EFFECTS OF ENERGY CONSERVATION AND MOTIVATION ON SELF-REGULATION

AN INVESTIGATION OF THE EFFECTS OF ENERGY CONSERVATION AND MOTIVATION ON SELF-REGULATION STRENGTH DEPLETION

By

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ABSTRACT

Baumeister and colleagues' (1998) limited strength model of self-regulation was used as a framework to investigate the independent and combined effects of motivation and conservation on self-control strength depletion. Volunteer university students (*N* = 72; 23 males and 49 females) participated in the study. Participants completed two maximum endurance isometric handgrip trials separated by the Stroop colour word interference task. Participants were randomized to either a conservation or no-conservation condition before completion of the Stroop task. After performing the Stroop task the participants were then further separated into an autonomy support condition or a no autonomy support condition. It was hypothesized that participants (1) who were provided with autonomy support would perform better on the second endurance trial and report higher feelings of autonomous regulation, (2) who were in the conservation condition would perform worse on the Stroop task and better on the second endurance trial, and (3) who were provided with autonomy support and were in the conservation condition would perform the best on the second endurance trial, while those who were not provided autonomy support and did not conserve were predicted to perform the worst of any group on the second endurance trial. Autonomy support was associated with better performance on the second endurance trial but not greater feelings of autonomous regulation. Conservation was associated with poorer performance on the Stroop task, but not superior performance on the second endurance trial. There was no evidence supporting the combined effects of autonomy support and conservation. Findings support conclusions that people conserve self-control strength when anticipating future strength

depletion and autonomy support helps people cope with self-control strength depletion and deliver superior performance on a muscular endurance task.

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An Investigation of the Effects of Energy Conservation and Motivation on Self-Regulation Strength Depletion

For their New Years resolution Stephan and Geoff decided that they want to be able to run a 15 kilometer race by the beginning of spring and cross the finish line together. They live similar lives, are employed at the same institution, and always train together for the upcoming race. A week before the big race a colleague of theirs, an exercise and health psychologist, informs them about her recent research highlighting the dangers of performing effortful tasks one after another. Specifically, performing a task that requires a high level of effort (either cognitive or physical) will reduce an individual's energy levels for subsequently demanding tasks. However, Katharina also informs them that, in certain circumstances, the human body is able to perform engaging tasks, one after another, by using one of two different strategies. First, individuals can overcome their fatigue through certain motivational *strategies, for example, by monetary incentives or through a sense of autonomy (perceived choice). Second, individuals can overcome this fatigue by underperforming on the first task in order to* conserve *their resources for the second task. On the day of the big race Geoff decides to take his morning easy and refrains from performing any physically demanding tasks, however, his excitement gets the best of him and he decides to statistically analyze his and Stephan's data from a revolutionary new experiment which they just completed collecting data for the day before. Stephan, on the other hand, takes Katharina's advice to heart and refrains from any physically or cognitively demanding tasks in order to conserve his energy for the race. Just before the race is about to start, Geoff informs Stephan of the* *new and exciting results but that it took him hours to cipher through everything. Stephan is shocked that Geoff didn't listen to Katharina's warnings about performing too many engaging tasks one after another but Geoff says that he is motivated by his choice to cross the line with Stephan and will dig deep to do just that. What Katharina didn't inform the gentlemen was that research has yet to be completed investigating the consequences of motivating oneself to consume resources beyond one's regular limit...*to be continued.

The above example is hopefully illustrative of what may be common interactions of mind and body that many people experience. The underlying premise is that performing tasks that require physical, cognitive, and emotional effort each draw resources from a common or shared pool of energy that is unique to each individual. In one of the earliest documented observations of the shared resource depletion phenomenon, Mosso (1904) reported that after some of his academic colleagues had delivered lectures or administered oral examinations they were unable to perform their habitual physical exercise routines at their normal intensity levels. It seemed that expending their cognitive energy had resulted in fatigue that spilled over to negatively affect their physical strength and endurance. The type of fatigue described by Mosso is consistent with the contemporary concept of central fatigue, which has been defined as a failure within the central nervous system (CNS) to drive voluntary muscle activation (Taylor, Todd & Gandevia, 2006).

Although Mosso's original observations of this phenomenon were recorded over a century ago, since that time there has been limited research dedicated to the investigation of a central energy resource in exercise science. Researchers in the areas of cognition and information processing (Gopher & Sanders, 1984; Hockey, 1997; Kahnenman, 1973; Sternberg, 1969) have formulated some models that integrate an energy perspective on cognitive performance. However, Baumeister and colleagues (Baumeister, Bratslavsky, Muraven, & Tice, 1998) have more recently developed a model which extends previous models and integrates an energy perspective on cognitive, emotional, and physical performance.

Limited Strength Model of Self-Regulation

Self-regulation is a term often used interchangeably with other terms such as self-control or willpower, which refers to the self's capacity to override a behaviour, thought, or emotion and replace it with another (Baumeister & Heatherton, 1996). Baumeister and colleagues (1998) developed the limited strength model of self-regulation. The focal feature of this model is self-regulatory strength, which is conceptualized as a central nervous system resource that is depleted when an individual uses self-control to regulate emotions, thoughts, or behaviours.

The theoretical basis of the self-regulation strength model is structured around six primary assumptions: (1) human beings have a limited resource (strength) that governs or regulates the ability to execute acts of self-regulation, (2) performing acts of self-regulation consumes the limited resource resulting in temporary depletion, (3) when self-control strength is depleted, the ability to self-regulate on other tasks becomes impaired, (4) acts of self-regulation, whether they involve emotional, behavioural, or cognitive control, all draw upon the same limited resource pool, (5) during acts of self-regulation the body begins to alter or conserve its responses before the resource pool becomes fully depleted, (6) replenishment of self-regulatory resources can be achieved through rest and possibly other mechanisms (Baumeister et al., 1998).

In an initial set of studies investigating self-regulation strength, Muraven, Tice and Baumeister (1998; Study 2) had one group of participants perform a thought-suppression task for ten minutes (instructed not to think of a white bear), while a control group was not provided with any instructions. Following the initial ten-minute task, participants were monitored on the length of time they spent trying to complete unsolvable puzzle tasks. Results showed that participants who had previously engaged in the thought suppression task displayed less persistence on the puzzle task compared to the control group, suggesting a depletion of self-control resources occurred as a consequence of performing the thought suppression task.

Many different types of tasks have been used to examine depletion within the same domain (cognitive vs. cognitive) and dissimilar domains (cognitive vs. emotional), however, research investigating the effects of self-regulatory strength depletion in the domain of physical task performance has been limited (Hagger, Wood, Stiff, & Chatzisarantis, 2010). The majority of the studies investigating self-regulation strength depletion in the physical domain have investigated physical effort regulation employing a task that requires participants to squeeze a spring-loaded handgrip squeezing device for as long as possible (e.g., Ciarocco, Sommer & Baumeister, 2001; Finkel, Dalton, Campbell, Brunell, Scarbeck & Chartrand, 2006; Martjin, Alberts, Merckelbach, Havermans, Huijts & DeVries, 2007; Muraven et al.,1998; Tyler & Burns, 2009; Vohs, Baumeister & Ciarocco, 2005). Those studies have consistently shown that participants who expend self-regulation strength prior to performing the handgrip-squeezing task exhibit greater decrements in task performance compared to controls with an average effect size of 0.85 (Hagger et al.).

In a recent study, Bray, Martin Ginis, Hicks and Woodgate (2008) demonstrated that after performing an incongruent Stroop task (a cognitive task known to deplete self-regulation strength) participants showed impaired physical stamina to perform an endurance handgrip squeezing task. However, in that study, participants who were depleted also displayed greater proportional electromyographic (EMG) amplitude scores in their hand flexor muscles when they performed the handgrip squeezing task. The authors suggested that expending prior self-regulatory strength on the cognitive task resulted in central fatigue which required greater motor unit recruitment to sustain the submaximal handgrip squeeze. Several additional studies have reported the similar depletion effects on physical effort regulation tasks following performance of the Stroop task and have also demonstrated that the poorer performers report higher subjective fatigue, higher perceived exertion, increasingly lower maximum contraction outputs, and an unwillingness to engage in future effortful behaviours compared to participants who performed non-depleting control tasks prior to physical exertion (Bray, Martin Ginis & Woodgate, 2011; Clayton, Bray & Martin Ginis, 2008; Martin Ginis & Bray, 2010).

In summary, a considerable body of literature demonstrates that when self-regulatory strength resources are utilized, deficits are seen in the ability to self-regulate on subsequent tasks. These effects are not limited to the same domain (cognitive-cognitive) but can be generalized to dissimilar domains (cognitive-physical). However, research examining the effects of self-control depletion in physical exercise tasks remains limited.

Motivation, Autonomous Regulation and Autonomy Support in Self-Regulation

Motivation is a term used ubiquitously in psychological science and varies on at least two important dimensions: quantity and quality. In terms of quantity, people can be motivated to greater or lesser degrees. Qualitatively, the self-determination perspective (Deci & Ryan, 2000) defines motivation in terms of a continuum ranging from controlled regulation to autonomous regulation. Controlled regulation typically occurs when one performs a behaviour on account of external influences such as being rewarded or coerced, whereas greater levels of autonomous regulation are thought to be present when performing an action for the inherent satisfaction or enjoyment of the task itself (Deci & Ryan). Autonomous regulation has been shown to produce greater adherence to exercise programs, clinical treatments, weight loss programs (Kasser & Ryan, 1999; Nix, Ryan, Manly & Deci, 1999; Ryan & Frederick, 1997; Williams, Grow, Freedman, Ryan & Deci, 1996), a decreased likelihood of dropout among high school students (Vallerand, Fortier, & Guay, 1997), and greater effort and persistence amongst college students toward attaining academic goals (Sheldon & Elliot, 1997). Thus, the degree to which one's participation in a task is autonomously regulated may be an important consideration for studies of self-regulation and self-regulatory strength depletion.

