 2005).

**Self-Regulation in Sports**

In addition to the evidence for ego depletion across a wide range of domains within the social sciences, sports
enthusiasts could likely provide a plethora of anecdotal evidence of the importance of self-regulation for athletic performance. For instance, in order for a football quarterback to successfully complete a pass to his teammate, he must engage in many behaviors that require self-control, such as regulating his attention (e.g., attending to certain players on his and the opposing team, while ignoring task-irrelevant cues such as taunting fans or opponents); engaging in response inhibition (e.g., waiting for a receiver to get open rather than erroneously forcing a pass) and initiation (e.g., deciding to pass to an open receiver); and planning his skill execution appropriately (e.g., accurately aiming his throw to a particular receiver). When a receiver becomes open, the quarterback must react quickly and coordinate his actions effectively (e.g., throw the ball accurately to his receiver before the defense is able to react and recover). If a quarterback’s self-control strength has been depleted, he may be unable to perform these self-regulatory behaviors, and, in turn, be unable to achieve his goal of successfully completing a pass to his receiver.

The question remains as to whether depleted self-control strength impairs an individual’s ability to perform subsequent sports tasks that require self-regulation. Ego depletion effects have been demonstrated for effort-based physical tasks (e.g., sustaining an isometric hand squeeze), which are unquestionably part of athletic performance. In regards to skill-based sports tasks, ego depletion effects are tenable, as there are numerous self-regulation behaviors under executive control that play a role in successfully carrying out skilled athletic tasks (e.g., regulating one’s attention, emotions, and motor skill execution). One recent study (Englert & Bertrams, 2012) found that self-control strength depletion was associated with diminished performance on a basketball free-throw shooting task as well as a dart-tossing task, but only among participants experiencing high state anxiety. The authors suggested that the observed performance decrements may have been the result of anxious participants requiring, but not having, sufficient self-control strength to selectively control their attention effectively. These findings support an interpretation that athletes’ efforts to actively and consciously control their internal states (e.g., thoughts, emotions) in an attempt to perform optimally may actually have the opposite desired effect and worsen performance (Gardner & Moore, 2004). However, in the absence of high state anxiety, it is questionable whether an individual’s ability to perform a sports task that requires self-regulation is influenced by self-control strength depletion.

The potential impact of self-control strength depletion on the performance of complex sports tasks is clear. However, from an empirical perspective, it is important to first determine whether ego depletion effects occur in the performance of a simple, skill-based sports task to see whether comparable ego depletion effects exist for this type of task performance as they do for other tasks (e.g., effort-based tasks such as an isometric handgrip squeeze). If evidence for this principle is established, further research of its effects in other sporting tasks could be conducted. Partial evidence of this effect has been shown in the work of Englert and Bertrams (2012). However, given that these effects were only found under instances of high anxiety, additional research needs to be conducted to determine if ego depletion effects do indeed occur in the execution of a sports task. Accordingly, the primary purpose of the current study was to examine the effects of self-control strength depletion on the performance of a skill-based sports task that requires self-regulation.

**Trait Self-Control as a Potential Moderator of Ego Depletion**

The strength model of self-control proposes that continual self-regulation can bring about a “state depletion” of individuals’ self-control resources, which can result in a temporary failure to obtain optimal outcomes (Hagger et al., 2010). However, researchers have also suggested that self-control is a dispositional trait that varies between individuals (Tangney, Baumeister, & Boone, 2004). Thus, individuals with greater self-control strength may be less susceptible to the detrimental effects of self-control strength depletion. Overall, research on the moderating influence of trait self-control has produced mixed results with some studies finding an interaction between self-control depletion and trait self-control (e.g., Dvorak & Simons, 2009; Gailliot & Baumeister, 2007), while other studies have produced no such findings (e.g., Gailliot & Baumeister, 2007; Stillman, Tice, Fincham, & Lambert, 2009). Due to an insufficient number of effect sizes, the authors of a meta-analysis on self-regulation (Hagger et al., 2010) were unable to estimate the potential effects of trait self-control. They recommended further research to address this question. Therefore, the secondary purpose of this study was to determine if trait self-control moderates the anticipated ego depletion effects for the performance of a skill-based sports task.

