EFFECTS OF COGNITIVE CONTROL EXERTION ON FEELING STATES AND PERFORMANCE OF A GRADED EXERCISE TEST

EFFECTS OF COGNITIVE CONTROL EXERTION ON FEELING STATES AND PERFORMANCE OF A GRADED EXERCISE TEST

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ABSTRACT

Exerting cognitive self-control leads to subsequent decrements in muscular and cardiovascular endurance performance. According to the Process Model of self-control, affective feeling states may account for later self-control impairments. Affective feeling states are sensitive to exercise and show a pronounced negative shift in valence at the ventilatory threshold (VT). The purpose of this study was to investigate feeling states in response to a challenging cognitive control task (stop-signal task; SST) followed by a graded exercise task to exhaustion (GXT). Recreationally active participants (N = 20; $M_{age} = 20.25$) completed two testing sessions separated by one week. Sessions were counterbalanced, with either a control (SST-C) or experimental (SST-E) task performed prior to each GXT. Feeling states were measured using the Feeling Scale (FS) and Felt Arousal Scale (FAS) throughout both tasks. Time to exhaustion on the GXT was significantly shorter following the SST-E than the SST-C (p < .05; d = .49). Repeated measures MANOVA showed similar within-task changes in FS in both conditions, but no significant differences between conditions during the SST tasks; however, FAS scores were significantly higher during the SST-E compared to the SST-C (p < .01). There were no significant differences in feeling states prior to, or upon completion of, the GXTs. However, FS was significantly less positive at iso-time corresponding to predicted VT in the SST-E condition (p < .05). Results show feeling states during exercise are altered by prior cognitive control exertion. Decreases in positive valence in concert with increased activation may prime a negative shift in affect as exercise becomes more strenuous and thereby reduce self-control (exercise tolerance), as predicted by the Process Model.

Alternatively, shifts in affect may reflect responses to physiological manifestations of fatigue that carry over from cognitive to physical tasks and become salient at moderate exercise intensities.

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LIST OF ABBREVIATIONS

ANOVA	analysis of variance
AX-CPT	AX-cognitive performance test
BRUMS	Brunel mood scale
FS	feeling scale
FAS	felt arousal scale
GXT	graded exercise test
HR	heart rate
IMI	intrinsic motivation inventory
MANOVA	multivariate analysis of variance
ms	millisecond
RER peak	peak respiratory exchange ratio
RPE	ratings of perceived exertion
RPME	ratings of perceived mental exertion
SPSS	Statistical Package for Social Sciences
SSD	stop-signal delay
SSRT	stop-signal response time
SST	stop-signal task
SST-C	control version of stop-signal task
SST-E	experimental version of stop-signal task
TLX	task load index
TTE	time to exhaustion
VCO ₂	carbon dioxide production
VO_2	oxygen consumption
VO ₂ peak	peak oxygen consumption
VT	ventilatory threshold
W	watts

DECLARATION OF ACADEMIC ACHIEVEMENT

J.C. Zering's role:

- Amended ethics application at McMaster University
- Designed study protocol and chose measures
- Recruited participants
- Organized visits and set up lab equipment and materials
- Supervised volunteers assisting with data collection

Role of co-authors:

- SB assisted JZ with ethics application
- SB assisted JZ with study design and selection of measures
- SB obtained study funding
- SB assisted JZ with data interpretation

Introduction

Self-control refers to the capacity or ability to exert control over thoughts, behaviours, and emotions to reach a desired outcome or goal (Baumeister, Vohs, & Tice, 2007). One area in which self-control serves an important role is in physical exercise (Hagger, Wood, Stiff, & Chatzisarantis, 2010a). For example, athletes use self-control to persist through exhausting workouts and complete the exercises required by their training schedule. In doing so, they override feelings of discomfort to purse a goal of increasing their bodies' abilities to run faster, lift more, or jump higher. However, many athletes would likely agree that while training is never supposed to be easy, some days it feels harder than others. One day, persistence may be relatively easy, and the athlete will find the strength to complete the tasks at hand. Yet, on another day, perhaps after writing a difficult exam, the athlete may fall short of his/her goals and give up before completing them. Of particular interest for this study was how people make decisions regarding selfcontrol, as well as what precipitating factors could influence their exertion of self-control and thus change behaviour and the outcome of their choices.

One theoretical model that has been used extensively to investigate how selfcontrol relates to successful and unsuccessful regulation of behaviour is the strength model of self-control (Baumeister et al., 2007). This model proposes that self-control is a limited resource that can be tapped out or depleted through use. In particular, the model suggests that how much of the resource one has available influences his/her performance on subsequent behaviours that require self-control. There have been a multitude of studies that have supported this idea (Hagger, Wood, Stiff and Chatzisarantis, 2010b). However,

the integrity of the strength model has come under criticism, primarily in terms of whether the self-control "resource" is truly limited or whether self-control is determined by motivational and affective processes that involve evaluation of costs and benefits associated with performing a behaviour or not (Inzlicht & Schmeichel, 2012; Kurzban, Duckworth, & Kable, 2013). Indeed, several studies have shown that when people are enticed with rewards or are more intrinsically motivated to exert self-control, they tend to perform better, while those who do not receive rewards or are less motivated do not (Graham, Bray, & Martin Ginis, 2014; Muraven & Slessareva, 2003). Other studies have shown that manipulating affective (emotional) states can also influence how much self-control people are willing or able to exert (e.g., Tice, Baumeister, Schmueli, & Muraven, 2007).

The process model of self-control (Inzlicht & Schmeichel, 2012; Saunders & Inzlicht, 2016) proposes that people naturally seek a state of "cognitive comfort" that is both satisfying and free of unpleasantness. The model further speculates that exerting self-control on tasks that do not have a high degree of reward or subjective utility is inherently aversive and brings about an unpleasant emotional episode that disrupts one's comfort. For example, when people resist temptations to engage in rewarding activities or override their habitual behavioural tendencies, it brings about feelings that are less pleasant than those experienced when they are rewarded or when they behave as they normally would.

To support this theorizing, Inzlicht and colleagues (Inzlicht & Scmeichel, 2012; Saunders & Inzlicht, 2016) point to research showing that prior performance of cognitive

control tasks involving response errors or conflicts primes negative affect as shown in faster responses to negative stimuli (Aarts, De Houwer, & Pourtois, 2012; Aarts, De Houwer, & Pourtois, 2013; Dreisbach & Fischer, 2012). Further evidence indicates that prior performance of tasks involving response conflict leads to increased activation of facial muscles involved in frowning, which provides an indirect indicator of negative affect (Larsen, Norris, & Cacioppo, 2003; Lindström, Mattson-Mårn, Golkar, & Olsson, 2013). Yet other evidence shows that providing spontaneous, surprise, rewards mitigates the negative affect response to conflict (Van Steenbergen, Band, & Hommel, 2009; Van Steenbergen, Band, & Hommel, 2012). Together these findings support the idea that exerting self-control brings about a shift in affect to something less pleasant than one might otherwise feel.

To bring the affective response associated with self-control exertion into a behavioural perspective, Saunders and Inzlicht (2016) highlight the role of affect as it relates to task motivation. Specifically, they note the negative affective experiences brought on by prior self-control exertion may decrease one's motivation or willingness to engage in subsequent activities that require self-control and thus exacerbate the negative feeling states already incurred by their prior exertion of self-control.

In the present study, people's affective responses to tasks requiring self-control exertion were investigated. Participants completed two experimental sessions involving sequential tasks. In one session, both tasks required high levels of self-control exertion while in the other, only the latter task required exertion of self-control. Throughout both tasks, participants' affective states were monitored and evaluated to determine the effects

of self-control exertion on affect during the tasks and whether prior self-control exertion was associated with differential affective responses from one task to the other.

Literature Review

Self-control refers to the capacity or ability to exert control over thoughts, behaviours, and emotions to reach a desired outcome or goal (Baumeister et al., 2007; Baumeister, 2014). Self-control is a central component for achieving success in both training and competition settings across sport and exercise activities (Kirschenbaum, 1987; McEwan, Martin Ginis & Bray, 2013; Weinberg & Gould, 2014). For example, waking up and arriving to a morning training session on time, choosing to forego a late night of partying to get adequate sleep prior to competition, and pushing oneself in weight training to achieve beyond what is expected and optimize performance all require selfcontrol.

The strength model of self-control suggests there is an internal resource that provides the energy necessary to exert control over one's emotions, behaviours, and cognitions (Baumeister, Bratslavsky, Muraven, & Tice, 1998). However, this resource can become depleted or fatigued with use, and leave people less able to exert control compared to when their self-control resources are fully intact (Baumeister et al., 2007). This weakened state is referred to as ego depletion or self-control strength depletion (Baumeister et al., 1998).

Although self-control may be studied in many ways, the most common method of investigating self-control strength, or ego-depletion, is a dual-task (or sequential-task) experiment (Hagger et al., 2010b). A typical dual-task experiment has two groups of

participants, wherein one group completes an initial task that requires self-control and the other performs a "control" task that does not involve self-control. After completing the initial task, all participants complete an identical criterion task that requires self-control and performance on the criterion task is compared between the groups. An alternative to the typical dual-task design is one in which all participants complete an initial criterion self-control task to establish a baseline score, then they are randomized to either perform another self-control task or a control task, followed by a repeat performance of the criterion self-control task. In the alternative design, a change score, representing the difference between the first and second score on the criterion task is used to compare group performance.