Within the self-regulation strength literature, researchers have recently shown that inducing greater motivation (i.e., a monetary incentive) for task persistence is associated with varying self-regulation depletion effects. In an illustrative study (Muraven &

Slessareva, 2003; Study 3), participants in a self-regulation depletion condition were instructed to hide or suppress their emotional expressions (i.e., laughing or smiling) while viewing a 5-min comedy video whereas participants in a non-depletion control condition were allowed to experience their emotions in an unconstrained manner. This task has previously been shown to deplete self-regulatory resources (Muraven et al., 1998). After viewing the comedy clip, participants were requested to consume as much of a foul-tasting drink (Kool-Aid prepared with vinegar instead of sugar) as possible. However, half the participants in the depletion condition were offered a high pay incentive of 25 cents for every ounce of Kool-Aid they consumed, while the other half of the participants were offered a low pay incentive of only 1 cent per ounce. Results showed the depleted participants in the high pay condition drank more of the bad tasting beverage compared to those in the low pay condition. Furthermore, those in the high pay condition drank as much as the control condition participants who were not depleted by the emotion suppression task. Thus, the results show that a monetary incentive can motivate individuals to exert additional self-regulatory resources even when they are depleted.

In a more recent study, Muraven, Rossman, and Gagne (2007; Study 1) extended Muraven and Slessareva's (2003) findings by manipulating the monetary compensation tactic. Specifically, in one experimental condition, they provided performance-contingent rewards, wherein participants received money based on their successful self-control of emotion. In another condition, they provided non-contingent rewards, wherein participants received money simply for participation in the study. They found that participants in the performance-contingent reward conditions, who felt pressure to exert self-control on an initial task, performed more poorly on a subsequent self-control task compared to participants in the non-contingent conditions. Furthermore, participants in the non-contingent reward condition reported greater feelings of autonomous regulation on the initial self-control task compared to those in the contingent reward conditions, indicating that autonomous regulation may have also played a role in moderating the depletion effect.

Autonomous regulation of motivation has been investigated in three studies relating to self-control depletion effects. Moller, Deci, and Ryan (2006), were the first to examine the effects of autonomous motivation on self-control depletion. In one of their investigations (Study 1), participants were informed that they would be required to prepare a persuasive speech on whether or not psychology should be taught at the high school level. Participants were presented with two folders, labeled "for psychology in high school" and "against psychology in high school", in the autonomous-choice condition they were told that it was entirely up to them which folder they chose, whereas in the controlled-choice condition they were told that there were already enough participants in one condition so the researchers instructed them to choose one folder over the other. Following their designation to either the controlled or autonomous choice conditions, the participants were monitored on the length of time spent trying to complete unsolvable puzzles. Results showed that participants in the autonomous-choice condition persisted longer and made more attempts on the puzzle tasks, indicating that controlled choices may lead to greater depletion than those that are autonomous.

Muraven, Gagne, and Rosman (2008) carried out three experiments which manipulated autonomous regulation. In each of these studies, some participants were exposed to either autonomy-supportive or controlling manipulations. For example in Study 1, participants were presented with a plate of cookies or radishes with the instructions to not eat either the cookies or radishes. In the autonomy support condition, the researchers went out of their way to answer questions, to explain the protocol in detail, to use the word "please" often, to make them feel like they were serving a valuable function in contributing to the research, and emphasized that the choice to participate in the study was entirely up to the participant. For example, the researchers said to participants: "We ask that you *please* don't eat the cookies/radishes. Is that okay?" In the controlling condition, participants were simply instructed on what to do, were made to feel like "just another participant", and the word "must" was emphasized. For example, the researchers said to participants: "You *must* not eat the cookies/radishes". After resisting the cookies or radishes for 5 minutes the participants then performed a concentration test on a computer. Numbers flashed (every 500ms) on the screen and all the participants were instructed to press the space bar in the event that they saw the number six follow the number four. Results showed that participants who were instructed to not eat cookies in a controlling way were less able to regulate their attention. Findings supported the idea that perceived autonomy moderates the depletion effect on self-control task performance.

The third study; a report by Muraven (2008), examined the association between autonomous regulation and self-control depletion using a quasi-experimental design. In that study, participants completed an initial handgrip endurance task after which they were left in a room for 5 minutes with a plate of cookies with the instructions to not eat the cookies. Following the session with the cookies, they completed the Self-Regulation Questionnaire (SRQ: Ryan & Connell, 1989) (a measure of controlled and autonomous regulation pertaining to healthy eating), and then an additional handgrip endurance task. The results showed that participants who reported resisting the temptation of eating cookies for more controlled reasons performed worse on the second handgrip task compared to those who reported resisting the cookies for more autonomous reasons. This study complements previous findings of the effects of autonomy on self-regulation depletion and was the only study to have used a physical self-control (i.e., handgrip endurance) task.

In summary, research suggests that stimulating autonomous regulation through autonomy support or other means can ameliorate the self-regulation depletion effects on many cognitive and emotional self-regulation tasks. However, research investigating how to stimulate autonomy support to induce autonomous regulation on physically demanding tasks such as exercise remains limited. Therefore, the first purpose of this thesis was to investigate the effect of perceived autonomy support on autonomous regulation to expend self-control resources on a physical self-regulation task. It was expected that individuals who are provided with autonomy support for self-control performance would report greater autonomous regulation and perform better on a subsequent self-control task than people who do not receive autonomy support.

Conservation of Self-Regulatory Resources

Based on the assumption that self-control strength is a limited and important resource within the human body, researchers have theorized that people may seek to conserve their self-control energy. The conservation of self-control strength has been suggested to occur unconsciously or consciously through choice and a desire (or motivation) to conserve the valuable and finite supply of those resources. Muraven, Schmueli and Burkley (2006) first suggested the conservation of resources hypothesis when they observed poor performance on a demanding self-control task when participants anticipated having to exert self-control on a later task. These researchers had study participants (Study 1) inhibit the thought of a white bear for 5 minutes, after which they were told that they would be performing a cold pressor task, which involved holding their hand in very cold water for as long as possible. Half the participants were also informed they would have to then perform a third task in which they would suppress their emotions while watching an extremely funny video, while the other half were given no advance information about the third task. Results showed participants who anticipated the third task displayed poorer performance on the intermediate task (cold pressor) compared to controls, suggesting they were conserving resources for the third self-control task.

In another study (Study 4), Muraven et al. (2006) used a similar design as above but measured participants' performance on the third task to see if conservation was actually effective in preserving self-control strength. Participants completed an initial typing task, where half of them had to retype a paragraph without pressing the letter *e* or the space bar (self-regulation depletion condition) and the others simply typed the paragraph. All the participants were informed they would have to complete the Stroop task after typing (second task), which would then be followed by an anagram-solving task (third task). The description of the anagram task provided by the experimenters to the participants differed across conditions and served as the manipulation of future self-control anticipation. Specifically, participants anticipated future self-control via instructions that they should expect to “work hard at overriding impulses while working on this task” while the other participants anticipated a difficult (but not self-control) task as they were told to expect to “think hard while working on this task”. Results showed that participants in the group that anticipated self-control expenditure on the third task performed worse on the Stroop task compared to the group that did not anticipate further self-control depletion. Furthermore, performance on the anagram task (third task), which in fact did require self-control, was superior among those who had conserved strength compared to those who did not. Therefore, this study provides support that self-control is a resource that can be conserved for the future, and allocated differently among tasks, when people are motivated to conserve.

In summary, there is emerging evidence consistent with the idea that people either strategically (consciously) or inadvertently (something in the body “shuts-off” further resource distribution) conserve their self-control resources. Research in this area is still in its infancy, however, large effect sizes (d = 0.96) have been observed (Hagger et al., 2010). Therefore, the second purpose of the thesis was to follow-up on Hagger et al.’s recommendations to investigate if individuals anticipating a future self-regulatory task will conserve their resources. It was predicted that individuals who are told (after the first task) that a third task, which requires self-control, will follow the second self-control task will conserve their resources for the third task. More specifically, it was expected that when they anticipate future self-control demands, people will conserve self-control strength; performing worse on the second task by holding back effort; and better on the third task because they have conserved strength.

Autonomy Support and Conservation in Self-Regulation

As highlighted above, the first purpose was to investigate the effect of autonomy support on autonomous regulation to expend additional resources on a physical self-regulation task, while the second purpose was to investigate if individuals anticipating a future self-regulatory task will conserve their resources on an interim task for that future task. Although these questions are of fundamental interest in self-regulation research, the two are not mutually exclusive. In fact, people may face situations where conservation and motivation could interact to affect physical performance (perhaps as in the analogy presented at the outset of this paper). Therefore, an additional purpose was to investigate the possibility of an interaction between conservation and autonomous motivation. In the analogy, one individual conserved his resources for the big race, whereas the other did not. However, both individuals were highly motivated to perform. Thus, a question that arises is whether motivation can be a supplement to, or substitute for, conservation. Based on the large effect sizes reported in research on the independent effects of conservation (d = 1.04) and motivation (d = 1.05) (Hagger et al., 2010), it was predicted that participants in the conservation condition and who are provided with autonomy support would outperform those in the other conditions on the third task, whereas individuals in the no conservation condition and who are not provided with autonomy support would perform the worst of all conditions on the third task.

Hypotheses Summary

Main Effects

1) Participants who are provided with autonomy support for self-control performance, compared to those in a control group who do not receive autonomy support, will:
   a) Perform better on a subsequent self-control task (longer sustained endurance times relative to baseline)
   b) Report greater autonomous regulation (higher scores on the Intrinsic Motivation Inventory)
2) Participants who are told (after the first task) that a third task which requires self-control, will follow the second task, will be motivated to conserve their resources for the third task, compared to individuals who are not anticipating the third task. It is expected that they will:
   a) Perform worse on the second task (fewer Stroop words completed and more errors)
   b) Perform better on the third task (longer sustained endurance times relative to baseline)

Interaction Effects

1) Participants in the conservation condition and who are provided with autonomy support will perform better on the third task (longer sustained endurance times relative to baseline) compared to all other conditions.

2) Participants in the no conservation condition and who are not provided with autonomy support will perform worse on the third task (shorter sustained endurance times relative to baseline) compared to all other conditions.