**Ego Depletion and Myoelectrical Activation**

Even though the effects of ego depletion are clearly evident, the mechanisms explaining these effects require research (Inzlicht & Schmeichel, 2012). Knowing the mechanisms by which ego depletion transpires would allow researchers to examine potential ways of preventing these negative effects from occurring or alleviating them if they do occur. It has also been proposed that—for the performance of physical tasks—there may be a psychophysiological component to ego depletion. For instance, Bray et al. (2008) hypothesized that the ego depletion effects observed in studies of effortful physical task performance may be due, in part, to self-control strength depletion causing an increase in muscle fatigue. Electromyography (EMG) measures the electrical activity produced by the skeletal muscles and an increase in EMG amplitude indicates a greater recruitment in the number of skeletal muscle motor units (Basmajian & De Luca, 1985). It is thought that the increase in neuromuscular activation that occurs when task demands remain constant.
reflects central fatigue, which may result in decreased physical task performance, such as one’s ability to maintain an isometric handgrip squeeze (an effort-based task; e.g., Bray et al., 2008). Consistent with their hypotheses, Bray et al. (2008) found that, in addition to being unable to sustain an isometric handgrip squeeze for a duration as long as that of participants who were not depleted, depleted participants also required greater muscle activation to sustain the handgrip than controls. This provided preliminary evidence that muscular activation may be related to the ego depletion effects observed for effort-based physical task performance. Determining whether muscle activation plays a role in the hypothesized ego depletion effects in skill-based sports task performance has yet to be assessed. As such, the third purpose of this study was to examine the effects of self-control strength depletion on individuals’ muscle activation while completing a skill-based sports task.

For the current study, it was hypothesized that the depletion of individuals’ self-control strength would result in poorer performance on a skill-based sports task. It was also hypothesized that these anticipated ego depletion effects would be moderated by individuals’ trait self-control; that is, those with higher trait self-control would show better performance on a skill-based sports task after they have been depleted than those with lower trait self-control. Moreover, it was predicted that individuals who experienced a depletion of their self-control strength would have greater muscle activation while completing the task than those who were not depleted.

**Method**

**Participants**

Sixty-two participants (31 males and 31 females) took part in this study. The average age was 22.8 years ± 3.95. All participants either never played darts before (n = 17), or only played recreationally (i.e., noncompetitively) once per year (n = 35) or once every few months (n = 10). The conditions did not differ significantly in age, sex, or dart-tossing experience (ps > .05).

**Experimental Task and Apparatus**

Performance on a dart-tossing task was used as the dependent measure, as we wanted to test our hypotheses with a simple closed-skill sports task that would allow us to maximize experimental control and rigor. Dart tossing has been used often to test novel hypotheses in sport psychology in laboratory-based settings (e.g., Van Raalte et al., 1995). It was also important that we chose a sports task that allowed for the connection of EMG electrodes to a participant’s throwing arm to measure muscle activity. The dart-tossing task allowed for this. As per standard rules, the dartboard was hung so that the bulls-eye was 1.73 m from the floor, with tosses taken 2.37 m from the dartboard. The dart-tossing task was modified by having a box with three lights—colored green, red, and yellow—above the dartboard. These lights were added to enhance the self-regulatory demands and executive functioning requirements of the task (cf. Hofmann, Schmeichel, & Baddeley, 2012), as will be described in the procedure section. This box was connected to a control panel, which the experimenter operated to flash each of the lights. The control panel was also connected to an EMG amplifier, which was connected to a computer that showed the activation of the cue light as well as the muscle activity of participants’ biceps and triceps.

**Measures**

**Task Performance.** Participants were instructed to aim for the bull’s-eye target on each toss. There were two measures of performance—accuracy and reaction time—both of which are often important in sports performance. Accuracy was operationalized as the distance (in centimeters) between where each toss landed and the center of the bull’s-eye (measured with a standard tape measure). Reaction time was measured using custom analysis software and was calculated as the time elapsed from the onset of the cue light signal to the initiation of activation in either the biceps or triceps (whichever was initiated first). To determine the initiation of the muscles, the experimenter noted the time when the muscle activity increased above a threshold level of 1.5 standard deviations greater than resting activity (as per Hodges & Bui, 1996). For each participant, reaction time scores for each toss were calculated twice to ensure consistency in the experimenter’s measurements (ICC = .99). The primary measure of participants’ performance was mean accuracy and reaction time for each round. In addition, a measure of consistency was calculated as the standard deviations for accuracy and reaction time for each round.