A recent meta-analysis summarized the literature on self-control strength depletion up to 2010. The overall results revealed that performance of an initial self-control demanding task leads to a carryover effect and negatively influences performance on subsequent tasks requiring self-control (Hagger et al., 2010b). Consistent with the strength model proposition that all acts of self-control draw upon a common resource, carryover decrements in self-control performance show similar effects within the same domain (e.g., two consecutive physical self-control tasks performed consecutively; d = .59) and across domains (e.g., emotional self-control tasks followed by cognitive self-control tasks; d = .63).

A variety of tasks have been used in studies investigating the self-control depletion effect. Of particular interest for the present study is research that has used physical performance as the criterion self-control task. One of the earliest studies to

investigate the ego-depletion effect showed that people who exerted self-control to supress the image of a white bear exhibited reduced performance on an endurance exercise task requiring participants to hold a submaximal isometric handgrip squeeze for as long as possible (Muraven, Tice, & Baumeister, 1998; Study 2). Handgrip endurance has since been investigated in numerous studies that reveal a consistent negative carryover effect following a variety of cognitive self-control manipulations (e.g., Bray, Graham, Martin Ginis, & Hicks, 2012; Bray, Martin Ginis, Hicks, & Woodgate, 2008; Bray, Martin Ginis, & Woodgate, 2011).

Although isometric endurance handgrip squeezing has been the exercise task that has received the most attention in the self-control strength depletion literature, the high self-control demands of other forms of exercise have also been shown to be vulnerable to self-control depletion. For example, negative effects of prior cognitive self-control exertion have also been seen for tasks involving skilled motor performance. McEwan et al (2013) found cognitive self-control depletion hampered performance on a dartthrowing task. Similarly, Englert, Persaud, Oudejans, and Bertrams (2015) showed performance on a sprint reaction time task was impaired by prior cognitive self-control exertion.

Research on self-control depletion on exercise has also looked at tasks requiring cardiovascular and muscular fitness. In the first study to investigate the effects of selfcontrol depletion on a task involving cardiovascular exercise and motivation to engage in exercise, Martin Ginis and Bray (2010) showed that exerting cognitive self-control performing a modified Stroop task led to reduced performance on a cycling exercise task

and reduced motivation to exert effort on subsequent resistance exercise tasks. Dorris and colleagues (2012) showed that prior performance of a cognitively demanding self-control task led to negative effects on performance for trained athletes performing maximum tests of strength using push-ups and sit-ups.

The manipulation of cognitive self-control has been the focus of most studies investigating self-control depletion in exercise. However, a recent study examined the effect of emotion control on subsequent exercise performance. Wagstaff (2014) had participants complete a modified Stroop task, watch a brief video, then perform a 10 km time-trial cycling test. The video contained content designed to induce disgust. Participants in the emotion self-control condition were instructed to supress their emotional responses and not express or show any emotions while watching the video. while those in the control (no emotion suppression) condition simply watched the video and responded naturally. A separate control group performed the same modified Stroop and exercise tasks, but did not watch a video. Results showed participants in the emotion suppression condition completed the time trial slower, reached lower mean power output, achieved a lower maximum heart rate, and reported higher ratings of perceived exertion, compared to the no-suppression and control conditions. There were no differences in completion time, mean power output, maximum heart rate, perceived exertion, or oxygen uptake between the no-suppression and control conditions.

An important aspect of Wagstaff's study was the criterion exercise task involved whole body, cardiovascular, exercise performance. Cardiovascular exercise capacity is not only a requirement for many sport tasks, but it is also a major target component of

public health recommendations (Tremblay, Warburton, Janssen, Paterson, Latimer, Rhodes, Kho, Hick, LeBlanc, Zehr, Murumets, & Duggan, 2011). Accordingly, understanding factors that could impede people's abilities to perform cardiovascular exercise has important implications for sport performance as well as population health.

In a recent study, Zering, Brown, Graham, and Bray (2016) investigated the aftereffects of prior cognitive self-control exertion using a graded exercise test (GXT) of cardiovascular exercise performance. In this study, a randomized crossover design was used. Recreationally-active participants (N=15) completed two maximal VO₂ exercise tests on a cycle ergometer. Prior to one test, participants performed a stop-signal task (SST; StopIt_{TM}; Logan, Cowan, & Davis, 1984) that involved response inhibition and high cognitive demands, while the other test was preceded by a time-matched control task with no cognitive demand (watching a brief documentary video). The VO₂ max task was selected because it is a progressive resistance test that gradually increases the exercise self-control demands beginning at a light resistance (50 Watts) and escalates at 1 Watt/2 seconds until the participant can no longer continue to pedal the cycle. This progressive protocol allowed for the investigation of a variety of psychological and physiological responses as participants' self-control was progressively challenged during the test. Physiological variables measured during the VO₂ test included heart rate, peak oxygen consumption (VO₂ peak), peak respiratory exchange ratio (RER peak), and ventilatory threshold (VT). The primary psychological factor was participants' ratings of perceived effort or exertion (RPE) throughout the tests.

Results of the study revealed participants' time to exhaustion (TTE) on the GXT was significantly shorter after completing the SST compared to the control task. VO₂ peak was also significantly lower after completing the SST compared to the control condition, which is likely attributable to the lower workload achieved. There were no significant differences between conditions for peak heart rate, RER peak, or VT. Furthermore, heart rate over the course of the exercise tasks revealed identical values between conditions. However, there were differences between the conditions in RPE. Interestingly, no differences were evident during the first two minutes of the GXT when the exercise workload was relatively low, yet RPE was significantly higher during the later minutes of the test when workload was more difficult.

Zering et al.'s (2016) study was the first to have used the sequential task paradigm from the self-control literature to show the negative carryover effect of a brief, demanding cognitive task on whole-body exercise performance. However, there have been three studies that have employed longer duration, cognitively demanding tasks to investigate the effect of "mental fatigue" on exercise performance.

In a study by Marcora, Staiano, and Manning (2009), the AX-cognitive performance test (AX-CPT) (Barch, Braver, Nystrom, Forman, Noll, & Cohen, 1997; Critchley, Mathias, Josephs, O'Doherty, Zanini, Dewar, Cipolotti, Shallice, & Dolan, 2003) was used to induce mental fatigue. The AX-CPT requires sustained attention, working memory, error monitoring, and response inhibition, which are all components of executive function (Miyake, Friedman, Emerson, Witzki, & Howerter, 2000) and require self-control strength (Hofmann, Schmeichel & Baddeley, 2012). Participants in the study

performed two endurance cycling tasks. In the control condition, they watched a 90minute documentary followed by the cycling task. In the experimental condition, they performed the AX-CPT for 90-minutes and then completed the cycling task. The cycling task had a 3-minute warm-up at 40% peak power, followed by a constant load of 80% peak power at which participants cycled until exhaustion. The variables assessed by the researchers included time to exhaustion (TTE) on the cycling task, as well as success motivation and intrinsic motivation related to the cycling task, RPE, subjective fatigue and vigour, in addition to physiological measures including: blood glucose, heart rate, respiratory gas exchange (VO₂ peak, minute ventilation), stroke volume, cardiac output, blood pressure, and mean arterial pressure.

Results showed TTE on the cycling task was significantly shorter in the experimental condition compared to the control condition (p < .01). There were significant differences between conditions in the physiological variables; however, these were reflective of the fact that participants cycled for longer in the control condition and thus showed higher heart rate and blood lactate levels at the completion of exercise in that condition. There was no difference in motivation between conditions. The BRUMS revealed a significant increase in fatigue in the experimental condition, which supported the intended effect of the AX-CPT manipulation. One notable finding was that RPE was significantly higher in the experimental condition from the outset of the exercise task compared to the control condition and remained higher until the ratings peaked at the end of the test when the cyclists were exhausted.

A study by MacMahon, Schücker, Hagemann and Strauss (2014) also investigated the connection between cognitive fatigue and physical performance. In contrast to Marcora et al.'s (2009) study that used a fixed-load endurance test, this study used a selfpaced running time trial. Twenty healthy runners (n = 2 female; $M_{age} = 25.4$) who normally ran an average of 2.8 times per week participated in this study. Participants completed two 3km time trials in counterbalanced order. One time trial was preceded by a full 90-minute session of the AX-CPT and the other by a documentary film that participants watched for 84 minutes and completed three minutes of the AX-CPT before and after the film. Results showed the time trial run was completed significantly faster in the control condition, with significantly faster first and last laps. There were no differences between conditions in heart rate, blood lactate, motivation, or RPE. The RPE results are interesting to note, insofar as they reflect the fact that participants felt the same level of exertion despite running slower in the cognitive fatigue condition.

A study by Pageaux, Lepers, Dietz, and Marcora (2014) also explored the effect of a demanding cognitive control task on subsequent self-paced, time-trial exercise. In this study, twelve recreationally-active participants completed two 5 km running time trials in separate testing sessions in counterbalanced order. One time trial was completed following performance of an incongruent Stroop task for 30 minutes (experimental condition) and the other following performance of a congruent Stroop task for 30 minutes (control condition). Participants completed the time trial run significantly slower in the experimental condition and there were no differences between conditions in motivation, mood, perceived mental fatigue, pacing strategy, heart rate, or blood lactate. However,

participants rated higher perceived exertion (RPE) during the 5km run in the experimental condition.

Together, the findings of Pageaux et al. (2014), Marcora et al. (2009), MacMahon et al. (2014), and Zering et al. (2016) show that having participants complete tasks requiring cognitive control exertion negatively influences performance on whole-body endurance exercise tasks. Interestingly, none of these studies found significant differences in physiological variables that would explain why time to exhaustion or time to complete the fixed-distance runs should vary. Yet, each of the studies indicated perceptions of effort (RPE) while performing the exercise was a factor.