Method

Participants

The current study included 72 university students (23 males and 49 females) with a mean age of 22.33 (*SD* = 3.46) years. Participants were recruited via a website advertisement on the McMaster daily news homepage, through posters placed around the McMaster University campus, announcements made in classrooms and through emails to past participants of Health and Exercise Psychology experiments. The McMaster research ethics board (MREB) approved the protocol prior to any recruitment or collection of data for this study.

Experimental Design

This study utilized a 2 (autonomy support/no autonomy support) X 2 (conservation/no conservation) factorial design (refer to Figure 1).

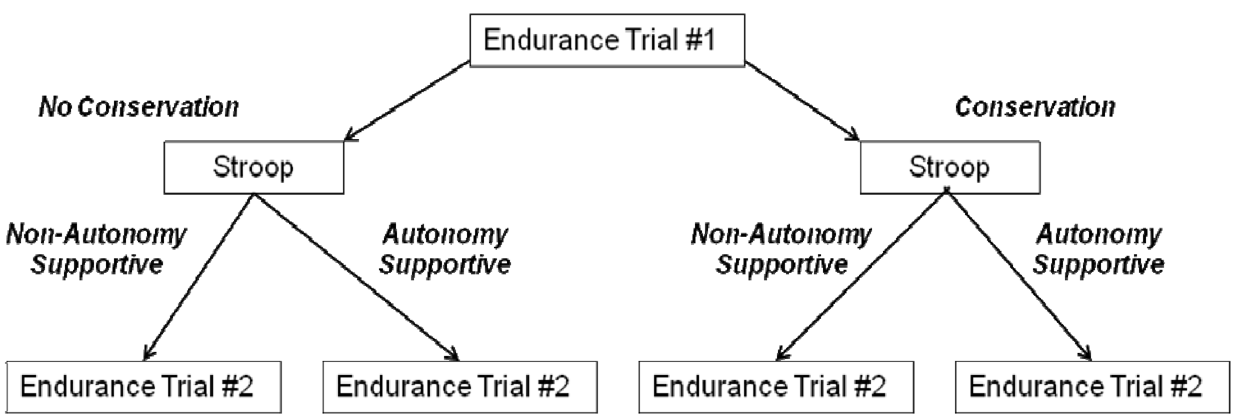


Figure 1. Flow diagram of the experimental design of the study and how each study condition was divided.

Measures

Primary Outcome Measure.

Isometric handgrip endurance performance. The common dependent variable for hypotheses 1, 2 and 3 in this study was the difference in the amount of time participants were able to endure holding a 50% maximum voluntary contraction (MVC) of an isometric handgrip squeeze between a baseline endurance trial and a second endurance trial. A handgrip dynamometer (model MLT003/D; ADInstruments) with a digital PC interface (Powerlab ML870; ADInstruments, Toronto, Canada) was used to monitor and record muscle force generation (in Newtons: N) during three pre-MVC's and the two endurance trials. Prior to the testing of the 50% MVC endurance trials, the participants engaged in three MVC trials lasting 4 seconds each. The mean of the three MVC pre-test trials served as the basis for establishing the 50% of MVC value for the endurance trials. Participants were instructed to hold the handgrip at the 50% MVC level for as long as they possibly could and to resist the temptation to quit. The 50% criterion level was presented as a horizontal red line displayed on a computer monitor set up in front of each participant. Participants squeezed the handgrip dynamometer to generate a force level with or greater than the criterion for as long as possible and when their force tracing dropped below the criterion line for more than 2 seconds, the trial was terminated and the endurance time was recorded. To control for individual differences in strength or effort expenditure on the first endurance trial, residualized change scores were calculated by regressing the second endurance trial duration on the first endurance trial duration (Cohen, Cohen, Aiken, & West, 2003).

Secondary Outcome and Process Measures.

Autonomous regulation. The hypothesis that people exposed to the autonomy support manipulation would perform better than those not exposed to autonomy support is, in part, based on an assumption that autonomy support would result in greater autonomous regulation for the second handgrip task. Autonomous regulation was measured using the Intrinsic Motivation Inventory (IMI; Ryan, 1982) which assessed arousal, mood, and motivation orientation. The inventory consists of 45-items which make up seven subscales and are rated on a 7-point Likert-type scale. Previous self-control studies that have utilized the IMI (i.e., Moller et al., 2006; Muraven et al., 2008) have primarily focused on the interest/enjoyment subscale (7-items), as this subscale is considered the measure of intrinsic motivation (Ryan). However, this study utilized the Task Evaluation Questionnaire, which encompassed four of the IMI's subscales: Interest/Enjoyment, Perceived Competence, Pressure/Tension, and Perceived Choice. Thus, a total of 22-items were rated on a 7-point scale ranging from 1 (*not at all true*) to 7 (*very true*) with a possible range of 7-28.

Cognitive self-control depletion task. Hypothesis 2 predicted that conservation of resources would be manifested in poorer (held back) performance on an intermediary task requiring self-control. The modified Stroop colour-word task (Wallace & Baumeister, 2002) was used as a self-regulatory strength depletion task that participants completed prior to the second handgrip task. This task consists of lists of colour words (blue, green, red, etc.) that are inconsistent with the ink colour they are printed in. The participants were instructed to read out loud the ink colour of the words, unless the word is written in red ink, where they must override the first rule and read the word they see written. Thus, the words they must say out loud are always the ink colour the word is printed in, unless the word is printed in red ink, then the word itself must be read. The Stroop task was performed for 5 minutes. Stroop task performances were represented by the number of words completed (count) and the number of errors made during the 5 minute test interval.

Manipulation Checks.

Ratings of perceived exertion (RPE). Participants rated perceived *physical* exertion (RPE) immediately following each endurance trial using Borg's 10-point CR-10 scale (Borg, 1998). This measure was used to check participants' motivational investment in the endurance handgrip tasks to ensure they exerted maximal perceived effort. It was expected that the participants would report RPE's between 8-10 across all conditions.

Rating of perceived mental exertion (RPME). Participants rated perceived *mental* exertion immediately following the Stroop task using an adapted version of Borg's 10-point ratings of perceived exertion scale (RPE). Several other studies assessing perceived mental exertion on cognitively-demanding tasks (e.g., Blackwood, MacHale, Power, Goodwin & Lawrie, 1998; Larsby, Hällgren, Lyxell & Arlinger, 2005) have used the same scale. It was expected that participants who were conserving their resources during this task would report lower ratings of perceived mental exertion for the task.

Subjective fatigue. Subjective feelings of general fatigue were assessed using the visual analogue scale (VAS: Gift, 1989). The VAS is a 100 mm horizontal line with the anchors of “extremely tired” and “extremely energized” at its extreme points. Participants used a pencil or pen to mark a point on the VAS scale corresponding to their perceived fatigue at that point in time. A standard metric ruler was used to convert the scale mark to a unit measure represented by millimeters with lower scores representing greater fatigue and higher score representing less fatigue. This scale was used to monitor any changes between tasks and between conditions on subjective feelings of energy levels.

Manipulation checks measures. A 4-item manipulation check (Bray et al., 2008; Muraven et al., 1998) was used to assess participants’ level of fatigue, effort, frustration and pleasantness after performing the Stroop colour word task (depletion paradigm) and is a 7-point Liker-type scale; (1) How fatigued are you after performing the word task? (1 = *not at all tired* to 7 = *extremely tired*), (2) How much effort did you exert during the word task? (1 = *little effort* to 7 = *extreme effort*), (3) How frustrated did you feel while doing the word task? (1 = *not at all frustrated* to 7 = *extremely frustrated*) and (4) How pleasant was the word task? (1 = *extremely unpleasant* to 7 = *extremely pleasant*). An identical 4-item manipulation check was used to assess participants’ level of fatigue, effort, frustration and pleasantness after the second endurance task.

A 2-item manipulation check was presented to all of the participants after the second endurance trial, in order to assess their levels of conservation during the Stroop task for the second endurance trial. The items include: *“How much energy were you trying to conserve for the final endurance trial?”* and *“How important was it for you to* *conserve your energy for the final endurance trail?",* and was rated on a 7-point Likert-type scale ranging from 1 (*minimum energy*) to 7 (*maximum energy*).

Mood Assessment. To assess levels of arousal and mood after the Stroop task, the Brief Mood Introspection Scale (BMIS; Mayer & Gaschke, 1988) was used. Participants had to describe their present mood on a 16-item list using adjectives such as "lively" and "drowsy." Their responses were made on a 7 point Likert-type scale which ranges from 1 (*definitely do not feel*) to 7 (*definitely feel*).

Self-Control Scale. The Self-Control Scale (SCS; Tangney, Baumeister, & Boone, 2004) is a measure of trait self-control that assesses how well people control impulses, regulate emotions, maintain self-discipline, control thoughts, and break out of bad habits, over 36-items. The SCS is a 5-point Likert-type scale ranging from 1 (*not at all like me*) to 5 (*very much like me*). The SCS demonstrates sound internal reliability with a coefficient alpha of .84 (Tangney et al.) and was assessed at the end of the study.

Study Manipulations

Conservation Manipulation. Following completion of the first handgrip endurance trial, half of the participants were randomly assigned (using a random number allocator, www.random.org) to either a conservation or no-conservation condition. Participants in the conservation conditions were informed that they would be completing a modified Stroop task, which would be followed by another sustained handgrip endurance trial and some questionnaires. Whereas, participants in the no-conservation conditions were only informed that they would be performing the modified Stroop task, some questionnaires, and then the study would be complete.

Autonomy Support Manipulation. Following completion of the modified Stroop task, half of the participants in each of the conservation and no-conservation conditions were randomly assigned (using a random number allocator, www.random.org) to either an autonomy support or no autonomy support condition. The autonomy support manipulation consisted of a script that was presented to the participants by the researcher. The script read as follows: *"You have exerted a lot of effort so far on both the endurance and colour reading tasks and I sincerely thank you. Advancing knowledge through research is an important undertaking and your willingness to put forth your best effort on the next task will assist our research the most. Of course, how much effort you put into this task is ultimately up to you. If you have any questions I would be happy to answer them."* The autonomy supportive manipulation was based on scripts and verbal strategies used in previous self-regulation depletion studies (Moller et al., 2006; Muraven, 2008; Muraven et al., 2008; Muraven et al. 2007).