**Muscle Activity.** Five disposable adhesive surface EMG electrode pairs (3 cm in diameter) were connected to the participant’s tossing arm. One ground electrode was placed on the participant’s lateral epicondyle; two electrodes were placed next to each other lengthwise on the belly of the biceps brachii and two were placed next to each other on the lateral head of the triceps brachii. The center-to-center distance between the two electrodes on each muscle was 3 cm. Data were collected with LabChart7 software (AD Instruments, Bella Vista, NSW, Australia) using a PC laptop computer and converted by a 12-bit A/D card (AD Instruments, Bella Vista, NSW, Australia). Surface EMG signals were processed through a differential amplifier (input impedance = 200 mΩ, 0.3–1000 Hz, CMRR = 85 dB at 1–60 Hz, AD Instruments, Powerlab 8/30, Bella Vista, NSW, Australia). The EMG signals were dual-pass filtered (20–500 Hz), full-wave rectified, and filtered using a sixth-order Butterworth filter with a cutoff of 1.5 Hz.

For each toss, muscle activity was determined by taking the peak myoelectrical activation of the biceps and triceps. Before the first round of dart tossing, participants completed a maximum voluntary effort (MVE) for both the biceps and triceps (described in further detail in the procedure section) so that EMG amplitudes could
subsequently be normalized. For both rounds of tossing, the mean normalized peak biceps and triceps amplitudes were determined.

**Trait Self-Control.** The Brief Trait Self-Control scale (Tangney et al., 2004) was used to assess trait self-control. This questionnaire consists of 13 items with participants indicating the degree to which they believe each statement (e.g., “I am good at resisting temptation”) applies to them. Responses are made on a 5-point scale (1 = not at all like me; 5 = very much like me). After reverse-scoring nine questions, the items are summed, with higher scores indicating greater self-control (possible range = 13–65). This scale has been shown to be valid and reliable in assessing individuals’ dispositional self-control (Tangney et al., 2004). In the current study, Cronbach’s alpha was .78.

**Self-Control Strength Manipulation**

A modified Stroop task was used as the experimental manipulation in this study. This task has been used in many laboratory studies of self-regulation (e.g., Bray et al., 2008; Wallace & Baumeister, 2002) as a means of depleting individuals’ self-control strength. In this task, participants are presented with lists of color words and required to read aloud the color of the print ink and ignore the text for each word presented. However, when participants encounter a word printed in red ink, they are required to override the general instructions and read aloud the printed word. In the depleting (i.e., experimental) condition, the print ink color and printed text are mismatched. For example, the word “BLUE” may be presented in yellow ink color—the correct verbal response in this case would thus be “yellow.” However, when the word “BLUE” is presented in red ink, the correct verbal response would be “blue.” In the nondepleting, control condition, the words are matched (e.g., the word “BLUE” is presented in blue ink, “RED” is presented in red ink). Three sheets of colored words were provided—each sheet had two columns of words and consisted of 46 total words. Participants were instructed to go through as many words as possible, while making as few errors as possible, over the 5-min span.

**Manipulation Checks**

Participants completed three manipulation checks, which assessed their perceived effort, fatigue, and mood following the experimental manipulation. For perceived effort, participants rated their mental exertion during the manipulation 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. Perceived fatigue was assessed using the Visual Analog Scale (Lee, Hicks, & Nino-Murcia, 1991), which consists of a 100-mm horizontal line, anchored with extremely tired and extremely energized. Participants indicated how fatigued they felt by drawing a vertical line through the bar. The distance (in millimeters) of the line from the right side of the bar was measured, with greater distances indicating greater fatigue. Mood was assessed with the 16-item Brief Mood Inspection Scale (Mayer & Gaschke, 1988). Participants indicated the degree to which each statement described their mood (1 = definitely do not feel; 7 = definitely do feel) and four subscale scores were obtained: the pleasant-unpleasant (P-U) subscale; the arousal-calm (A-C) subscale; the positive-tired (P-T) scale; and the negative-relaxed (N-R).

**Procedure**

The current study took place at a Canadian university and received approval from the university’s Research Ethics Board. The study used a single-blind, randomized controlled experimental design. Upon giving written consent, participants completed a demographic questionnaire in which they provided their age, sex, and previous experience playing darts. After cleansing the skin with an alcohol pad, five EMG electrodes were connected to the participant’s throwing arm to measure muscle activation during the two rounds of dart tossing. Participants then completed an isometric MVE of their biceps against resistance with their arm at their side, palm facing up, and the elbow flexed 90 degrees. For the triceps isometric MVE, participants placed their arm at their side, with their elbow flexed 90 degrees, their palm facing medially, and then attempted to maximally extend their triceps against resistance.