Although RPE during endurance exercise has been found to increase following prior exertion of cognitive self-control, it is not clear what processes may lead to greater RPE during exercise. One limitation of RPE is that it was developed as an indicator of one type of feeling state: perceived exertion experienced during exercise. Consequently, RPE has questionable utility for investigating people's feeling states when they are engaged in activities other than exercise.

As noted earlier, Saunders and Inzlicht (2016) recently proposed that negative carryover effects between tasks that require high levels of self-control may be explained by changes in affective feeling states. Drawing from the dimensional perspective of core affect and Russell's (2003) conceptualization of affective feeling states, Saunders and Inzlicht highlight two orthogonal continua of feeling states that are relevant to selfcontrol. One refers to valence, ranging from unpleasant to pleasant, and the other refers to arousal or activation, ranging from sleep to frenzy. In contrast to RPE, the dimensional

perspective of affect accommodates the measurement of feeling states regardless of whether they are attributable to cognitive or physical stimuli.

To date, no study has investigated affective feeling states in a study involving sequential cognitive and physical exertion tasks; however, research by Hall, Ekkekakis, and Petruzzello (2002) has measured feeling state responses to a GXT. In that study, 30 healthy university students (n = 13 female; $M_{age} = 23.9$; $M_{VO2max} = 49.6$) completed a GXT on a treadmill and rated their affective valence and arousal during the GXT, as well as during rest/recovery, up to 20 minutes post-exercise. Results revealed during exercise activation increased linearly and valence decreased linearly as the GXT progressed, with the most pronounced negative shift in valence occurring after the participants reached their ventilatory threshold (VT). These results provide support that a GXT to exhaustion may provide a useful and relevant model to explore changes in affect that occur in response to both cognitive control exertion and whole-body exercise.

Statement of the Problem

The purpose of the present study was to investigate the affective feeling state responses to cognitive self-control exertion and progressive exercise to volitional exhaustion. Using a design similar to that of Zering et al. (2016), participants performed two progressive maximal graded exercise tests (GXT) in a counterbalanced design. In one condition they performed a stop-signal task (SST) involving response inhibition and cognitive self-control prior to the GXT and, in the other, a less-demanding version of the SST that did not involve response inhibition or cognitive control. Participants' affective

feeling states were assessed throughout the SST tasks, during the transition period between tasks, and during the GXTs.

Hypotheses

Based on prior research (Zering et al., 2016), it was hypothesized that exercise performance would be significantly lower (shorter time to exhaustion) in the cognitive self-control condition compared to the control condition. Based on theorizing by Saunders and Inzlicht (2016), it was hypothesized that participants would have less positive affective valence when performing the SST due to exertion of cognitive control and that valence would become progressively less positive throughout the task. Based on Saunders and Inzlicht (2016), it was hypothesized that the changes in affective valence caused by the cognitive control task would persist beyond the completion of the task. such that affective valence would be less positive at the beginning of the exercise test in the cognitive self-control exertion condition compared to the control condition. Drawing from Hall et al.'s (2002) evidence of the pattern of affective responses during a GXT, it was hypothesized that affective valence would be less positive in the cognitive selfcontrol condition compared to the control condition, with the greatest difference in valence occurring around the VT. Additionally, it was hypothesized that at termination of the GXT affective valence would be equal between conditions, revealing participants reached the same affective state in the cognitive self-control condition as in the control condition, but at a significantly earlier time in the test.

Method

Participants

The participants were 22 (n = 11 women) recreationally active university students ($M_{age} = 20.25$; range = 18 – 23). Inclusion criteria stated participants had to engage in at minimum three sessions of moderate or vigorous physical activity (MVPA) per week, but less than 120 minutes of leisure time physical activity per week and not actively engaged in a cardiovascular exercise training program. The Godin Leisure Time Exercise Questionnaire (Godin & Shephard, 1985) was administered prior to the start of the study to verify participants' current levels of exercise. Responses to this measure confirmed that all participants fell within the range that met the study criteria (Mean frequency MVPA = 5.60 ± 2.12 sessions of 10 minutes per week; Range 3.00-11.50).

Task, Measures, and Apparatus

Baseline graded exercise test (GXT).

Participants performed a graded exercise test (GXT) to exhaustion on a cycle ergometer (Lode Corival, Groningen, The Netherlands). Each participant was fitted to the ergometer, with the handle bars adjusted to the participants' comfort, and the seat set so their leg was close to full extension (165 to 175 degrees) at the down-stroke while pedaling. Participants completed a ramped protocol consisting of a two minute warm-up at 50 Watts, followed by continuous ramp increasing in resistance of 30 Watts perminute, or 1 Watt every 2 seconds. Participants were instructed to maintain a pedalling speed of 60 to 100 RPM and to continue pedalling until they reached volitional exhaustion, which was operationally defined as when the subjects' speed fell below 50

RPM. Participants were given no feedback on time or workload completed. Additionally, no motivational encouragement was provided at any time during the test. The primary outcome from this test was peak power (the maximum workload achieved).

A metabolic cart (2700 series; Hans Rudolph, Kansas City, MO) with an online gas collection system was utilized to monitor oxygen consumption (VO₂) and carbon dioxide production (VCO₂) during the GXT. Participants were fitted with a nose clip and two-way valve mouthpiece connected to the metabolic cart. Respiratory gas exchange data from the metabolic cart were exported from ExPairTM software and imported into WinBreakTM (Version 3.7; Epistemic Mindworks, Ames, IA) software for the determination of VT, which was computed using the V-slope method derived from Beaver's algorithm (Beaver, Wasserman, & Whipp, 1986). The Watts achieved at the time of VT was recorded and later used along with the peak power achieved on the GXT to create the individualized protocols for sessions two and three.

Modified GXT.

Previous studies have discovered cognitive fatigue affects perceived exertion, as measured by RPE (Marcora et al., 2009), and exercise performance at intensities beyond the estimated ventilatory threshold (Zering, Brown, Graham & Bray, 2016). Therefore, the goal in designing this two-stage protocol was to have participants reach their estimated VT at an early and equivalent time (approximately 3 minutes and 30 seconds) after the beginning of the first stage and then continue on a progressive ramp that would reach their predicted peak power (as determined by their baseline GXT) approximately seven minutes after reaching their VT. For example, a participant with a peak power of

175 Watts who reached their estimated VT at 105 Watts would have the standard 2 minute warm-up at 50 Watts, followed by a 15 Watt per minute increase to VT at 105 Watts (Slope 1 = (Watts at VT [105] – 50Watts) / 3.5) for the first stage and then a 10 Watt per minute increase from VT to peak power (Slope 2 = (Watts at Peak Power [175] – Watts at VT [105]) / 7) for the second stage.

As was the case for the baseline GXT, participants were instructed to maintain a speed of 60 to 100 RPM and to continue pedalling until they reached volitional exhaustion, which was operationally defined as the time in the test at which the participant's speed fell below 50 RPM. Participants were given no feedback on time or workload completed. Additionally, no motivational encouragement was provided at any time during the test.

Primary Outcomes

Time to exhaustion (TTE) on the GXT. TTE was the primary dependent variable and was represented by the duration of time (seconds) elapsed from the onset of Stage 1 to the point of voluntary exhaustion on the modified GXT.

Feeling Scale (FS). The Feeling Scale (Hardy & Rejeski, 1989) was used to measure the valence (pleasure/displeasure) dimension of affective feeling states throughout the SSTs and the modified GXTs. The FS is a single-item measure that employs an 11-point, bi-polar scale ranging from -5 (very bad) to +5 (very good). Participants were educated about how to rate their feeling states on the FS using the original instructions developed by Hardy and Rejeski (1989) prior to its use in each session (See Appendix A for full instructions).

The scale was printed and laminated on a piece of 8" by 11" paper in size 16 Times New Roman font. During the SSTs, the scale was held in front of the computer monitor and participants were prompted to either point to the number or verbally respond with their score. For the modified GXTs, the scale was held in front of the participants' handlebars, and they were asked to either point to or verbally respond to indicate what number on the scale represented their current feeling.

Felt Arousal Scale (FAS). The Felt Arousal Scale (Svebak & Murgatroyd, 1985) was used to measure the activation dimension of affective feeling states throughout the SSTs and the modified GXTs. The FAS is a single-item measure that employs a 6-point scale ranging from 1 (low) to 6 (high). Participants were educated about how to rate their feeling states on the FAS using the original instructions developed by Svebak and Murgatroyd (1985) prior to its use in each session (See Appendix A for full instructions). The FAS was printed and laminated on a piece of 8" by 11" paper in size 16 Times New Roman font. Administration of the FAS was identical to that for the FS for the SST and GXT.

Secondary Outcomes

Heart rate (HR). Heart rate was recorded at 30-second intervals during the modified GXTs beginning at the start of the warm-up and continuing until termination of the tests. HR was measured using a Polar heart rate monitor (T31 transmitter; Polar Electro OY, Kempele, Finland) and corresponding watch (Polar FT1; Polar Electro OY, Kempele, Finland).

Rating of perceived exertion (RPE). The Borg's RPE scale was employed to assess participants' perceived physical exertion (Borg, 1998) during the modified GXTs. The RPE scale is a single-item measure that employs a 15-point scale ranging from 6 (no exertion at all) to 20 (maximum exertion). Instructions for this scale were provided prior to the first modified GXT (See Appendix A for full instructions). Participants were prompted to provide a RPE at the start of the warm-up for modified GXTs and at oneminute intervals beginning at the onset of the GXT ramp and a final rating upon termination of the test. The scale was printed and laminated on a sheet of 8" by 11" paper in Times New Roman font, size 16. The scale was held in front of the participants' handlebars, and they were asked to either point to or verbally respond to indicate what number on the scale represented their current RPE.