Participants in the no autonomy support condition received instructions indicating that they would be performing another endurance trial, which stated *"Now it is necessary that you complete another maximum handgrip endurance trial. Your compliance to put forth your best effort on the task is required. You must resist the temptation to quit on this task in order to complete this endurance trial correctly. The endurance trial will start momentarily so you should be ready and remember it is required that you put forth your maximum effort possible. You must begin now."*

Note: As suggested in the proposal meeting the autonomy support and no autonomy support scripts were altered through suggestions from a Self-Determination

Theory expert (Dr. Philip Wilson) to be more sensitive (i.e., more autonomous words or controlling words), briefer and the same in length. Also, as suggested a pilot study was conducted to assess the sensitivity of the autonomy supportive manipulation and its subjective (IMI score) and objective (performance on the second endurance trial) outcomes. However, for the pilot study a very minor change was made to the first sentence of the autonomy supportive script which read *"You have exerted a lot of effort so far on the endurance task and I sincerely thank you"* instead of *"You have exerted a lot of effort so far on both the endurance and colour reading tasks and I sincerely thank you"* since the participants did not complete the Stroop task during the pilot study.

In the pilot study, 12 participants performed two 50% sustained MVC endurance tasks separated by 2 minutes rest. Following the second trial they completed the IMI Task Evaluation Questionnaire. To control for individual differences in strength or effort expenditure on the first endurance trial, residualized change scores were calculated by regressing the second endurance trial duration on the first endurance trial duration (Cohen et al., 2003). A one-way analysis of variance (ANOVA) was computed on the residualized change scores comparing the two conditions, autonomy support ($M = 8.96$) and no autonomy support ($M = -8.96$), and showed significant differences between the groups on the second endurance trial performance $F(1, 11) = 6.40$, $p = .03$ ($d = 1.45$).

A one-way ANOVA was computed on the IMI scores comparing the two conditions on subjective ratings of intrinsic motivation and showed no significant differences between conditions on: the full scale $F(1, 11) = 0.84$, $p = .38$, the interest/enjoyment subscale $F(1, 11) = 0.63$, $p = .43$, the perceived competence subscale

$F(1, 11) = 1.17$, $p = .31$, the perceived choice subscale $F(1, 11) = 1.59$, $p = .24$, and the tension/pressure scale $F(1, 11) = 0.96$, $p = .35$. However, the scale of specific interest was the perceived choice subscale and due to the relatively small number of participants the effect size for this subscale was calculated and a large effect size was found ($d = 0.74$).

Procedure

Participants were screened though email based on the inclusion criteria. Upon each participant's arrival at the lab, informed consent was obtained. Participants then performed three maximal voluntary contractions (MVC's) of their hand flexor muscles (maximum handgrip squeezes) using a handgrip dynamometer and held each for four seconds, with one minute of rest in between. After the 3 MVC's participants completed the visual analogue scale (VAS) that assessed their level of subjective overall fatigue.

The scores obtained from the three MVC's were averaged and 50% of their maximum force production was used for the next portion of the experiment, a self-control endurance trial. Their real-time force production for the handgrip squeeze was shown on a computer monitor and they were asked to maintain the squeeze tension in such a way as to keep it above a static line set at 50% of their maximum MVC shown on the computer monitor. They were asked to try to *"resist the temptation to quit"* and hold the handgrip (to keep the tension at the line) for as long as they could. To verify if participants had put forth maximum effort they rated perceived physical exertion (RPE) at the end of the endurance trial as well as subjective fatigue (VAS).

Half of the participants were then randomly assigned to the conservation condition or the no-conservation condition. At this time, participants in the conservation condition were informed that there would be two more tasks to complete. The first one would be a modified Stroop word task and they were instructed that they would have 5 minutes to read out loud the ink colour of the words, unless the word is written in red ink, where they must override the first rule and read the word they see written. Participants were told that this task would involve levels of self-control, in which they will have to work hard at overriding impulses but their objective is to complete as many words on the lists as possible. Additionally, the participants in the conservation condition were informed of a second sustained 50% MVC endurance trial which would occur after the Stroop task that will also *"require self-control in order to resist the temptation to quit"*. The participants in the no-conservation condition were not given any information about the second endurance handgrip squeeze and were told that the study would be completed after the Stroop task.

Following these instructions, all of the participants completed the 5-minute Stroop task. After completing the Stroop task, participants rated their levels of perceived mental exertion (RPME), completed the BMIS, and the two manipulation check measures.

Upon completion of the post-Stroop questionnaires, half of the participants in each of the conservation and no-conservation conditions were randomly assigned to receive an autonomy supportive manipulation condition or a non-autonomy supportive manipulation condition. At this time all participants were informed of the final endurance handgrip trial, but the manner by which they were informed was different between the autonomy supportive and non-autonomy supportive conditions. Participants in the autonomy supportive condition were presented with instructions from the autonomy support script and participants in the no autonomy support condition were presented with instructions from the no autonomy support script. After the second endurance trial, all of the participants rated their RPE for the trial, completed the BMIS, IMI, VAS, manipulation checks, and the SCS questionnaire.

Data Analysis Strategy

Although the study design involved a 2 X 2 factorial and was amenable to analyses using factorial ANOVA, given the hypotheses 1 and 2 specified independent main effects for conservation and autonomy support, the primary analyses were carried out using independent univariate ANOVAs. Hypothesis 3 was also tested using univariate ANOVA with planned contrasts among the four conditions to evaluate differences between the conservation/autonomy support condition and other conditions and the no conservation/no autonomy support conditions and other conditions.

To test hypothesis 1, a one-way analysis of variance (ANOVA) was calculated on residualized change scores to see if there were differences between the autonomy supportive conditions on endurance performance scores. Also, a one-way analysis of variance (ANOVA) was calculated on the IMI to see if there were differences between conditions on reports of autonomous motivation for the second endurance trial.

To test hypothesis 2, separate one-way ANOVAs were calculated on Stroop scores using two performance indicators (words completed and errors made) to see if the conservation manipulation affected performance. A one-way ANOVA was computed using residualized change scores to see if there were differences between the conservation conditions on the endurance performance scores.

To test hypothesis 3, a one-way ANOVA was calculated on residualized change scores for handgrip performance and apriori planned contrasts were computed to determine if there were differences between the conservation/autonomy support condition and the three other conditions. Planned contrasts were also used to evaluate differences between no conservation/no autonomy support conditions and other three conditions.

Results

Data Screening and Preliminary Analyses

It was expected that RPE ratings of 8-10 would be reported across all conditions to ensure that the participants were performing the endurance tasks correctly. However, six participants reported low RPE scores (ranging from 1.5-6) for both the endurance trials suggesting that they did not exert maximal effort on the endurance trials. Therefore they did not complete the task as required and as a result, their data were discarded from the analysis. In addition, the data from one participant was removed because the second endurance trial score was 3.4 standard deviations from the overall mean.

Data from three additional participants were also removed from the dataset prior to analysis. Two participants prematurely terminated the second endurance trial. The first of the two, stopped because she believed that she didn't have the handgrip gripped properly and then proceeded to ask for a rest before she made another attempt. The second participant thought that when the force line went below the target red line that the trial was over. One participant became suspicious that there would be another endurance trial and was in essence conserving to some degree. This participant's data were discarded as she was in the no conservation condition.

To have 80% power in order to detect significant differences between the groups with an alpha level set at $p = .05$, based on large effect sizes for conservation ($d = 1.04$) and autonomy support ($d = 1.05$) on self-regulatory tests (Hagger et al., 2010), 72 participants were needed (Cohen, 1992). Therefore, following data screening and deferring inclusion of 10 of the original participant pool, 10 additional participants were recruited and were all randomized (using a random number allocator, www.random.org) to conditions before entering the lab.

Testing the Assumptions of Analysis of Variance (ANOVA)

To ensure normality of distributions of the data, for each hypothesis, Shapiro-Wilk tests were performed, as well as examining frequency histograms and residual scatter plots. In addition, the homogeneity of variances were examined through Levene's test of significance. As seen in Table 1, the Stroop Error scores were positively skewed and did not represent a normal distribution in the no conservation condition. As well, there were two extreme outliers (above 3.5 SD's from the mean) within each condition.

Following recommendations from Tabachnick and Fidell (2001) the two extreme outliers were removed and a square root transformation was performed on the Stroop errors data. As seen in Table 2, these procedures corrected for violations of skewness and normality.

Data from the IMI scale were also skewed and did not represent a normal distribution (Table 3). To correct for this a logarithmic (LN) transformation was performed and this corrected the data (Table 4).

Demographics

The demographic information for the complete sample by condition is presented in Table 5. A one-way analysis of variance (ANOVA) was computed comparing the demographics of the four conditions (autonomy support/conservation (*N* = 19), autonomy support/no conservation (*N* = 18), no autonomy support/conservation (*N* = 17), and no autonomy support/no conservation (*N* = 18)) and showed no significant differences between the groups based on demographic information such as age, $F(3,68) = 0.24$, $p = .93$; strenuous intensity bouts of exercise per week, $F(3,68) = 0.85$, $p = .47$; moderate intensity bouts of exercise per week, $F(3,68) = 1.15$, $p = .33$; and mild intensity bouts of exercise per week, $F(3,68) = 2.35$, $p = .08$.

The distributions of men and women across groups was evaluated using a contingency table and were not significantly different, $\chi^2(3, N = 72) = 1.93$, $p > .05$. As well, the distributions of lifting weights for exercise across groups was evaluated using a contingency table and were not significantly different, $\chi^2(3, N = 72) = 3.67$, $p > .05$.