Participants were then given 2 to 3 min to practice tossing the darts before completing an initial round of dart tossing. For each toss in this first round, participants were instructed to toss when they saw the green light flash and not toss when they saw the red or yellow light flash. They were also instructed to react as quickly as possible when they saw the cue light flash. These modifications ensured that the task was (at least partially) under executive control and demanding of participants’ self-control strength (cf. Hofmann, Schmeichel, & Baddeley, 2012). For instance, the task involved cognitive decision making (e.g., tossing on the correct cue light and resisting the urge to toss when the other lights flashed), planning and executing an appropriate motor action (e.g., tossing in a manner that resulted in an accurate and quick toss), and regulating attention (e.g., focusing on task-relevant information such as the lightbox above the dartboard, the bullseye, and their bodily orientation, posture, positioning, and movement, while ignoring task-irrelevant stimuli). The experimenter then ensured that the participant understood the procedure (i.e., when to toss the dart) and commenced with the first round of dart tossing (20 tosses).

Once the participant indicated that he or she was ready to begin, the experimenter said “begin” and started recording EMG activity. There was a 1-, 4-, 7-, or 10-s interval between the point when the experimenter said to begin and when the green cue light flashed. During the 4-, 7-, and 10-s foreperiods, noncue lights flashed at 1-s intervals prior to the cue light being flashed (e.g., for a 4-s foreperiod, the red light may flash at s1, the yellow light at s2, the yellow light at s3, and the green light at s4).
To ensure consistency across participants, the foreperiod before each toss was the same for all participants. Muscle activity readings for each toss were stopped once the dart hit the dartboard. At this point, the experimenter measured how far the dart landed from the bulls-eye, retrieved the dart from the dartboard, and handed it to the participant for the next toss. This procedure was repeated for each toss until the round was completed. The experimenter provided no verbal feedback to the participants regarding their accuracy or reaction time. The experimenter also noted the number of toss errors that participants made; that is, the number of tosses taken when a noncue light flashed (i.e., the red or yellow light).

Participants were then randomly assigned (by lottery) to either a self-control strength depletion (experimental) condition or nondepletion (control) condition. In both conditions, the Stroop task was carried out for 5 min. Upon completion of the Stroop task, participants completed the manipulation checks. They then completed a second round of dart tossing. The protocol for this round was almost identical to the first round—participants took 20 tosses aiming for the bulls-eye while their muscle activity was recorded. However, instead of tossing on the green light, participants were instructed to toss on the red light, as such a rule change has been shown to be demanding of individuals’ self-control strength (Hall, Fong, Epp, & Elias, 2008). Once again, measures of accuracy, reaction time, muscle activity, and toss errors were taken throughout the round. After the second round of tossing, participants completed the trait self-control questionnaire. They were then debriefed and given a $20 remuneration. The duration of each experimental session was approximately 30 min.

**Data Analyses**

Separate 2 (Time) × 2 (Condition) repeated-measures ANOVAs were conducted to examine between-group differences in performance over time (i.e., from the pre- to postmanipulation rounds of tossing) on the dependent measures of the following: mean accuracy and consistency in accuracy; mean reaction time and consistency in reaction time; and mean peak EMG activity for the biceps and triceps. When significant Time × Condition effects emerged, t tests were conducted to determine the nature of the interaction using a priori, planned comparison alphas of \( p < .05 \) (Keppel, 1993). To determine whether the anticipated ego depletion effects on mean accuracy and reaction time were moderated by trait self-control, separate multiple regressions were conducted. In the first regression, Round 1 mean accuracy, condition, zero-centered trait self-control scores, and the interaction between condition and zero-centered trait self-control scores were regressed on Round 2 mean accuracy. In the second regression, Round 1 mean reaction time, condition, zero-centered trait self-control scores, and the interaction between condition and zero-centered trait self-control were regressed on Round 2 mean reaction time scores. For all tests, alpha was set at .05.

**Results**

**Participant Characteristics and Preliminary Analyses**

Means and standard deviations for all measures at baseline and postmanipulation are presented in Table 1. A series of one-way ANOVAs revealed that there were no significant differences between the experimental and control conditions on any of the manipulation checks or on scores of trait self-control. There were no toss errors (i.e., incorrectly tossing on the red or yellow light instead of the green light) by any participants in either condition in the first round of tossing. However, there were six toss errors (i.e., incorrectly tossing on the green or yellow light instead of the red light) taken by the experimental group (all by different participants) in the second round of tossing compared with zero incorrect tosses taken by the control group. A post hoc chi-square revealed that this difference between groups was significant, \( \chi^2(1) = 6.64; p = .010 \).