Experimental Manipulations

Stop-signal task (SST-E). The cognitively-demanding self-control task was a 10 minute and 30 second computerized stop-signal task (StopItTM)(Verbruggen, Logan, & Stevens, 2008). The StopItTM task consisted of a practice block of 10 trials and three test blocks of 30 trials each, for a total of 100 trials. All trials begin with a fixation sign (+) presented in the center of a computer monitor followed by a stimulus that is either a square or circle shape appearing in place of the fixation sign. The response task requires participants to press the "z" key on the computer keyboard as quickly and accurately as possible when the square shape appears and the "/" key when a circle shape appears. During 75% of the trials, the square and circle images appeared in silence. For the other 25% of the trials an auditory signal (beep) occurred after the image appeared, as the stop-

signal delay (SSD). The SSD trials were randomly dispersed within the blocks. Participants were instructed to inhibit their response and refrain from pressing the target key for the trials on which the tone sounded. The maximum response execution time for each trial was 1,250 ms, with a 2,000 ms gap between trials, regardless of response time.

The StopItTM test uses the "horse-race" model (Logan & Cowan, 1984) to ensure participants inhibit approximately 50% of their responses; meaning, the SSD automatically adjusts in speed based on a staircase-tracking pattern. That is, when inhibition is successful on a SSD trial, the program increases the latency of the SSD by 50 ms for the next SSD trial, creating a longer gap between the visual stimulus and the tone, causing the participant to wait to respond to the image in anticipation that a tone may sound. When inhibition is unsuccessful on a SSD trial, the SSD decreases by 50 ms for the next SSD trial. The reaction times on trials with no inhibition component are ranked and the number of these reaction times is then multiplied by the probability of responding on an inhibition trial. This value provides an estimate of the inhibition process relative to the go-signal (image appearing on screen). By subtracting the SSD from this value (inhibition process time), the stop-signal response time (SSRT) is determined (Logan, 1994). Several studies have used the SST as a measure of executive function (e.g., Berkman, Kahn & Merchant, 2014; Padilla, Perez, Andres, & Parmentier, 2013) as well as to investigate cognitive self-control, both as a dependent variable (e.g., Muraven, 2010) and a method for inducing cognitive self-control fatigue (e.g., Hofmann, Friese & Roefs, 2009).

Stop-signal control task (SST-C). The SST-C utilized the same StopItTM

computer program as the cognitively-demanding SST-E task. However, for the SST-C, there were no auditory beeps presented and therefore no response inhibition was required by the task. Participants were directed to respond as quickly as possible to the square and circle images on all trials using the "z" and "/" keys, respectively.

Manipulation checks

Rating of perceived mental exertion (RPME). A modified version of Borg's CR-10 RPE scale was used to measure participants' perceived mental exertion. The RPME scale is a single-item measure upon which participants rate how much mental effort they exerted using an 11-point scale ranging from 1 (no effort at all) to 10 (maximum effort). The RPME scale has been used to assess mental exertion in previous studies (e.g., Bray et al., 2012; Graham et al., 2014; Zering et al., 2016)

NASA Task Load Index (TLX). Participants assessed how demanding the SST was using the NASA TLX (Hart & Staveland, 1988). The NASA TLX is comprised of six items (mental demand, physical demand, temporal demand, performance, effort, frustration) that are rated on 21-point scales ranging from very low (1) to very high (21), with the exception of performance, which is anchored by the descriptors "perfect" and "failure".

Potential covariates

Task motivation. Current theorizing has suggested that motivation may play an influential role in changes that are observed in self-control strength following self-control depletion tasks (Inzlicht & Schmeichel, 2012). Motivation was measured using the

Intrinsic Motivation Inventory (IMI) 5-item effort and importance subscale (Ryan, 1982) immediately before the modified GXTs. Example items from the scale include: "I will put a lot of effort into this task," "I am going to try very hard on this activity," and "It is important to me to do well at this task." The measure was completed prior to the GXTs and was prefaced with the statement: "For the bicycle task I am about to do:". Internal consistency for the scale at each administration was high (Cronbach's $\alpha > .90$).

Design & Procedures

This study utilized a randomized crossover design. Ten participants performed the SST-E trial first and ten performed the SST-E trial second. The order groupings (SST-E first, control second; control first, SST-E second) were stratified by gender and balanced for mean peak power (SST-E first: M_{PP} = 237.0; SST-E second: M_{PP} = 232.8). Participants performed each testing session at the same time of day, with one week between each testing session. Participants were instructed to avoid consuming caffeine within 3 hours of testing, to get at least 8 hours of devoted rest the night before each session, and consume similar meals on both the day before and the day of testing.

Participants attended the lab on three occasions. The first session was a habituation session, designed for participants to gain comprehension of the measures being taken in the study (primarily RPE, FS, FAS) and complete the baseline GXT. At the beginning of the session, participants were given information about the study procedures and provided informed consent. They were then fitted with the heart rate monitor and completed the demographics questionnaire. Next, the researcher fully explained the rating instructions for the RPE, FS, and FAS, height (cm) and weight (kg) were measured using

a Detecto scale (Detecto Weigh-Beam Eye Level Scale; Webb City, MO). Then participants were set up on the cycle ergometer and metabolic cart and then performed the GXT. Upon completion of the GXT, participants performed a cool down for 3 minutes at a resistance of 50 Watts. Following the cool down the heart rate monitor was returned and the next testing session was scheduled.

During the second and third testing sessions, participants were fitted with a heart rate monitor and given instructions for completing the RPME scale, Felt Arousal Scale, and Feeling Scale. Participants then completed the SST-E during one session and the SST-C in the other. Following the practice block and each of the testing blocks of the SST, participants completed the RPME, FS, and FAS measures. Upon completion of each SST, there was a standard 5-minute transition period during which participants completed the NASA TLX and the IMI measure and were fitted to the ergometer for the modified GXT. The experimenter briefly went over the instructions for the RPE, FS, and FAS scales once again to verify the participants understood the measures.

They then performed the modified GXT. RPE, FS, and FAS ratings and HR were recorded at the beginning of the warm-up and upon completion of the warm-up prior to beginning the first stage of the GXT. Thereafter, participants provided ratings of RPE at the 60-second point of each minute of exercise completed and ratings of FS and FAS at the 30-second point of each minute. Heart rate was also recorded at the top of each minute. Ratings on the RPE, FS, and FAS measures, as well as HR, were obtained at termination of the modified GXT, after which participants performed a 2-minute cool down at 50 Watts and dismounted the ergometer. They then either verified the date and

time of their next session if it was their second testing session, or were debriefed and thanked for their participation in the study if it was their final testing session. Participants were given no verbal encouragement at any time during the exercise or cognitive tests. Participants were given honoraria of \$5 for the first session and \$10 for each of sessions two and three. All procedures were reviewed and approved by an institutional research ethics board.

Sample Size Calculation

Sample size for the experiment was determined based on the primary hypothesis predicting a main effect for experimental condition on TTE on the modified GXT. G-power calculations based on a 2 (condition) 1-way repeated measures design with power = .80, alpha = .05, and a large effect size (partial η^2 = .50; based on prior research by Zering et al., 2016), indicate a sample size of 6/order group is sufficient. However, given the additional hypotheses relating to affect and other responses to exercise, a larger sample was recruited (N = 22).

Data Analysis

Preliminary data screening was performed and descriptive statistics were computed for all variables. For the manipulation checks, RPME scores were analyzed using a 2 (condition) X 4 (time) repeated measures ANOVA, and NASA-TLX scores were evaluated using paired *t*-tests for each of the 6-items. The potential covariate, task motivation, was evaluated using a one-way repeated measures ANOVA.

The first hypothesis was analyzed using a 2 (condition) X 2 (order) mixed ANOVA for time to exhaustion (TTE) on the GXT, treating order of testing as a between

groups factor. To investigate the impact of the different versions of the SST on affective valence and activation, the second hypothesis was evaluated using a 2 (feeling state) X 4 (time) X 2 (condition) repeated measures MANOVA. A 2 (feeling state) X 2 (condition) repeated measures MANOVA was computed on the FS and FAS scores taken at the beginning of the warm-up on the modified GXTs to evaluate the carryover effect of affective feeling states from the SST. Differences in valence and activation from the beginning of the modified GXT ramp to the VT (3:30 into the GXT ramp) were assessed using a 2 (feeling state) X 4 (time) X 2 (condition) repeated measures MANOVA. A 2 (feeling state) X 4 (time) X 2 (condition) repeated measures MANOVA. A 2 (feeling state) X 4 (time) X 2 (condition) repeated measures MANOVA. A 2 (feeling state) X 4 (time) X 2 (condition) repeated measures MANOVA. A 2 (feeling states between conditions at the termination of the modified GXT. Heart rate and RPE measures from the modified GXT were analyzed using separate 2 (condition) X 6 (time) repeated measures ANOVAs.
Results

Data screening and checking assumptions

All data were screened for normality; ranges of skewness and kurtosis fell within the acceptable range of -2 to +2, with the exception of the FAS and FS scores taken at the termination of the GXT. These final scores were all clustered at the end of the scales, as participants hit the extreme levels of feeling states at exhaustion. After examination of these scores, one participant showed non-varying FAS values in all sessions and therefore was dropped from the study.