Table 1

Normality and Homogeneity of Stroop Errors

Condition	Skewness	Kurtosis	Normality	Levene's Value
Conservation	0.14	-0.65	.58	.18
No conservation	1.01	0.82	.01	

Table 2

Normality and Homogeneity of Square Root Transformed Stroop Errors

Condition	Skewness	Kurtosis	Normality	Levene's Value
Conservation	-0.21	-0.37	.56	.15
No conservation	-0.17	-0.88	.32	

Table 3

Normality and Homogeneity of the IMI Scale

Condition	Skewness	Kurtosis	Normality	Levene's Value
Autonomy	-0.25	-0.42	.07	.32
No autonomy	3.03	-0.11	.02	

Table 4

Normality and Homogeneity of the Logarithmic Transformed IMI Scale

Condition	Skewness	Kurtosis	Normality	Levene's Value
Autonomy	-0.11	-0.59	.77	.30
No autonomy	-0.90	0.90	.07	

Table 5

Demographic Characteristics of the Sample

Demographic Information	AS/Con.	AS/No Con.	No AS/Con.	No AS/No Con.	All participants
	n = 19	*n* = 18	*n* = 17	*n* = 18	*N* = 72
	M (*SD*)	*M* (*SD*)	*M* (*SD*)	*M* (*SD*)	*M* (*SD*)
Age	22.74 (3.71)	22.39 (4.06)	22.12 (3.43)	22.06 (2.77)	22.33 (3.46)
Gender					
Male	8 (11.1%)	5 (6.9%)	6 (8.3%)	4 (5.6%)	23 (32.0%)
Female	11 (15.3%)	13 (18.1%)	12 (16.7%)	14 (19.4%)	49 (68.1%)
Lift weights	5 (6.9%)	9 (12.5%)	7 (9.7%)	10 (7.2%)	31 (43.1%)
Bouts of exercise/week					
Strenuous	1.74 (1.56)	2.28 (1.76)	2.65 (1.80)	2.22 (1.77)	2.08 (1.72)
Moderate	2.74 (1.85)	2.06 (1.30)	2.47 (1.74)	3.00 (1.41)	2.57 (1.60)
Mild	2.63 (2.48)	3.72 (2.40)	3.77 (3.15)	2.33 (2.52)	3.10 (2.67)

Note: Values with percentages (%) are accompanied by count data, *n* = sample size, *M* = mean, (*SD*) = standard deviation, AS = autonomy support, No AS = no autonomy support, Con. = conservation, No Con. = no conservation

Manipulation Checks

The descriptive statistics for the various manipulation checks by condition are presented in Table 6. The descriptive statistics and scale internal consistencies for the manipulation checks/covariate measures are presented in Table 7**.** A series of one-way ANOVAs were computed comparing the manipulation checks items of the four conditions (autonomy support/conservation, autonomy support/no conservation, no autonomy support/conservation, and no autonomy support/no conservation) on ratings of perceived *physical* exertion (RPE; after the first and second endurance trials), ratings of perceived *mental* exertion (RPME; after the Stroop task), the Visual Analogue Scale (VAS; subjective fatigue before and after the endurance tasks and Stroop task), the Brief Mood Introspection scale (after Stroop), the 4-item manipulation checks after the Stroop and after the second endurance trial (assessing task effort, fatigue, frustration and pleasantness). No significant differences were found between conditions on: RPE after the first endurance trial, $F(3, 68) = 0.38$, $p = .76$; RPE after the second endurance trial, $F(3,68) = 1.79$, $p = .16$; VAS before the first endurance trial, $F(3,68) = 2.47$, $p = .07$; VAS after the first endurance trial, $F(3,68)$, $p = 0.79$; VAS after the Stroop task, $F(3,68) = 0.72$, $p = .54$; VAS after the second endurance trial, $F(3,68) = 0.81$, $p = .49$.

Moreover, no significant differences were found between conditions after the Stroop task on ratings of: mental effort, $F(3,68) = 0.06$, $p = .98$; mental fatigue, $F(3,68) = 0.65$, $p = .59$; mental frustration, $F(3,68) = 1.09$, $p = .36$; and pleasantness, $F(3,68) = 0.29$, $p = .83$. No significant differences were found between conditions after the second endurance trial on ratings of: task effort, $F(3,68) = 0.74$, $p = .53$; task fatigue, $F(3,68) =$

0.04, $p = .99$; task frustration, $F(3,68) = .267$, $p = .85$; and pleasantness, $F(3,68) = 0.33$, $p = .80$. In addition, no significant differences were found between conditions on ratings of present mood (BMIS; pleasant/unpleasant), $F(3,68) = 1.14$, $p = .34$.

As predicted, the non significant differences between these specific manipulation checks indicate that each task was perceived to be the same between conditions and that the only difference should have been the amount of perceived self-control required. However, because they were expected to hold back effort on the task, it was expected that participants who were conserving their resources during the Stroop task would report lower ratings of perceived mental exertion (RPME) for the task. This was not found to be the case, $F(3,68) = 0.23$, $p = .87$ ($d = 0.07$).

The final manipulation check measure was the Self-Control Scale (SCS) and a univariate ANOVA was computed to compare individual differences on levels of self-control between conditions. Significant differences were found between the conditions, $F(3,68) = 3.80$, $p = .01$. Tukey's post hoc test showed that there were significant differences between condition 1 (conservation/autonomy support) and condition 2 (no conservation/autonomy support), mean difference = -16.73, $p < .01$ ($d = 0.97$); condition 1 and condition 3 (conservation/no autonomy support), mean difference = -.14.37, $p = .01$ ($d = 0.83$); and condition 1 and condition 4 (no conservation/no autonomy support), mean difference = -12.23, $p = .03$ ($d = 0.71$). Therefore, the SCS score was used as a covariate between conditions for each hypothesis test (as condition 1 statistically differed from all the other conditions) to control for individual differences in abilities to exert self-control on the specific tasks requiring self-control (the two endurance trials and the Stroop task).

Table 6

Descriptive Statistics of the Manipulation Checks

Manipulation Checks	AS/Con. *n* = 19 *M* (*SD*)	AS/No Con. *n* = 18 *M* (*SD*)	No AS/ Con. *n* = 17 *M (SD)*	No AS/No Con. *n* = 18 *M* (*SD*)	All participants *N* = 72 *M* (*SD*)
RPE					
After 1st endurance	8.13 (1.32)	7.86 (1.50)	8.12 (1.69)	7.67 (1.61)	7.94 (1.52)
After 2nd endurance	8.97 (1.20)	8.92 (1.14)	9.47 (0.80)	8.58 (1.34)	8.98 (1.16)
RPME	5.92 (1.42)	6.44 (2.57)	6.35 (2.13)	6.11 (2.17)	6.20 (1.07)
VAS					
Before 1st endurance	59.95 (20.09)	72.06 (14.58)	69.06 (17.52)	60.72 (11.82)	65.32 (16.85)
After 1st endurance	59.11 (16.92)	61.11 (19.50)	63.71 (20.24)	57.95 (14.70)	60.40 (17.68)
After Stroop	51.05 (20.02)	58.22 (20.99)	58.35 (22.01)	52.00 (14.94)	54.81 (19.53)
After 2nd endurance	54.90 (15.52)	54.28 (24.03)	45.71 (23.20)	49.33 (17.55)	51.18 (20.21)

Ratings of Mental					
Effort	5.47 (0.61)	5.44 (1.30)	5.41 (0.94)	5.33 (1.19)	5.42 (1.02)
Fatigue	3.32 (1.20)	3.61 (1.54)	3.35 (1.58)	3.89 (1.28)	3.54 (1.40)
Frustration	3.79 (1.58)	3.00 (1.33)	2.94 (1.75)	3.11 (1.78)	3.22 (1.62)
Pleasantness	4.11 (1.37)	4.22 (1.40)	4.00 (1.22)	4.39 (1.20)	4.18 (1.28)
Ratings of Physical					
Effort	6.53 (0.61)	6.56 (0.51)	6.71 (0.47)	6.44 (0.51)	6.56 (0.53)
Fatigue	4.63 (1.07)	4.78 (1.44)	4.71 (1.79)	4.67 (1.08)	4.69 (1.34)
Frustration	2.58 (1.35)	2.22 (1.22)	2.65 (1.87)	2.50 (1.62)	2.49 (1.50)
Pleasantness	3.74 (1.56)	3.89 (1.64)	3.82 (1.38)	3.44 (1.15)	3.72 (1.43)

Note. *n* = sample size, *M* = mean, (*SD*) = standard deviation, AS = autonomy support, No AS = no autonomy support, Con. = conservation, No Con. = no conservation, RPE = ratings of perceived exertion, RPME = ratings of perceived mental exertion, VAS = visual analogue scale.

Table 7

Descriptive Statistics and Scale Internal Consistencies of the Covariate Measures

Covariate Measures	AS/Con. *n* = 19 *M* (*SD*)	AS/No Con. *n* = 18 *M* (*SD*)	No AS/Con. *n* = 17 *M* (*SD*)	No AS/No Con. *n* = 18 *M* (*SD*)	All participants *N* = 72 *M* (*SD*)
BMIS	15.63 (11.19)	22.22 (11.90)	19.82 (11.71)	18.94 (8.97)	19.10 (11.03)
ICC	--	--	--	--	0.75
SCS	113.11 (18.73)	129.83 (15.61)	127.47 (15.68)	125.33 (15.50)	123.74 (17.43)
ICC	--	--	--	--	0.89

Note: *n* = sample size, *M* = mean, (*SD*) = standard deviation, ICC = intraclass correlation coefficient, BMIS = brief mood introspection scale, SCS = self-control scale, AS = autonomy support, No AS = no autonomy support, Con. = conservation, No con. = no conservation.

Hypothesis Testing

Main Effects.