**Overall Performance**

Using accuracy as the dependent measure of performance, the ANOVA revealed no significant main effects for time, \( F(1, 60) = 0.05, p = .820, \) Cohen’s \( d = .06 \), or condition, \( F(1, 60) = 0.87, p = .376, d = .22 \). As hypothesized, there was a significant Time × Condition interaction, \( F(1, 60) = 8.16, p = .006, d = .74 \). Paired t tests revealed no significant difference in mean accuracy between conditions at Round 1, \( t(60) = 0.18, p = .862, d = .05 \), but that the control group was significantly more accurate than the experimental group at Round 2 \( t(60) = –2.13, p = .038, d = .55 \). The control group’s mean accuracy improved by 0.79 cm from Round 1 to Round 2; an independent-samples test revealed that this improvement approached significance, \( t(30) = –1.86, p = .073, d = .22 \). The experimental group’s mean accuracy declined by 0.93 cm; an independent-samples test showed that this deterioration was significant, \( t(30) = 2.18, p = .037, d = .37 \). Thus, depleted self-control strength was associated with decrements in performance accuracy.

It was also noted, post hoc, that more control group participants took their most accurate toss in the second round (69%) rather than the first round (31%), \( \chi^2(1) = 4.17, p = .041 \), whereas 61% of participants in the experimental group took their most accurate toss in Round 1 compared with 39% in Round 2, \( \chi^2(1) = 1.29, p = .25 \). In addition, significantly more experimental group participants took their least accurate toss in the second round of tossing (84%) as opposed to the first round (16%), \( \chi^2(1) = 14.23, p < .001 \); whereas 54% of participants in the control group took their least accurate shot in Round 1 compared with 46% in Round 2, \( \chi^2(1) = 0.29, p = .590 \). These results suggest that the experimental manipulation prevented experimental group participants from executing their best performance (in terms of accuracy on one toss), and even resulted in these participants experiencing their worst performance.
Using reaction time as the dependent variable, the ANOVA indicated no significant main effects for time, $F(1, 60) = 0.39, p = .537, d = .16$, or condition, $F(1, 60) = 1.02, p = .318, d = .26$. Contrary to hypothesis, the Time × Condition interaction was not significant, $F(1, 60) = 0.01, p = .769, d = .03$. Thus, the self-control manipulation did not affect mean reaction times.

### Trait Self-Control as a Moderator of Depletion Effects

The first multiple regression showed that the overall model was significant, $R^2 = .61$, adjusted $R^2 = .58$, $F(4, 57) = 22.06, p < .001$, in predicting Round 2 accuracy scores. A significant main effect emerged for Round 1 mean accuracy, $\beta = .74, p < .001$, indicating that higher Round 1 mean accuracy scores predicted higher Round 2 accuracy scores. A significant main effect also emerged for condition, $\beta = .28, p = .001$, as participants in the control group showed better accuracy in Round 2. Consistent with hypothesis, a significant Condition × Trait self-control interaction was found, $\beta = -.17, p = .044$, thus superseding the main effect observed for condition.

To decompose the interaction, three simple regression equations were then computed: (a) $1 SD$ below the mean moderator score, (b) the mean moderator score, and (c) $1 SD$ above the mean moderator score. These equations were computed for both the control and experimental group (Cohen & Cohen, 1983). The resulting visual depiction of this moderation is given in Figure 1. As shown, there was a negative slope for the experimental group and a positive slope for the control group. The Johnson–Neyman technique (Johnson & Fay, 1950; Aiken & West, 1991) was then used to determine the point on the regression lines where the control and experimental groups differed significantly in mean accuracy. Results showed that the region below the trait self-control score of 3.77 crossed the significance level, $p < .05$. The shaded area in Figure 1 represents this area of significance. In other words, participants in the experimental condition were significantly less accurate in the second round of dart tossing than participants in the control condition when they had a centered trait self-control score of 3.77 (approximately $+0.5 SD$) or lower. Participants with trait self-control scores higher than 3.77 were essentially unaffected by the experimental manipulation, relative to the control condition.