Response time data (SSRT) from the SST were screened as recommended by Verbruggen et al. (2008), to ensure participants completed the task properly and the distributions of scores were normal. Specifically, in accordance with the horse-race model that the program is based on, the probability of responding accurately to the signals (SSD) should be 50 percent if the participants are completing the task properly (Band, Der Molen, & Logan, 2003). Data from one participant were dropped from the study because SSD response probability was significantly different from 50, indicating the participant did not complete the task correctly. Therefore after screening, data from 20 participants were used for analysis.

Potential Covariates

The motivation measure revealed high scores on the IMI scale in both conditions prior to performing the GXTs: SST-C (M = $6.23 \pm .67$), SST-E ($6.22 \pm .69$). A one-way ANOVA revealed motivation was not significantly different between conditions, *F* (1, 19) = .01, *p* = .92, partial η^2 = .00.

Manipulation Checks

Ratings of perceived mental exertion (RPME) for the SST-C and the SST-E are presented in Table 1. Results of a 2 (condition) X 4 (time) repeated measures ANOVA show significant main effects for time, F(3, 17) = 7.50, p < .001, partial $\eta^2 = .57$, and condition, F(1, 19) = 17.82, p < .001, partial $\eta^2 = .48$, and a significant condition X time interaction, F(3, 17) = 3.28, p = .046, partial $\eta^2 = .37$. Post-hoc paired *t*-tests revealed significantly greater RPME after completing the SST-E compared to the SST-C at postpractice, t(19)=-2.42, p = .03, post-block 1, t(19)=-4.20, p < .001, post-block 2, t(19)=-4.90, p < .001, and post-block 3, t(19)=-3.82, p < .001. These results support an interpretation that the SST-E required significantly more mental exertion compared to the SST-C.

Table 1

	SST-C	SST-E		
	$M \pm SD$	$M \pm SD$	t	
RPME post-practice	.85 ± .94	1.46 ± 1.14	-2.42*	
RPME post-block 1	1.01 ± 1.01	2.01 ± 1.18	-4.20**	
RPME post-block 2	$1.08 \pm .98$	2.39 ± 1.47	-4.90**	
RPME post-block 3	1.32 ± 1.24	2.54 ± 1.50	-3.82**	

Ratings of Perceived Mental Exertion throughout the SST

Note. SST-C = stop signal test – control; SST-E = stop signal test – experimental; RPME = rating of perceived mental exertion.*: p < .05; **: p < .01

Scores for the NASA TLI are presented in Table 2. Paired *t*-tests were used to evaluate the differences in the six sets of scores. Results reveal significant differences for mental, t(19) = -4.53, p < .001, temporal, t(19) = -2.31, p = .03, performance, t(19) = -5.52, p < .001, effort, t(19) = -2.73, p = .01, and frustration, t(19) = -5.59, p < .001. There was no significant difference between conditions on the score for the physical item, t(19) = -1.84, p = .08.

Table 2

NASA Task Load Index scoring demand required by the SST

	SST-C	SST-E	
	$M \pm SD$	$M \pm SD$	t
Mental	3.78 ± 2.91	7.93 ± 4.28	-4.53**
Temporal	6.20 ± 5.22	9.08 ± 4.46	-2.31*
Performance	4.15 ± 3.48	8.68 ± 3.55	-5.52**
Effort	5.93 ± 5.15	9.78± 4.69	-2.73*
Frustration	4.10 ± 3.97	8.98 ± 4.58	-5.59**
Physical	1.53 ± 1.43	2.45 ± 2.31	-1.84

Note. SST-C = stop signal test – control; SST-E = stop signal test – experimental. *: p < .05; **: p < .01

Main Analyses

Time to Exhaustion (TTE). Examinations of the mean scores for conditions showed participants performed the GXT for 588.20 ± 135.55 seconds in the control condition and 570.10 ± 137.87 in the experimental condition, revealing a difference of 18.10 seconds between conditions. Participants' results on the two GXT measures are presented as intersecting points in Figure 1. The transverse diagonal line reflects equivalent performance on both tests. Points below the line represent participants who performed worse on the GXT following the experimental manipulation compared to the control, and points above the line indicate the participant performed better following the experimental manipulation. As evident from the Figure, a higher proportion of participants performed worse following the SST-E (15/20) than better (5/20). The effect of the experimental manipulation was evaluated using a mixed 2 X 2 ANOVA with SST condition as a repeated measures factor and order of testing as a between-subjects factor. Results revealed a significant main effect for condition, F(1, 18) = 4.39, p = .05, partial $\eta^2 = .20$. There was no main effect for order, F(1, 18) = .37, p = .55, partial $\eta^2 = .02$. Additionally, the interaction between condition and order was not significant, F(1, 18) = 1.11, p = .31, partial $\eta^2 = .06$.



Time to Exhaustion

Figure 1: Time to exhaustion (TTE) on the modified GXTs. The diagonal line represents equal performance in both conditions (reaching exhaustion at the same time). All points below the diagonal indicate TTE occurred sooner following the SST-E; all points above the diagonal indicate TTE occurred later flowing the SST-E.

Feeling states during SST. Scores for the felt arousal and feeling scales are presented by condition and over time in Table 3 and graphically represented in Figure 2 and Figure 3, respectively. The overall depiction of feeling states through the course of the experiment is shown in circumplex space in Figure 6. Following analyses reported by Hall et al. (2002), differences in feeling states during the SST-E and the SST-C and over time were evaluated using a 2 (feeling state) X 4 (time) X 2 (condition) repeated measures MANOVA. The main effects for feeling states, F(1, 19) = .85, p = .37, partial $\eta^2 = .04$,

time, F(3, 17) = .62, p = .61, partial $\eta^2 = .10$, and condition, F(1, 19) = 3.86, p = .06, partial $\eta^2 = .17$, were not significant. The interactions for feeling state X time, F(3, 17) =6.78, p < .001, partial $\eta^2 = .55$, feeling state X condition, F(1, 19) = 9.14, p = .01, partial $\eta^2 = .33$, and feeling state X time X condition, F(3, 17) = 4.41, p = .02, partial $\eta^2 = .44$, were significant. The time X condition interaction was not significant, F(3, 17) = 1.09, p = .38, partial n^2 = .16. The three-way interaction was not investigated further because the difference in the feeling state scales reflects their theoretical orthogonality and scaling (FS: -5 to +5; FAS: 1 to 6). However, pairwise comparisons of the independent feeling states between conditions were completed for each time point to decompose the condition X feeling state interaction effect. There were no significant differences in FS scores at any time point: post-practice, t(19) = -.13, p = .90, post-block 1, t(19) = .89, p = .38, postblock 2, t(19) = 1.41, p = .18, post-block 3, t(19) = 1.17, p = .26. Scores on the FAS were not significantly different post-practice, t(19) = -1.79, p = .09; however, there were significant differences post-block 1, t(19) = -4.47, p < .001, post-block 2, t(19) = -4.92, p = p < .001, and post-block 3, t(19) = -4.33, p < .001.



SST Block

Figure 2: Feeling scale scores by condition during the SST (post-practice, post-block 1, post-block 2, post-block 3). Bars represent standard deviations.



FAS during SST

Figure 3: Felt arousal scale scores by condition during the SST (post-practice, post-block 1, post-block 2, post-block 3). Bars represent standard deviations. **: p < .001

Feeling states at the start of the GXT warm-up. Scores for the FAS and FS at the start of the warm-up for the GXT are presented by condition in Table 3 and graphically depicted in Figures 4 and 5, respectively. The overall depiction of feeling states through the course of the experiment is shown in circumplex space in Figure 6. A one-way repeated measures MANOVA was computed to compare FS and FAS scores between conditions. Results showed the main effect for feeling state, F(1, 19) = 2.53, p = .13, partial $\eta^2 = .12$, the main effect for condition, F(1, 19) = .35, p = .56, partial $\eta^2 = .02$, and

the feeling state X condition interaction, F(1, 19) = .01, p = .95, partial $\eta^2 = .00$, were not significant.

Feeling states during GXT. Scores for the FS and FAS during Stage 1 of the GXT are shown descriptively in Table 3 and graphically in Figures 4, 5, and 6. Following analyses reported by Hall et al. (2002), differences in feeling states between conditions and over time (during Stage 1 of the GXT) were evaluated using a 2 feeling state (FS, FAS) X 4 time (0, 1:30, 2:30, 3:30) X 2 condition (SST-E, SST-C) repeated measures MANOVA. Results show a significant main effect for feeling state, F(1, 19) = 22.93, p < .01, partial $\eta^2 = .55$. However, there were no main effects for time, F(3, 17) = 2.44, p = .10, partial $\eta^2 = .30$, or condition, F(1, 19) = 3.71, p = .07, partial $\eta^2 = .16$. There was a significant feeling state X time interaction, F(3, 17) = 27.96, p < .01, partial $\eta^2 = .83$. The following interactions were not significant: feeling state X condition, F(1, 19) = .91, p = .35, partial $\eta^2 = .05$, time X condition, F (3, 17) = 1.04, p = .40, partial $\eta^2 = .16$, and feeling state X time X condition, F(3, 17) = .40, p = .76, partial $\eta^2 = .07$. Despite finding no significant main effect for time, there are noticeable differences in all feeling state scores with the progression of time (see Figures 4 and 5). Post-hoc analyses were not completed, as the interaction between feeling state and time is a reflection of the difference in the measurement of the two feeling state scales (FS: -5 to +5; FAS: 1 to 6). However, pairwise comparisons were completed between conditions at each time point for the FS and FAS separately (see Table 3). Results showed FS was significantly different between conditions at 3:30 into the GXT ramp, t(19) = 2.16, p = .04.