Hypothesis 1a. *Individuals who are provided with autonomy support for self-control performance will perform better (longer sustained endurance times relative to baseline) on the second endurance trial compared to individuals who are not provided with autonomy support.*

A univariate analysis of covariance was computed on the unstandarized residualized change scores for the second endurance trial co-varying for Self-Control Scale scores to compare differences between the autonomy support conditions' (N = 37) and no autonomy support conditions' (N = 35) performances on the second endurance trial. As seen in Figure 2, the difference between the average residualized change scores (M = 4.92 vs. M = -4.58) was found to be significant, $F(2,69) = 6.61$, $p = .01$ ($d = 0.62$). In other words, the participants who received the autonomy supportive manipulation performed better on the second endurance trial (longer sustained endurance times relative to baseline) compared to participants who did not receive the autonomy supportive manipulation.

Hypothesis 1b. *Individuals who are provided with autonomy support for self-control performance will report greater autonomous regulation (higher scores on the IMI) compared to individuals who are not provided with autonomy support.*

Descriptive statistics summarizing the IMI full and sub-scale scores for the autonomy support and no autonomy support conditions are presented in Table 8. A one-way ANOVA was computed comparing the IMI scores of the autonomy support conditions and no autonomy support conditions and no significant differences were found between conditions on: the full scale, $F(1,70) = 0.97$, $p = .33$; the interest/enjoyment subscale, $F(1,70) = 1.72$, $p = .19$; the perceived competence subscale, $F(1,70) = 1.58$, $p = .21$; the perceived choice subscale, $F(1,70) = 2.54$, $p = .12$ and the pressure/tension subscale, $F(1,70) = .001$, $p = .97$.

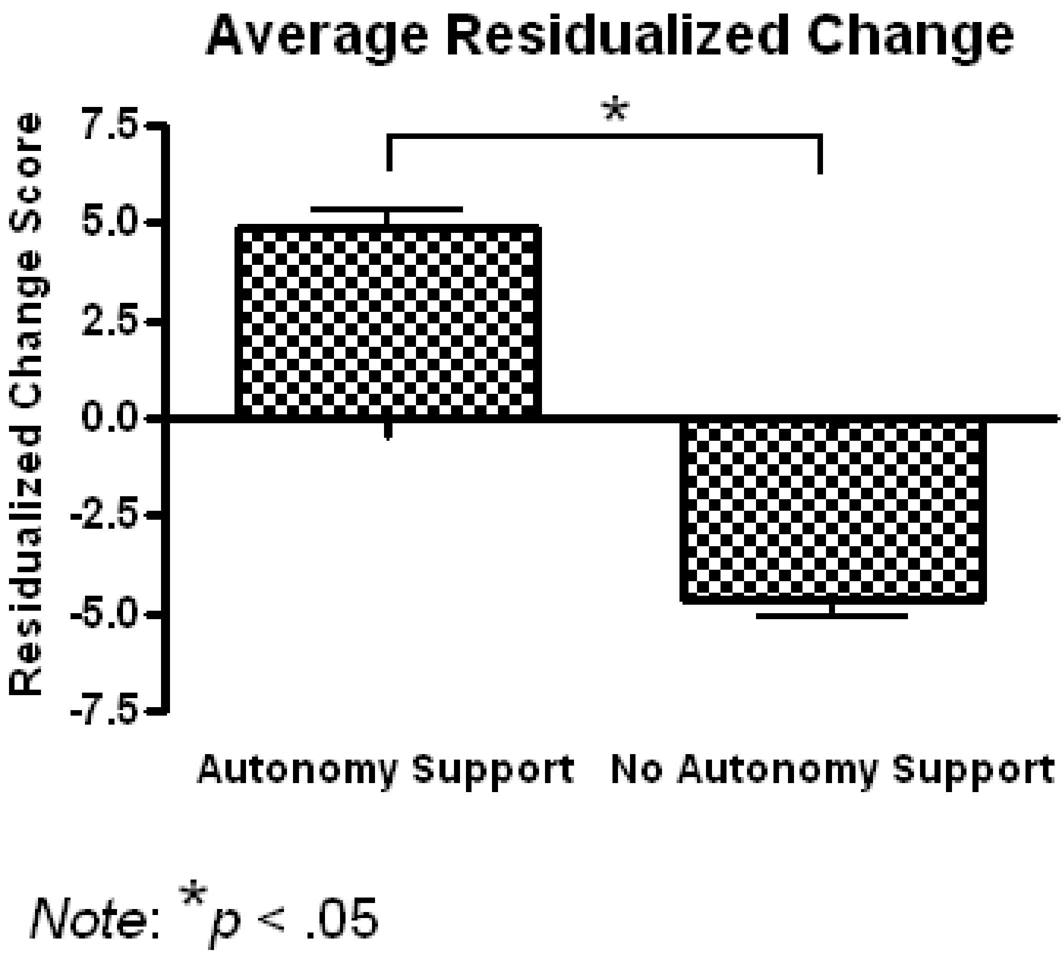


Figure 2. Difference in average residualized change scores for endurance handgrip performances between the autonomy and no autonomy conditions adjusted for SCS scores.

Table 8

Intrinsic Motivation Inventory Scores Between the Autonomy and No Autonomy Conditions

Variables of Interest	AS *n* = 37 *M* (*SD*)	No AS *n* = 35 *M* (*SD*)	*p*	*d*	ICC
IMI Full Scale (LN Transformed)	31.44 (7.63)	33.12 (6.82)	.33	0.23	.77
Interest/Enjoyment Subscale	4.02 (1.43)	4.44 (1.32)	.19	0.31	.92
Perceived Competence Subscale	4.07 (0.85)	3.78 (1.12)	.21	0.30	.74
Perceived Choice Subscale	5.28 (1.33)	5.74 (1.14)	.12	0.37	.81
Pressure/Tension Subscale	3.83 (0.85)	3.84 (0.93)	.97	0.01	.34

Note: *n* = sample size, *M* = mean, (*SD*) = standard deviation, ICC = interaclass correlation coefficient, *d* = effect size, AS = autonomy support, No AS = no autonomy support, IMI = intrinsic motivation inventory.

Hypothesis 2a. *Individuals who are told (after the first task) that a third task which requires self-control, will follow the second task, will be motivated to conserve their resources for the third task and will perform worse on the second task (fewer Stroop words completed and more errors), compared to individuals who are not anticipating the third task.*

Descriptive statistics summarizing the Stroop task performance scores and manipulation check items for the conservation and no conservation conditions are presented in Table 9. A one-way ANOVA was computed comparing the Stroop scores of the conservation conditions ($N = 36$) and no conservation conditions ($N = 36$).

Significant differences were found between conditions on Stroop words completed, $F(1,70) = 11.68$, $p < .01$ and on the number of errors (SQRT transformed values) made, $F(1,68) = 86.27$, $p < .01$, presented in Table 9. These results indicate that participants in the conservation conditions completed fewer words and made more errors on the Stroop task.

Table 9

Stroop Task and Two-item Scores Between the Conservation and No Conservation Conditions

Variables of Interest	Conservation $n = 36$ M (SD)	No conservation $n = 36$ M (SD)	p	d
Words Completed	244.56 (53.16)	284.25 (45.05)	<.01	0.80
Errors Made (SQRT Transformed)	4.13 (0.61)	2.63 (0.74)	<.01	2.11
Amount of Conservation	3.08 (1.89)	1.86 (1.24)	<.01	0.76
Importance of Conservation	3.19 (2.07)	1.92 (1.40)	<.01	0.72

Note: n = sample size, M = mean, (SD) = standard deviation, d = effect size.

In addition, a one-way ANOVA was computed on the two-item manipulation check items of the conservation conditions and no conservation conditions and significant differences were found between conditions on item 1 ("*How much energy were you trying to conserve for the last endurance trial?*"), $F(1,70) = 10.51$, $p < .01$ and on item 2 (*"How important was it for you to conserve your energy for the last endurance trial"?*), $F(1,70) = 9.42$, $p < .01$. In other words, individuals in the conservation condition scored higher on these two items.

Hypothesis 2b. *Individuals who are told (after the first task) that a third task which requires self-control, will follow the second task, will be motivated to conserve their resources for the third task and will perform better on the third task (longer sustained endurance times relative to baseline)*, *compared to individuals who are not anticipating the third task.*

A univariate analysis of covariance was computed on the unstandarized residual change scores for the second endurance trial co-varying for Self-Control Scale scores to compare differences between the conservation conditions' and no conservation conditions' performances on the second endurance trial. As seen in Figure 3, the difference between the average residualized change scores (M = 0.85 vs. M = -.29) was not significant, $F(2,69) = 0.08$, $p = .77$ ($d = 0.07$), in other words, the participants who were in the conservation condition did not perform better on the second endurance trial (in comparison to the first endurance trial) compared to those who were not conserving.