### Table 1 Descriptive Statistics for Outcome Measures at Round 1 and Round 2

<table>
<thead>
<tr>
<th></th>
<th>Control Group</th>
<th>Experimental Group</th>
<th>$p$-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mean accuracy</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Round 1</td>
<td>11.41 ± 4.29</td>
<td>11.25 ± 2.42</td>
<td>0.862</td>
</tr>
<tr>
<td>Round 2</td>
<td>10.61 ± 3.13</td>
<td>12.18 ± 2.64</td>
<td>0.038</td>
</tr>
<tr>
<td><strong>Accuracy standard deviation</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Round 1</td>
<td>6.33 ± 2.83</td>
<td>5.71 ± 1.14</td>
<td>0.264</td>
</tr>
<tr>
<td>Round 2</td>
<td>5.94 ± 1.82</td>
<td>7.08 ± 1.93</td>
<td>0.019</td>
</tr>
<tr>
<td><strong>Mean reaction time</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Round 1</td>
<td>1.05 ± 0.27</td>
<td>1.13 ± 0.32</td>
<td>0.532</td>
</tr>
<tr>
<td>Round 2</td>
<td>1.04 ± 0.31</td>
<td>1.11 ± 0.39</td>
<td>0.420</td>
</tr>
<tr>
<td><strong>Reaction time standard deviation</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Round 1</td>
<td>0.33 ± 0.13</td>
<td>0.32 ± 0.13</td>
<td>0.532</td>
</tr>
<tr>
<td>Round 2</td>
<td>0.25 ± 0.12</td>
<td>0.29 ± 0.12</td>
<td>0.148</td>
</tr>
<tr>
<td><strong>Mean peak biceps activation</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Round 1</td>
<td>0.16 ± 0.13</td>
<td>0.19 ± 0.16</td>
<td>0.446</td>
</tr>
<tr>
<td>Round 2</td>
<td>0.16 ± 0.13</td>
<td>0.21 ± 0.18</td>
<td>0.236</td>
</tr>
<tr>
<td><strong>Mean peak triceps activation</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Round 1</td>
<td>0.47 ± 0.24</td>
<td>0.54 ± 0.30</td>
<td>0.314</td>
</tr>
<tr>
<td>Round 2</td>
<td>0.49 ± 0.22</td>
<td>0.58 ± 0.25</td>
<td>0.121</td>
</tr>
</tbody>
</table>

*Note. $p$-value: difference between conditions on each variable.*
improvements. Therefore, nondepleted participants did not change significantly (–0.02 s), t(30) = –1.06, p = .17. By contrast, the experimental group’s consistency deteriorated by 1.38 cm from Round 1 to Round 2; an independent-samples t test revealed that this deterioration was significant, t(30) = 4.05, p < .001, d = .88. Hence, the self-control manipulation seemed to impair performance in terms of consistency in accuracy.

For consistency in reaction time, the ANOVA revealed a significant main effect for time, F(1, 60) = 11.45, p = .001, d = .87, but not for condition, F(1, 60) = 0.21, p = .664, d = .12. As hypothesized, there was a significant Time × Condition interaction, F(1, 60) = 3.87, p = .050, d = .51. Paired t tests showed that there were no significant differences between groups at Round 1, t(60) = 0.63, p = .532, d = .16, or Round 2, t(60) = –1.47, p = .148, d = .42. However, an independent-samples t test revealed that the reaction time consistency for the control group decreased significantly from Round 1 to Round 2 (–0.09 s), t(30) = –3.59, p = .001, d = –.73. The experimental group’s reaction time consistency did not change significantly (–0.02 s), t(30) = –1.06, p = .297, d = .16. Therefore, nondepleted participants demonstrated improvements in consistency in reaction time, whereas the self-control manipulation seemed to prevent the experimental group from obtaining similar improvements.

**Consistency**

The primary purpose of this study was to determine whether ego depletion effects occur in the performance of a self-regulatory demanding dart-tossing task. In many instances, our hypotheses were supported. In terms of accuracy, we found that the experimental condition showed poorer mean performance and consistency than the control condition in the postmanipulation round of dart tossing, and that this effect was moderated by participants’ trait self-control. The experimental manipulation also seemed to prevent experimental condition participants from executing their most accurate toss (as was the case for the control condition participants) and actually resulted in them executing their least accurate toss. In regards to reaction time, the experimental manipulation seemed to prevent experimental group participants from obtaining significant improvements in consistency from the pre- to postmanipulation rounds of dart tossing, as was the case for the control group.