FS during GXT

Figure 4: Measures of the Feeling Scale during the modified GXT (start of warm-up, start of GXT ramp, 1:30 into ramp, 2:30 into ramp, 3:30 into ramp (VT), termination of GXT). Bars represent standard deviations. *: p < .05



FAS during GXT

Figure 5: Measures of the Felt Arousal Scale during the modified GXT (start of warmup, start of GXT ramp, 1:30 into ramp, 2:30 into ramp, 3:30 into ramp (VT), termination of GXT). Bars represent standard deviations.

Feeling states at termination of GXT. Scores for the FAS and FS at the termination of the GXT are presented by condition in Table 3 and graphically depicted in Figures 4 and 5, respectively. The overall depiction of feeling states through the course of the experiment is shown in circumplex space in Figure 6. To evaluate the differences in feeling states between conditions at the termination of the GXT, a 2 (feeling state) X 2 (condition) repeated measures MANOVA was computed. Results reveal a significant

main effect for feeling state, F(1, 19) = 289.17, p < .001, partial $\eta^2 = .94$. However, the main effect for condition, F(1, 19) = .00, p = .95, partial $\eta^2 = .00$, and the feeling state X condition interaction, F(1, 19) = .37, p = .55, partial $\eta^2 = .02$, were not significant. The significant main effect simply reflects a difference in the measurement scales between the FS (-5 to +5) and the FAS (1 to 6).



Figure 6: Affect circumplex showing the progression of participants' valence and arousal throughout the SST and GXT.

Table 3

Feeling states as represented by the Feeling Scale and Felt Arousal Scale by condition and over time throughout the SST and the modified GXT.

Feeling Scale				
	SST-C	SST-E		
Time point	Mean \pm SD	Mean \pm SD	t	р
Post-Practice SST	2.75 ± 2.12	2.80 ± 1.96	13	.90
SST Post-Block 1	2.55 ± 2.14	2.30 ± 2.02	.89	.38
SST Post-Block 2	2.35 ± 2.11	1.95 ± 1.93	1.41	.18
SST Post-Block 3	2.25 ± 2.02	1.93 ± 1.93	1.17	.26
Start of GXT warm-up	2.70 ± 2.08	2.60 ± 1.76	.36	.73
Start of GXT ramp	2.35 ± 1.95	2.10 ± 1.62	.89	.38
1:30 into GXT ramp	1.45 ± 1.82	1.12 ± 1.79	1.00	.33
2:30 into GXT ramp	.95 ± 1.64	.53 ± 1.93	1.33	.20
3:30 into GXT ramp (VT)	$.28 \pm 1.94$	40 ± 2.28	2.16	.04
End of GXT	-2.63 ± 1.80	-2.53 ± 2.39	30	.77

Table continues...

Felt Arousal Scale				
	Ctrl	Exp		
Time point	Mean ± SD	Mean \pm SD	t	р
Post-Practice SST	1.48±.68	1.65 ± .81	-1.79	.09
SST Post-Block 1	$1.40 \pm .50$	2.45 ± 1.15	-4.47	<.01
SST Post-Block 2	1.50 ± .69	2.58 ± 1.12	-4.92	<.01
SST Post-Block 3	$1.60 \pm .68$	2.58 ± 1.07	-4.33	<.01
Start of GXT warm-up	1.93 ± .86	1.85 ± .67	.44	.67
Start of GXT ramp	2.55 ± 1.10	2.50 ± .89	.27	.79
1:30 into GXT ramp	3.43 ± 1.04	3.20 ± 1.01	1.06	.30
2:30 into GXT ramp	3.70 ± 1.13	3.68 ± .92	.15	.88
3:30 into GXT ramp (VT)	4.20 ± 1.06	4.00 ± .97	1.07	.30
End of GXT	5.25 ± 1.16	5.13 ± 1.17	.65	.52

Note. SST = stop-signal task; GXT = graded exercise test.

Heart rate during GXT. Heart rate during the GXT was analyzed using a 2 (condition) X 6 (time) repeated measures ANOVA. Heart rate measures in 1-minute intervals throughout the GXT are presented in Figure 7. There was no main effect for condition, F(1, 19) = .26, p = .62, partial $\eta^2 = .01$. There was a main effect for time, F(5, 15) = 151.06, p < .01, partial $\eta^2 = .98$, meaning heart rate increased as did workload

demand throughout the GXT. There was no condition X time interaction effect, F(5, 15) = .51, p = .76, partial $\eta^2 = .15$. This supports the idea that there were no significant physiological differences occurring between conditions during the GXT, and that heart rate progressed normally in both conditions.



Figure 7: Heart rate at 1-minute intervals during the modified GXT. Bars represent standard deviations.

Perceived exertion during GXT. Measures of RPE in a series of 1-minute intervals during the GXT are presented in Figure 8. RPE scores were analyzed using a 2 (condition) X 6 (time) repeated measures ANOVA. Results reveal no significant differences between conditions, F(1, 19) = 2.33, p = .14, partial $\eta^2 = .11$. There was a

main effect for time, F(5, 15) = 74.53, p < .01, partial $\eta^2 = .96$, meaning perceived exertion increases throughout the course of the GXT, as does the resistance. There was no condition X time interaction effect, F(5, 15) = 0.57, p = .72, partial $\eta^2 = .16$.



RPE by Time

Figure 8: Ratings of perceived exertion at 1-minute intervals during the modified GXT. Bars represent standard deviations.

Discussion

The purpose of the present study was to investigate the affective feeling state responses to cognitive self-control exertion and progressive exercise to volitional exhaustion. Consistent with prior research, participants reached volitional exhaustion during progressively difficult exercise in shorter duration following prior exertion of cognitive control compared to when they had not exerted cognitive control before exercising. Findings showed feeling states became less pleasant during both the experimental and control SST tasks, but these feelings were accompanied by significantly greater felt arousal only during the SST-E. Overall, results showed there were no differences between conditions in feeling states experienced during the GXTs. However, there was some evidence that affective valence was significantly less positive at, or about, the ventilatory threshold following prior exertion of cognitive control on the SST-E. At termination of the GXTs, there were no differences in affect between the conditions, indicating participants reached equivalent feeling states despite a significantly shorter time to exhaustion following the SST-E.

Time to Exhaustion

It was predicted that participants' cardiovascular exercise performance would suffer, reaching exhaustion more quickly, in the cognitive self-control condition compared to the control condition. This hypothesis was supported by significant results with a medium to large effect size (d = .49). Although not particularly novel, these findings are important insofar as they support a growing body of evidence showing prior performance of computer-based tasks involving high levels of cognitive control disrupts

normal performance on self-paced, constant load, and incrementally-demanding whole body endurance exercise (MacMahon et al., 2014; Marcora et al., 2009; Pageaux et al., 2014; Zering et al., 2016).

Feeling States during the SST

It was hypothesized that participants' affective valence would be less positive when completing the cognitive control exertion task and that valence would become increasingly less positive as the task continued. This hypothesis was not supported. However, the results must be qualified by the additional findings that valence showed a slight decline during the SST-C task as well. These results suggest the control task required repetitive attentional demands that brought about less pleasant feeling states over the course of 10+ minutes of task performance. Although no differences were observed for valence, there was a significant difference between conditions for felt arousal. That is, arousal ratings were significantly elevated compared to the practice trial and during each test block when participants performed the SST-E compared to the SST-C.

Together, these findings show the cognitive control demands of the SST-E led to changes in affect consistent with higher arousal and negative valence, while the SST-C evoked changes towards feelings of negative valence along with sustained low levels of activation (see Figure 6). These findings support the process model (Saunders & Inzlicht, 2016) inasmuch as evidence was obtained showing the high cognitive control demands of the SST-E brought on an emotional episode that was distinguishable from that seen for the SST-C.

It was also hypothesized that the changes in affective valence associated with performing the SST-E would endure beyond completion of that task, such that affect would be less positive at the start of the GXT in that condition compared to the control condition. However, contrary to this prediction, results showed arousal and valence both returned to similar levels prior to the start of the GXT warm-up in both conditions. These findings suggest the negative affective responses brought on by exerting cognitive control dissipate quickly when the control demands of the task are no longer present. Although these results do not support the hypothesis in this study, they are consistent with the premise of the process model, that cognitive control demands bring about an emotional episode and when the stimulus eliciting the emotional response is removed the episode ends.

Feeling States during the GXT

The hypothesis that affective responses to progressive exercise would show different patterns over the course of the GXT received partial support. That is, from the onset of the ramp to the 2:30 minute point of the GXT, there were no significant differences between the groups in either affective valence or arousal. However, at the 3:30 minute point, corresponding to the ventilatory threshold, there was a significant difference in valence. Loss of data due to participants reaching exhaustion at varied times precluded analyses of data after the point of VT; however, as can be seen in Figures 4, 5, and 6, there is evidence that participants were experiencing gradually-increasing negative shifts in affect beginning at the start of the GXT ramp.

The different patterns of changes in affective responses to exercise between the cognitive control and control conditions are interesting to interpret in light of the process model. That is, Saunders and Inzlicht (2016) propose that cognitive control elicits a negatively-valenced emotional episode; however, the extent of cognitive control required by exercise is not an explicit aspect of their model. Another aspect of the model that is not clear is whether the negative affect induced by cognitive control exertion follows a graded, dose-response pattern, whereby greater exertion of cognitive control could bring about greater negative affect responses. Based on their theorizing and the present findings, it seems reasonable to suggest that exercise requires greater cognitive control as intensity or workload increases on a progressive exercise test, such as the GXT. Following this interpretation then, it would seem that prior exertion of cognitive control on the SST-E may set up, or prime, heightened negative affective responses to cognitive control is required by higher workloads on the GXT, a more pronounced change in negative affect is experienced.