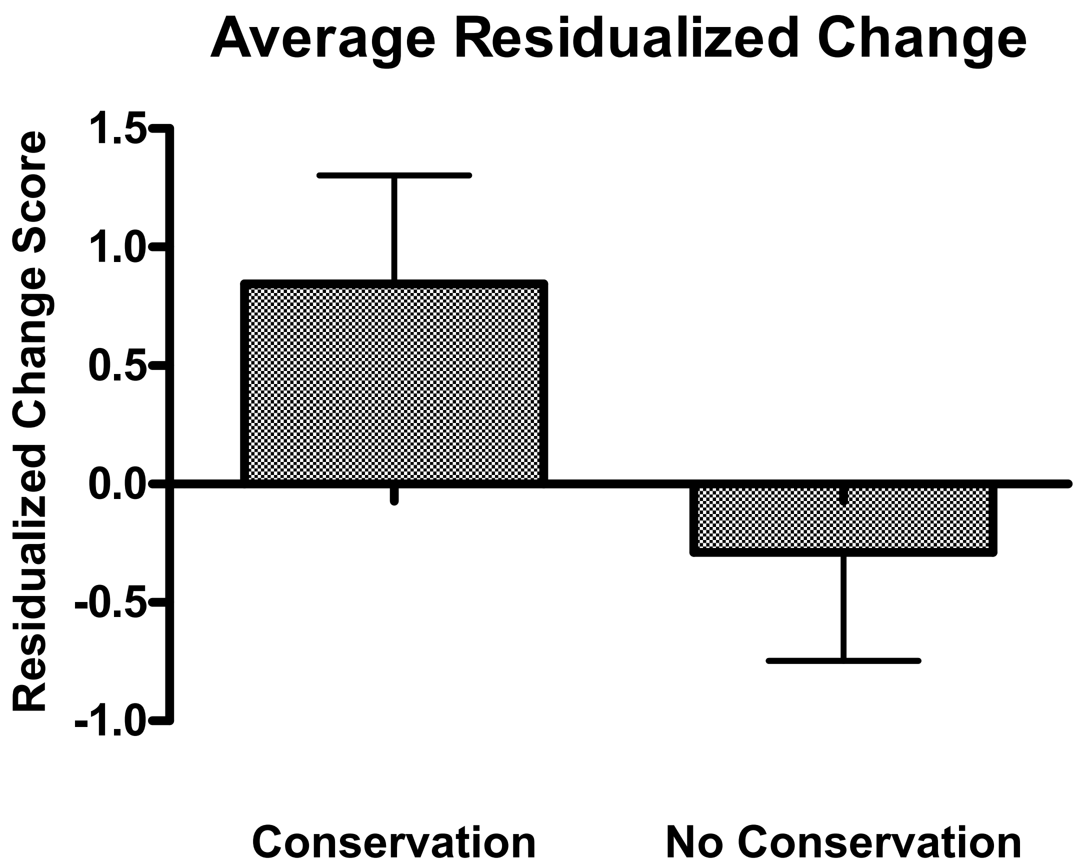
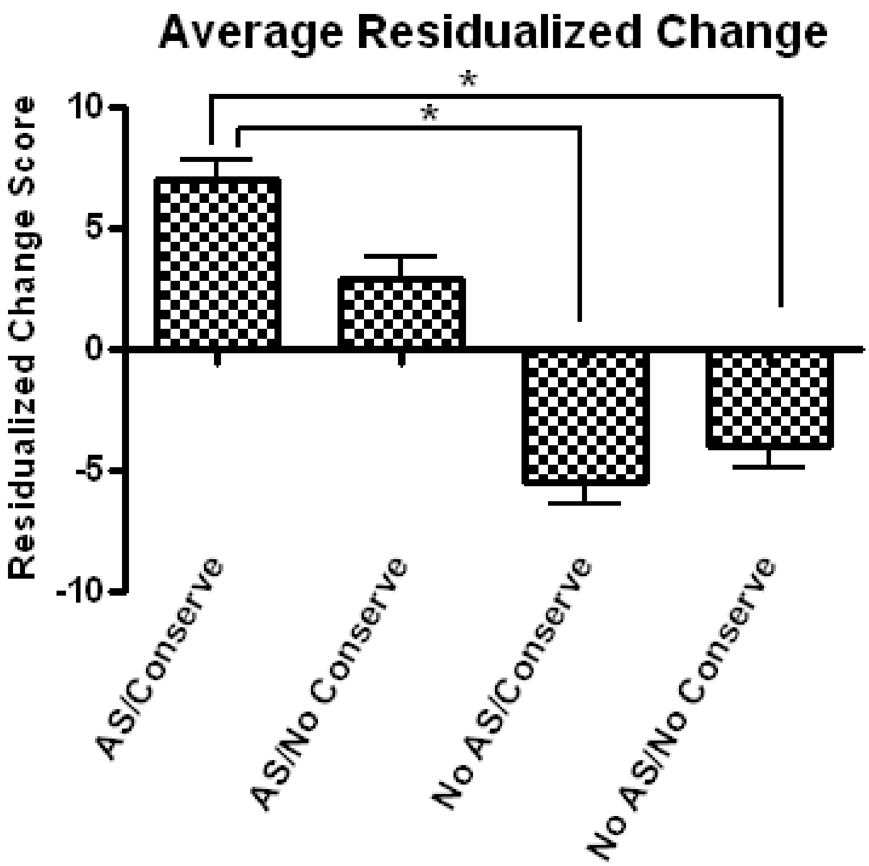


Figure 3. Difference in average residualized change scores for endurance handgrip performances between the conservation and no conservation conditions adjusted for SCS scores.

Planned Contrast Effects

Hypothesis 3a. *Participants in the conservation condition and who are provided with autonomy support will perform better on the third task (longer sustained endurance times relative to baseline) compared to all other conditions.*

A univariate analysis of variance with simple planned contrasts was computed on the unstandarized residual change scores for the second endurance trial, co-varying for Self-Control Scale scores, to compare differences between condition 1 (conservation/autonomy support) and the other 3 conditions. As seen in Figure 4, the difference between the average residualized change scores in the conservation/autonomy condition (M = 6.99) and the conservation/no autonomy condition (M = -5.49), was found to be significant, Contrast Estimate = -12.47 (95%CI: 1.48 to 23.47), SE = 5.51, p = .03 (d = 0.76). As well, a significant difference was found between the conservation/autonomy condition (M = 6.99) and the no conservation/no autonomy condition (M = -3.97), Contrast Estimate = -10.96 (95%CI: .252 to 21.66), SE = 5.36, p = .04 (d = 0.78). However, the difference between the conservation/autonomy support condition (M = 6.99) and no conservation/autonomy support condition (M = 2.89) was not significant, Contrast Estimate = -4.091 (95%CI: -6.93 to 15.11), SE = 5.52, p = .46 (d = 0.30).



Note: $^{*}p < .05$

Figure 4. Difference in average residualized change scores for endurance handgrip performances between all conditions adjusted for SCS scores.

Hypothesis 3b. *Participants in the no conservation condition and who are not provided with autonomy support will perform significantly worse on the third task (shorter sustained endurance times) compared to all other conditions*

A univariate analysis of covariance with simple planned contrasts was computed on the unstandarized residual change scores for the second endurance trial, co-varying for Self-Control Scale scores, to compare differences between condition 4 (no conservation/no autonomy support) and the other 3. A significant difference was found between the no conservation/no autonomy condition (M = -3.97) and the conservation/autonomy condition (M = 6.99), Contrast Estimate = -10.96 (95%CI: -21.66 to -.25), SE = 5.36, p = .04 (d = 0.78). However, no significant difference was found between the no conservation/no autonomy condition (M = -3.97) and the No Conservation/Autonomy condition (M = 2.89), Contrast Estimate = -6.86 (95%CI: -17.38 to 3.65), SE = 5.27, p = .20 (d = 0.46). As well, no significant difference was found between the no conservation/no autonomy support condition (M = -3.97) and conservation/no autonomy support condition (M = -5.49), Contrast Estimate = 1.52 (95%CI: -9.11 to 12.15), SE = 5.52, p = .78 (d = 0.09).

Discussion

The purpose of this thesis was to extend previous research by experimentally exploring the independent and combined effects of autonomy support and self-control conservation on performance of self-control tasks. Based on prior research investigating autonomous regulation, it was hypothesized that stimulating autonomous regulation through autonomy support would ameliorate self-control depletion effects on performance of a physical endurance self-control task. In addition, prior research based on the resource conservation hypothesis, led to the hypothesis that when participants were told (after the first task) that a third task which required self-control would follow the second task, they would be motivated to conserve their resources for the third task by withdrawing their performance on the second task. Finally, the two perspectives were drawn together leading to the hypothesis that participants who received autonomy support and who were conserving self-control would exhibit the best self-control performance on the third task, while those who did not receive autonomy support and who were not conserving resources would show the worst performance. Results were mixed, but generally provided full or partial support for the hypotheses. The findings, their implications and future directions are discussed in the following sections.

Hypothesis 1: Individuals who were provided with autonomy support for self-control performance, compared to those who did not receive autonomy support, would:

a) **Perform better on the second endurance trial (longer times relative to baseline)**

b) Report greater autonomous regulation (higher scores on the Intrinsic Motivation Inventory)

Results revealed a significant (p = .01), medium-sized (d = 0.62; Cohen, 1992), association between autonomy support and self-control performance of endurance handgrip exercise. In other words, participants who were provided with autonomy support performed better (relative to baseline) on the second endurance handgrip trial compared to those who were not provided with autonomy support. This finding supports hypothesis 1a and is consistent with other research that has also demonstrated that autonomous regulation was positively associated with self-control task performance (Moller et al., 2006; Muraven, 2008; Muraven et al., 2008; Muraven et al., 2007).

It was outlined earlier that previous research (Moller et al., 2006; Muraven et al., 2008; Muraven et al., 2007) investigating the effects of autonomy support on self-control depletion has primarily used cognitive (e.g., inhibiting thoughts) or emotional (e.g., suppressing laughter) self-control tasks as manipulations or dependent measures. However, only one study has focused on physical endurance, specifically handgrip performance, and manipulated autonomous regulation by providing participants with self-determined or controlled choices (Muraven, 2008). That study showed that resisting the temptation to eat cookies for autonomous reasons was associated with greater self-control strength on a task requiring muscular endurance. Thus, the present study contributes to a small, but growing body of literature that supports the theoretical notion that an autonomously-supportive environment can increase task motivation and over-ride the negative aftereffects of self-control depletion on physical task performance.

Although autonomy support was associated with ameliorated self-control depletion effects, contrary to hypothesis 1b, analyses revealed that the effect was not associated with autonomous regulation as there were no between-group differences in IMI scores. However, this null finding may be related to measurement characteristics of the instrument used to assess autonomous regulation. Consistent with the majority of previous studies that have assessed autonomous regulation on self-control tasks, the Intrinsic Motivation Inventory (IMI; Ryan, 1982), or a modified version of that questionnaire, was used in the present study. However, recall that the study by Muraven (2008) was the only other study to have examined physical endurance, and in that study Muraven assessed motivation using a modified version of the Self-Regulation questionnaire (Ryan & Connell, 1989) which included 4-items with each item assessing a different type of motivation (external, introjected, identified, and intrinsic). Because the IMI contains a greater number items (N =22), it was reasoned that this measure should be more sensitive in assessing autonomous regulation as the questionnaire primarily focuses on the interest/enjoyment of a task. However, the data showed that interest and enjoyment scores for the physical endurance task were low across all groups, which may be due to the muscle fatigue and hand discomfort experienced while performing the task. In short, participants may have been motivated to perform the task for more autonomous reasons, but this motivation may have not been adequately assessed by the measure of interest and enjoyment. Therefore, it is possible the modified version of the Self-Regulation questionnaire used by Muraven, or another measure of autonomous regulation, may have been more appropriate for the present study.