These findings suggest that the depletion of individuals’ self-control strength is detrimental to performance on a skill-based sports task, particularly a task requiring accuracy. As this is one of the first studies to test these effects on this type of task, there are numerous potential...
explanations for our findings. Our a priori hypothesis was that myoelectrical activation would explain—at least in part—why these effects occurred. We did find that the peak EMG amplitude of the biceps increased from Round 1 to Round 2 by an average of 2.2% for the experimental group (Cohen’s $d = .13$); in comparison, there was a 0.3% increase for the control group ($d = .02$). Likewise, there was a 4.2% increase in the peak EMG amplitude of the triceps from Round 1 to Round 2 for the experimental group ($d = .15$) compared with a 1.6% increase for the control group ($d = .07$). However, these between-group differences did not reach statistical significance, as the study was not adequately powered to detect small effect sizes. The nonsignificant findings may also be due to the type of task performed. That is, compared with some other physical tasks, such as throwing a baseball as hard as possible or taking a slap shot in hockey, dart tossing does not require as much muscular activation. Indeed, Bray et al. (2008) found between-group differences in muscle activation, postdepletion, on a maximum endurance handgrip squeeze task, which requires much more muscular activation than dart tossing. Therefore, it is likely that myoelectrical activation only has a meaningful impact on the performance of skill-based tasks that place a high demand on the muscles. Had we tested the effects of ego depletion on this type of a task, we may have found significant differences between groups in muscle activity, postmanipulation. For this task, however, there seem to be other reasons why depleted self-regulation diminished performance.

Perhaps a more probable explanation is that depleted self-regulation impaired individuals’ executive functioning, which, in turn, decreased performance. For instance, while completing the dart-tossing task, participants were required to make quick and accurate decisions (e.g., deciding whether to toss as soon as a light flashed). Along similar lines of previous research on response inhibition (e.g., Baumeister et al., 1998; Muraven et al., 1998), individuals whose self-control strength was depleted may have been less effective at engaging in this cognitive decision making. This contention is supported by the finding of more tosses on noncue lights (i.e., toss errors) in the postmanipulation round of tossing for the experimental group than for the control group. Depleted participants may have also had a poorer ability to develop, execute, and maintain controlled and effective motor movements, as it has been shown that improvements in procedural motor learning and execution can be impeded by disrupting the executive functioning areas of the brain (Pascual-Leone, Wassermann, Grafman, & Hallett, 1996). This may explain, in part, why the experimental group’s consistency either decreased (accuracy) or stayed the same (reaction time), whereas the control group’s consistency either improved (reaction time) or stayed the same (accuracy). Self-control strength depletion may have also affected individuals’ abilities to regulate their attention effectively (e.g., attend to task-relevant stimuli such as the light box, the bulls-eye, proprioceptive information, while ignoring other task-irrelevant stimuli). Consistent with previous findings (Englert & Bertrams, 2012; Rothbart, Ellis, & Posner, 2011), it may be that the depletion of experimental participants’ self-control strength resulted in a poorer ability for them to focus their attention in an appropriate and effective manner.

Our result regarding trait self-control as a potential moderator of ego depletion is also noteworthy. We found that experimental group participants with higher trait self-control were less likely to show deteriorations in their mean accuracy, postmanipulation, compared with experimental group participants who scored lower on trait self-control. This provides evidence that individuals with greater dispositional self-control strength may be less prone to the negative effects of depleted self-regulation in completing a sports task compared with those with lower trait self-control. This is an important contribution to the self-regulation literature, as it suggests that individuals’ trait self-control may indeed have a significant impact on determining whether depleted self-regulation impairs task performance, as has been suggested by previous researchers (e.g., Tangney et al., 2004). This finding also provides some indirect evidence that increasing individuals’ self-control strength may result in better task performance, postdepletion, which has also been shown in previous self-regulation training studies (e.g., Oaten & Cheng, 2006).