The final hypothesis predicted that at termination of the GXT, there would be no differences between conditions in affect; yet, those similar feeling states would be reached at an earlier time in the cognitive control condition compared to the control condition. As can be clearly seen in Figures 4, 5, and 6, this hypothesis was supported, with no significant differences between conditions in valence or arousal at termination of the GXT, despite there being a significant difference in time to exhaustion. These findings are noteworthy and suggest that the point at which one reaches voluntary exhaustion or withdraws their effort to continue exercising may be determined by their

emotional state rather than by reaching the limits of their cardiorespiratory or musculoenergetic capacity.

Along these lines, recent theorizing by Noakes (2012) and others (e.g., St. Clair Gibson, Baden, Lambert, Lambert, Harley, Hampson, Russell, & Noakes, 2003) propose that fatigue experienced during exercise is an emotional state and that extreme feelings of fatigue serve as a protective signal to the brain that exercise should be terminated in order to avoid catastrophic threats to homeostasis. What is important to acknowledge; however, is that Noakes' concept of "fatigue" is what dimensional emotion theorists, such as Russell (2003), refer to as a categorical label for a discrete emotional state and that all such emotional labels can be identified (without the label) within the 2-dimensional space of the affect circumplex model. Interestingly, research investigating the correspondence between the dimensional and categorical perspectives of emotion place "fatigue" in the lower left quadrant of the circumplex as an unpleasant, low arousal state (Posner, Russell, & Peterson, 2005). In contrast to this, our data and those of Hall et al. (2002) suggest that the fatigue experienced during exhaustive exercise is better described as an unpleasant, high arousal state. This mismatch of label and dimension highlight a potential problem for researchers interested in exercise-related fatigue, as participants and researchers may use such labels to describe affective states that may be misconstrued or misinterpreted by participants, other researchers, and even themselves. It would appear advantageous to use dimensional measures to assess and describe affective states rather than, or in concert with, categorical labels in future research investigating emotional states experienced during exercise.

Heart Rate and Perceived Exertion during the GXT

There were no significant differences between conditions in either heart rate or RPE during the GXT. Both increased gradually with increasing workload and overlapped for the duration of the GXT. These findings replicate those of Zering et al. (2016) for HR; however, deviate in terms of RPE. Zering et al. showed similar patterns of RPE during the early minutes of the GXTs, then diverged to indicate greater RPE in the cognitive control condition compared to the control condition. The difference in the RPE findings may be attributable to the manner in which the GXT was adapted for the current study. That is, by increasing the slope and standardizing the workload demands of the ramp during the first 210 seconds of the GXT in the present protocol, RPE may have shown a faster and more uniform increase compared to the more gradual workload demands in Zering et al.'s study.

Overall Insights: The Role of Affect during Progressive Exercise to Exhaustion and Implications for Exercise Adherence.

The dominant perspective of self-control postulates that an initial task requiring self-control consumes one's resources, thus leaving the individual with less willpower to persist in subsequent self-control demanding activities (Baumeister, 2014). This elegant and sensible model has received considerable support in the literature (Hagger et al., 2010b). However, considerable evidence currently challenges this perspective and alternative theorizing recognizes cognitive and affective processes play important roles in determining behaviours involving self-control. The present study demonstrates that prior

exertion of cognitive control leads to a different pattern of affect experienced during strenuous exercise.

With the process model (Saunders & Inzlicht, 2016) as a theoretical foundation, the present study explored the fluctuations in affective feeling states experienced over sequential self-control challenges. In support of this theorizing, results showed reductions in positive valence along with increased activation during the cognitive task. This change in feeling states, while appearing to recover to normal in the 5-minute period between the SST and GXT, seems to prime a negative shift in affect that is experienced as exercise becomes more strenuous and thereby reduces one's maximal tolerance. This reduction in exercise tolerance exemplifies precisely what the process model predicts. That is, individuals seek a more comfortable state when self-control challenges become too demanding. More specifically, the negative shift in affect following prior self-control exertion causes participants to reach a negative feeling state more quickly during progressively-demanding exercise, thus signalling to the brain to terminate exercise in order to return to a more comfortable affective state.

From this study, we can ascertain that affect becomes influential as exercise demand increases and allows activities completed prior to exercise to determine the intensity participants are willing to reach before voluntarily terminating activity. Several studies have investigated affective experiences during exercise in post-exercise recovery to help understand adherence to physical activity programs (Ekkekakis, Parfitt, & Petruzzello, 2011; Hall et al., 2002). The present study relates to these studies of

adherence as it reveals the affective experience of exercise may not only be based on the exercise itself, but is also affected by activities completed prior to exercise.

Future Directions

The present study showed feeling states are sensitive to tasks involving cognitive control demands and that feeling states may carryover from tasks that do not have intense physical demands to tasks that do. To further explore this phenomenon, future studies should utilize feeling state methodology to investigate carryover effects of cognitive control exertion to other behaviour. For example, Marcora et al. (2009) employed a protocol in which participants cycled at a constant load (80% of peak power output) for as long as possible with and without prior exertion of cognitive control. A future study could investigate feeling states during both those activities. Based on the current findings, one would expect participants to experience more negative feeling states at the onset of the constant workload task after prior exertion of cognitive control.

Future studies should also explore feeling states in more applicable, real-life situations involving cognitive self-control and subsequent exercise performance. For instance, it would be interesting to measure feeling states of university students during a regular week of classes, as well as during their regular exercise sessions, to see if prior affective feeling states altered affect during exercise. Furthermore, participants' affective states could be tracked during their course examinations to explore feeling states under heavy cognitive demand, and compare their affective experiences during exercise between the two situations.

Strengths and Limitations

Although the present study does not provide definitive information about affective responses to cognitive control or strenuous exercise, there are a number of strengths that should be recognized. One strength of the study relates to the investigation of feeling states as a potential mechanism that might explain how prior exertion of cognitive control may lead to a diminished performance on other tasks that demand controlled effort. In this respect, the study drew upon theorizing by Inzlicht and others (Inzlicht & Schmeichel, 2012; Saunders & Inzlicht, 2016), which has criticized Baumeister's selfcontrol strength model on grounds that the model fails to acknowledge any cognitive or affective processes that could explain why prior cognitive control exertion typically results in performance deterioration. As far as we are aware, this is the first study to have investigated affective responses during exercise following prior cognitive control exertion. Another strength of the study was the use of a within-subjects crossover design. Historically, research on the carryover effects of self-control exertion has relied almost exclusively on between-group comparisons. The design of the present study minimized variability between conditions that would be due to individual differences in exercise tolerance, as well as affective responses to cognitive control and exercise that would make it more difficult to detect the subtle differences in affect that were observed during exercise.

The methods used to assess feeling states may also be considered a strength of the study. Prior research has shown negative carryover effects from cognitive tasks to exercise tasks (e.g., MacMahon et al., 2014; Marcora et al., 2009) utilized a measure of

RPE that was not compatible for both the exercise and cognitive tasks. In this study, the FS and FAS allowed for consistent measurement throughout the cognitive and physical exertion tasks. Methodologically, these scales have several features that should promote their use for studies in this area, as they are validated one-item measurements allowing for time-efficient data collection during an activity requiring high attentional demands (Ekkekakis & Petruzzello, 2002). Additionally, these measures combine to create the affect circumplex (Figure 6), which provides an extremely powerful image for comprehension of how feeling states fluctuate during activities, as well as information beyond adjectives often used to describe emotional states in each quadrant (high valence, low activation: tension, distress; high valence, high activation: energy, vigour; low valence, low activation: tiredness, boredom; high valence, low activation: calmness, relaxation) (Ekkekakis et al., 2011).

Despite these strengths, there are a number of limitations that should also be noted. One limitation in this study was a relatively small sample size, which may have resulted in less power than optimal for the analyses of the affect data. Also, this sample was restricted to recreational exercisers, which may have proved problematic as we expected participants to reach the same peak power they achieved in the initial trial, but many were unable to reach the output in their second and third GXT. This issue may have been exacerbated by the way in which the modified GXT was constructed. That is, the modified GXT involved a much steeper ramp during the first few minutes of the test, but then became more gradual. Our findings suggest that for untrained individuals, when they

are taken to VT more quickly, they do not have the same endurance as they do when progressive exercise is more gradual.

An additional limitation relates to the control version of the SST task. Results showed a slight decrease in affective valence and a marginal increase in arousal during the SST-C, indicating that it was not as neutral as what had been intended. The task did not have the response-inhibition component that requires cognitive control; however, it may have caused unpleasantness due to other factors, such as boredom. An additional notask control group or a different control task should be considered for future studies.

Conclusion

The present investigation found performance of a cognitive self-control task led to a changes in affective feeling states reflective of less pleasant valence and greater activation. Participants' affective states returned to normal prior to beginning the exercise task, but those earlier experiences appeared to primed a faster return to negative affective states as exercise demand increased, leading to a faster peak in negative feeling states and a shorter time to exhaustion in the SST-E compared to the SST-C conditions. Findings support previous research indicating affective valence becomes abruptly more negative when people surpass their ventilatory threshold, but are the first to show prior cognitive self-control tasks may accelerate this decline leading to lower exercise tolerance and earlier physical exhaustion.

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Appendix A: Study Materials

Consent form

Demographics & Godin Questionnaire

Ratings of Perceived Mental Exertion (RPME)

NASA Task Load Index

Feeling Scale (FS)

Felt Arousal Scale (FAS)

Ratings of Perceived Exertion (RPE)

Instructions for the physical RPE

Intrinsic Motivation Inventory (IMI)

LETTER OF INFORMATION

Self-Regulation and affect during physical exertion.