**Implications**

The results of this study have important theoretical and practical implications. From a theoretical perspective, this study has shown that—in addition to many other aspects of behavior—the tenets of the strength model of self-control extend to the performance of skill-based sports tasks. Specifically, our findings—like those of Englert and Bertrams (2012)—suggest that performance on tasks that demand self-control can deteriorate under conditions in which self-control strength is depleted. In addition, it is noteworthy that control group participants’ performance tended to improve (or, at the very least, did not decline), whereas experimental group participants’ performance tended to deteriorate (or, at the very least, did not improve). This is an important contribution as it provides further support for the viability of using the strength model of self-control—rather than a skill model—to understand self-regulation failures in the sport domain, which is consistent with Hagger et al.’s (2010) meta-analytic findings. Our results also suggest that muscle activation does not seem to be the primary mechanism for ego depletion effects in low-exertion, skill-based sports task. Rather, other mechanisms might explain the observed effects, such as a poorer ability make appropriate decisions, regulate attention, and/or plan and execute effective motor movements. The lack of research examining potential mediators underlying depletion effects has been a strong point of criticism in the self-regulation literature (Inzlicht & Schmeichel, 2012). Our study is among the few to test a potential mechanism and provides direction for future investigators’ choice of
potential mediators to be tested. We also identified trait self-control as a moderator of the ego depletion effects. Ascertainment of potential mediators and moderators of ego depletion effects, such as these, is important to expand the strength model’s ability to account for such effects (Inzlicht & Schmeichel, 2012).

From a practical perspective, our results suggest that self-control strength depletion can impact performance on a skill-based sports task that requires self-regulation, particularly for accuracy. Although additional research is needed to determine if our results generalize to other athletic tasks and to elite athletes, the present results may be important for sports teams and athletes to consider. That is, the amount of self-control strength that individuals have may influence their performance on skilled sports tasks. Therefore, it may be vital for athletes to avoid situations that could sap their self-control strength before or during competition. In addition, increasing one’s self-control strength during training may also be beneficial since (a) performance decrements are less likely to occur for those with higher trait self-control compared with those with lower trait self-control, and (b) studies have shown promising results for the effects of self-regulation training programs in improving individuals’ self-regulation (Hagger et al., 2010). By taking appropriate steps for preventing the potentially detrimental effects of ego depletion, athletes may be more likely to perform optimally.

**Limitations**

Despite yielding important findings, there are some study limitations worth noting. Specifically, we cannot generalize our results to other sports or to more elite skill levels, as our sample consisted of recreational (noncompetitive) dart tossers. It is also possible that experimenter bias impacted the results of this study, as the experimenter conducting the study was aware of the hypotheses. This was considered beforehand and numerous steps were taken to eliminate or reduce any potential issues, such as employing a script for the entire experimental trial. The experimenter was mindful to only say things outlined in the script as best as he could and avoid providing praise or encouragement for some participants but not others. Nonetheless, it would have been beneficial to ensure the experimenter remained blind to condition assignment perhaps by employing another experimenter to conduct part of the experiment. This may have included having a second experimenter who was blind to condition assignment measure accuracy and a third experimenter conduct the Stroop task. Another possible method could have been to have participants complete an electronic version of the Stroop task on a laptop with the experimenter being unable to see this task being completed.

**Future Directions**

To address the limited generalizability of our results, it would be valuable for researchers to conduct similar experiments on other skill-based sports tasks with both elite and nonelite athletes. In addition, similar to our findings that support the assertion that there are individual differences in trait self-control (Tangney et al., 2004), it has recently been suggested that self-control strength depletion may be moderated by situational factors (e.g., motivation and instruction sets) as well as individual differences and feedback (e.g., Clarkson, Hirt, Jia, & Alexander, 2010; Vohs, Baumeister, & Schmeichel, 2012). In light of these recent advances, it may be valuable to determine the extent to which athletes’ motivation or perceptions of their depletion have an effect on their performance following self-control strength depletion. It may also prove beneficial to assess the efficacy of a self-regulation training program for improving performance on skill-based tasks that require self-regulation by bolstering trait self-control (cf. Oaten & Cheng, 2006). Discovering ways to ameliorate the negative effects of ego depletion on task performance is important and may provide a beneficial addition to athletes’ current psychological skills training programs. Future research should also test for the explanatory mechanisms underlying ego depletion effects. While it is clear from considerable experimental evidence that depleting individuals’ self-control strength generally results in poorer performance on a second task that also requires self-regulation, there is limited evidence that explains why this occurs. It is also not clear if certain aspects of self-regulation (e.g., cognitive decision making, attention regulation, planning motor movements) are more important than others in the performance of a skill-based sports task. These should be considered important next steps in self-regulation research. By digging deeper into these causal explanations, researchers would provide a more complete model of self-regulation.

**Conclusion**

The results of the current study make an important and unique contribution to the self-regulation literature. Namely, we have provided evidence that ego depletion effects also occur in the execution of skill-based sports tasks. This opens up a new and potentially very important line of research within the areas of self-regulation and sport psychology.

**References**


*Manuscript submitted: July 9, 2012
Revision accepted: January 12, 2013*