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Purpose of the Study

The purpose of this study is to measure the level of physical exertion in a cycling task after completing a cognitive decision-making task.

Procedures:

There are 3 sessions in the study. The first visit will take approximately 15 minute and each of the second and third visits will each take approximately 30 min to complete.

Session 1 (15 minutes)

- In the first session we will ask you to complete some brief questionnaires and then do a baseline cycling test. We will ask you to pedal on a stationary bike to the best of your ability. The task will get progressively more difficult and we would like you to keep going for as long as you can.
- For the cycling task, we will be measuring how hard you are working by sampling your expired air and heart rate. For this, we will ask you to wear a facemask that fits like a snorkel in your mouth and nose clips. You will breathe in normal room air, but the breath you exhale will be analyzed. We will also ask you to wear an elastic strap around your chest (Polar Heart Rate Monitor) to monitor how fast your heart is beating
- We will ask you to rate how hard you are working, how the exercise is making you feel, how "worked-up" you feel from the exercise, and how much mental effort it is taking to continue the exercise every minute. We will ask you to fill out a few questionnaires to measure how you feel.
- This visit will take approximately 15 minutes.

Session 2 (30 minutes)

- You will be doing the cycling task again, but before that test, we will ask you to perform a decision-making task on at computer. For this task, a series of shapes will be shown on the computer screen and you will follow instructions to press buttons on the keyboard when certain shapes appear. This task will take approximately 10 minutes.
- You will be doing a cycling task for approximately the same amount of time as session 1, but we will not be measuring expired gas, so there will be no facemask to wear during the exercise.

Session 3 (30 minutes)

• You will be doing the same cycling task as session 2, but before that test, we will ask you to perform a decision-making task on at computer. For this task, a series of shapes will be shown on the computer screen and you will follow instructions to press buttons on the keyboard when certain shapes appear. This task will take approximately 10 minutes.

Potential Harms, Risks, and Discomforts

The risks involved in participating in this study are minimal. You may find the computer decision-making task to be a challenge and fatiguing. The cycling tasks will likely tire you for a short duration. You may worry about your performance in the cycling task, but please keep in mind that your numbers are kept confidential and only compared against your other scores. We are merely asking for your best effort. Some muscle soreness or discomfort during or after the cycling test is possible, but we will demonstrate how to decrease any discomfort or soreness you may experience. The headset and mouthpiece may feel awkward to wear, but can be adjusted so it should feel comfortable.

Potential Benefits

There is no direct benefit to participating in this study. You will however, be contributing to the scientific community's understanding of self-regulation and how it relates to exercise. By attending the visits and completing the tasks you will be contributing data to an original study investigating cognitive and physical exercise task performance.

Payment or Reimbursement

You will receive \$5 for the completion Session 1 and \$10 for the completion of each of Sessions 2 and 3. Therefore, \$25 will be received for the completion of the study.

Confidentiality

Any information that is obtained during this study and that can be identified with you will remain confidential and will only be disclosed with your permission.

All of the printed information collected is completely private and will be kept in a locked filing cabinet in The Health and Exercise Laboratory for a period of five years (including the screening questionnaire). Data collected on the researcher's computer will only use participant number to identify the data set and will be a password-protected partition on the hard drive. Once the data analysis is complete and the studies are presented, confidential files will be destroyed.

Your name and demographic information will be kept separate from your participation data and can only be traced back with the use of the master participant numbering list, which is kept secure at all times in a password protected file on the experimenter's computer. All of the data and measurements that we collect from you will not have your name attached. All of the study documents will be organized by participant number. Only the research students (Jennifer Zering and Jeff Graham) and Dr. Bray will have access to this information. Your identity will <u>never</u> be revealed in any reports of this study.

Participation and Withdrawal

It is entirely your choice whether or not to participate in this study. If you choose to volunteer for this study you may withdraw at any time without penalty. You can choose to have your data removed from the study at any time. Should you choose to withdraw at any time during the study you will be compensated for each session you attend, even if you do not complete the whole session.

Information about the Study Results

The study should completed by April 2015. If you would like a brief summary of the results please leave your email contact and a summary of the study findings will be sent to you by May 2015.

Participant Name

Participant Signature

Date

If you are interested in receiving a copy of the results from this study, please provide your email here:

Questions about the Study

If you have any questions or require more information about the study itself please contact one of us.

Jeni Zering (zeringjc@mcmaster.ca) Jeff Graham (grahajd2@mcmaster.ca)

This study has been reviewed by the McMaster University Research Ethics Board and received ethics clearance.

If you have concerns or questions about your rights as a participant or about the way the study is conducted, please contact:

McMaster Research Ethics Secretariat Telephone: (905) 525-9140 ext. 23142 c/o Research Office for Administrative Development and Support E-mail: ethicsoffice@mcmaster.ca

DEMOGRAPHICS

To begin, we are interested in getting to know some basic information about you. Please complete the following questions.

Age: _____

Sex: Female _____ Male _____

EXERCISE SCREENING QUESTIONNAIRE

Do you lift weights for exercise? Yes _____ No _____

Over the past 6 months, how many times **on average** have you done the following kinds of exercise for 30 minutes or more during your **free time** in a week? Free time is your leisure time, it represents the time in which you freely chose to do things, not because you have to do them for some other activity or task.

Times per week

STRENUOUS EXERCISE (your heart beats rapidly):

(e.g., running, jogging, hockey, football, soccer, squash, basketball, cross country skiing, judo, roller skating, vigorous swimming, vigorous long distance bicycling, skating)

MODERATE EXERCISE (not exhausting):

(e.g., fast walking, weight-training, baseball, tennis, easy bicycling, volleyball, badminton, easy swimming, alpine skiing, dancing)

MILD EXERCISE (minimal effort):

(e.g., yoga, archery, fishing, bowling, horseshoes, golf, snow-mobiling, easy walking)

RATINGS OF PERCEIVED MENTAL EXERTION

0 Nothing at all	
0.3	
0.5 Extremely weak	
1 Very weak	
1.5	
2 Weak	
2.5	
3 Moderate	
4	
5 Strong	
6	
7 Very Strong	
8	
9	
10 Absolute Maximum	1

Figure 8.6

NASA Task Load Index

Hart and Staveland's NASA Task Load Index (TLX) method assesses work load on five 7-point scales. Increments of high, medium and low estimates for each point result in 21 gradations on the scales.

Name	Task		Date
Mental Demand	Но	w mentally den	nanding was the task?
		1	
			Von High
Very LOW			very right
Physical Demand	How physica	ally demanding	was the task?
		1	
Very Low			Very High
Temporal Demand	How hurried	or rushed was	the pace of the task?
remperarbernaria			
Very Low			Very High
Derformance		of durana vou i	n aaamuliahing what
Ferformance	you were as	ked to do?	n accomplishing what
Perfect			Failure
Effort	How hard di	d you have to	work to accomplish
	your level of	performance?	
Very Low			Very High
Frustration	How insecu and annoye	re, discourage d wereyou?	d, irritated, stressed,
			Very High
VOLY LOW			very riigh

Feeling Scale (Hardy & Rejeski, 1989)

While participating in exercise, it is common to experience changes in mood. Some individuals find exercise pleasurable, whereas others find it to be unpleasant. Additionally, feeling may fluctuate across time. That is, one might feel good and bad a number of times during exercise. Point to the number that corresponds with how you feel.

+5	Very good
+4	
+3	Good
+2	
+1	Fairly good
0	Neutral
-1	Fairly bad
-1 -2	Fairly bad
-1 -2 -3	Fairly bad Bad
-1 -2 -3 -4	Fairly bad Bad
-1 -2 -3 -4 -5	Fairly bad Bad Very bad

Felt Arousal Scale (FAS) (Svebak & Murgatryod, 1985)

Estimate here how aroused you feel. Point to the appropriate number. By "arousal" we mean how "worked-up" you feel. You might experience high arousal in one of a variety of ways, for example, as excitement or anxiety or anger. Low arousal might also be experienced as relaxation or boredom or calmness.

1	2	3	4	5	6
Low Arousal					High Arousal

Ratings of Perceived Exertion

6	No exertion at all
7	Frature and Pack 4
8	Extremely light
9	Very light
10	
11	Light
12	
13	Somewhat hard
14	
15	Hard
16	
17	Very hard
18	
19	Extremely hard
20	Maximal exertion

Instructions for the Physical Rating of Perceived Exertion Scale

While doing physical activity, we want you to rate your perception of exertion. This feeling should reflect how heavy and strenuous the exercise feels to you, combining all sensations and feelings of physical stress and fatigue. Do not concern yourself with any one factor such as leg pain or shortness of breath, but try to focus on your total feeling of exertion. Look at the rating scale below while you are engaging in the activity; it ranges from 6 to 20, where 6 means "no exertion at all" and 20 means "maximal exertion." Choose the number from below that best describes your level of exercise, which is based only on the physical sensations that you feel as a result of the exercise, NOT the mental and psychological effort required to continue the task. Try to appraise your feeling of exertion as honestly as possible, without thinking about what the actual physical load is. Your own feeling of physical effort and exertion is important, not how it compares to other people. Look at the scales and the expressions and indicate a number.

Intrinsic Motivation Inventory

For each of the following statements, please indicate how true it is for you, using the following scale:

1234567Not true at allSomewhat trueVery true

For the bicycle task I am <u>about to do</u>:

- 1. I am going to put a lot of effort into this.
- 2. I am not going to try very hard to do well at this activity.
- 3. I am going to try very hard on this activity.
- 4. It is important to me to do well at this task.
- 5. I am not going to put much energy into this.