One important question that arises from these findings relates to the processes by which autonomy support may lessen the depletion effect. Moller et al. (2006) and Muraven et al. (2007) suggest that when self-control feels more volitional it may lead to greater feelings of vitality, which is a "positive feeling of having energy available to the self" (Nix et al., 1999, p.266). The vitality that is created by autonomy support or autonomous regulation then may lead to heightened energy available to the individual when it would otherwise be lacking (Ryan & Deci, 2008). Alternatively, it has been proposed that feeling autonomous may change the nature of how an individual perceives having to exert self-control to perform the task itself (Moller et al., 2006). In other words, even if the task is unpleasant to perform, if one does not mind performing it because they had a choice or because they think it is important to do, then it may not be as depleting as it would otherwise be. Thus, even though people may perform the same task, it is suggested that when they feel more autonomously regulated, less self-control is required to perform a task compared to when they feel more controlled.

Hypothesis 2: Individuals who were told (after the first endurance trial) that a second endurance trial would follow the Stroop task, would conserve their resources for the second endurance trial, compared to individuals who were not anticipating a second endurance trial. It was expected that those conserving would:

a) Perform worse on the Stroop task (fewer words completed and more errors)

b) Perform better on the second endurance trial (longer times relative to baseline)

As predicted, participants who were led to believe they would have to expend additional self-control strength later on in the study session performed worse on a test of cognitive self-control compared to participants who were given no foreknowledge of further self-control demands. That is, significant ($p < .01$) and large-sized (Cohen, 1992), effects were found for Stroop task performance: with fewer words completed ($d = 0.80$) and more errors made ($d = 2.11$) by participants who were informed that a second muscular endurance trial would follow the Stroop task. These results are consistent with an inference that self-control strength conservation was occurring among those participants, but is also corroborated by a manipulation check indicating participants in the conservation condition were indeed conserving resources ($d = 0.75$) and they perceived it to be important for them to conserve ($d = 0.72$) their resources for the second endurance trial.

Although the conservation hypothesis has received limited attention in the self-control depletion literature, these results are consistent with those obtained in previous research (Muraven et al., 2006; Tyler & Burns, 2009) where performance on a proximal self-control task was negatively affected by providing participants with an expectation that they would have to expend further self-control strength later on in the experiments. However, the present investigation is the first to have investigated the prospect that people who have conserved their self-control strength should outperform those who have not conserved on a subsequent task requiring self-control of physical (muscular) endurance. The hypothesis that the participants who were conserving self-control resources would outperform those who were not conserving on the final endurance task was based on the assumption that self-control strength is a limited and important resource and that conservation of self-control strength should translate over to improved performance on a future self-control task. Contrary to predictions, data did not support this hypothesis as participants in the conservation condition did not outperform controls on the second endurance trial (relative to baseline). However, it should be noted that a small to medium effect ($d = .41$) was found in the expected direction.

Past research by Muraven et al. (Study 4; 2006) suggests that the conservation of resources does have a beneficial, or protective, effect on subsequent tests of self-control strength. However, there are differences between Muraven et al.'s study and the present study that warrant discussion and may account for the divergent findings. For instance, the studies differed in terms of the types of tasks performed. Muraven et al. utilized cognitive task performance (anagram task) as the dependent measure whereas the present study utilized a physical endurance task that may have unique physiological demands. When individuals are suppressing their impulse to give up on unsolvable anagrams their performance is ultimately determined by how much they want to keep doing it. Whereas, when performing a physical endurance self-control task other physiological factors, such as muscle fatigue, hydration, and the accumulation of hydrogen ion (i.e., lactic acidosis) and heat (i.e., hyperthermia) are known to place an upper limit on one's endurance (Coyle, 1999; Gibson & Noakes, 2004). Thus, it is possible that individuals may have terminated the task before they exhausted their self-control resources.

Consistent with this interpretation, Baumeister, Tice and Heatherton (1994) illustrate several situations where differences in impulse suppression (self-control) can occur between resistible and irresistible impulses. They highlighted the fact that truly irresistible impulses may be impossible to suppress regardless of perceived consequences or rational choices. In their words:

> Even if someone is holding a gun and threatening to shoot you, you will act on an irresistible impulse. For example, the urge to urinate or to lie down can eventually become irresistible, and under extreme conditions a person will do either of those things even when someone is threatening to shoot him or her for doing so. But overeating, or smoking a cigarette, or beating one's spouse would almost certainly not qualify as an irresistible impulse by that criterion (p. 249).

These ideas are relevant in the present context because people may not be able to sustain an endurance handgrip task and resist the urge to let go for as long as they desire due to the extreme physiological demands associated with the task as they may succumb to muscle fatigue before succumbing to self-control fatigue. Anecdotally, several participants in the study had to be cut off when their force generation failed to be at the criterion level. Although they tried as hard as they could to continue the task they could not muster enough force to maintain a hard enough squeeze. As a result, one might assert that in these instances participants were still trying to exert self-control over their handgrip squeezing but were unable to generate enough force to maintain the task. This could be another reason why divergent results were found between Muraven et al.'s (2006) study and the present study as participants performed the endurance task on average for about half the time (74 seconds compared to 147 seconds) they did in that study. Therefore, perhaps when assessing complete self-control exhaustion it is dependent on the type of task you use (i.e., cognitive vs. physical).

In summary, additional research is warranted to investigate the carry-over of the conservation effect as the current evidence remains somewhat unclear. It appears that conservation effects occur predictably on interim tasks, but that perhaps the nature of the self-control tasks dictates the degree to which conservation effects can be observed on future tasks.

Hypothesis 3: Participants in the conservation condition and who were provided with autonomy support would achieve the longest sustained contraction time on the second endurance trial compared to all the other conditions. Whereas, individuals in the no conservation condition who were not provided with autonomy support would have the shortest sustained contraction time on the second endurance trial compared to all the other conditions.

The most ambitious and novel aspect of this thesis was the investigation of the hypothesis that participants who conserve resources and receive autonomy support would outperform (longer sustained endurance times relative to baseline on the final test of self-control) compared to all other conditions. This hypothesis was partially supported. Results revealed that participants in that condition performed significantly better than the two no autonomy support conditions (conservation, $d = 0.76$ and no conservation, $d = 0.78$) but not better than those in the no conservation and autonomy support condition ($d = 0.30$).

The investigation of these two effects in combination was inspired by Hagger et al.'s (2010) recommendations that the conservation of self-control resources should be studied in conjunction with motivation. However, based on evidence from the present study only, autonomy support seems to be the most influential factor in overcoming self-regulation depletion. In support of this argument, small-medium effect sizes were observed in the expected directions between the autonomy support and no conservation condition in reference to the no autonomy support and conservation (d = 0.50, p = .14), and the no autonomy support and no conservation condition (d = 0.47, p = .21).

The hypothesis that the participants who were in the no conservation condition and who were not provided with autonomy support would perform worse on the third task (shorter sustained endurance times relative to baseline) compared to all other conditions was also not supported. Although they did perform worse in comparison to the conservation/autonomy condition (d = 0.78), performance was not worse than the other two conditions (autonomy/no conserve, d = 0.46 and no autonomy/conserve; d = 0.09). These results suggest that instructions for a task which are presented in a non-autonomy supportive way lead to poorer performances than autonomy supportive instructions, regardless of conservation.

Together these results suggest that autonomy support may not only lead to greater self-control strength utilization, but may also supersede the conservation effect. However, this was the first study to test these two effects in combination and future research is needed to explore these relationships. As mentioned above, an important consideration in future studies is to determine the extent to which different types of self-control tasks may reveal different effects. In particular, physical endurance tasks may have some unique characteristics that may limit conservation effects when compared to other types of self-regulation tasks.

Future Research Directions

The present study extends the sparse literature on motivation, conservation and self-control depletion and is the first to have investigated the combined effects of autonomy support and conservation on self-control performance. Given the dearth of evidence in these areas and the potential for application of self-control depletion research in exercise psychology (Hagger, Wood, Stiff & Chatzisarantis, 2009; Martin Ginis & Bray, 2010) there is abundant room for future study. The present investigation provides support for a positive relationship between autonomy support and self-control performance. However, future studies should manipulate the wording within different autonomy support scripts in regards to the task being performed in order to investigate whether these effects generalize across a broad range of self-control tasks (i.e., cognitive, physical, emotional). For instance, manipulating autonomy support on physically unpleasant tasks may be more difficult than for cognitive or emotional tasks, or vice versa. It would be interesting and worthwhile to investigate if one simple autonomy supportive script will suffice for any type of task or if certain scripts produce better performances for certain types of task.

A future avenue for research with application to exercise psychology could be to investigate the conservation hypothesis as it relates to exercise behaviour. As an example, a study could replicate the present design but substitute the Stroop task with an exercise task such as jogging at a moderate-to-high intensity on a treadmill. Based on the present findings, it would be hypothesized that individuals would jog slower or in some way hold back their effort to exercise, if they knew a future self-control task would follow.

Another example of a future study that has relevance to exercise psychology could use a similar design as the present study to investigate the effects of autonomy support on self-control of exercise. In such a study, the final self-control task could be an exercise session with a personal trainer. Autonomy support could be manipulated by the way in which the trainer conveyed their workout instructions (i.e., in an autonomously supportive or controlling way). Based on the current findings, it would be expected that participants who were autonomously supported would work at a higher intensity, execute more repetitions, or lift heavier amounts of weight when compared to individuals who were not autonomously supported prior to their workout.

Although there are many ways to pursue future work in this area, as a final example, I would suggest a future study should expand on the present study design to incorporate control conditions in which participants did not perform the mismatched Stroop task and instead they perform the matched Stroop task (no depletion). This design would provide a non-depletion comparison group, which would allow for additional inferences to be made about the observed effects of the manipulations (e.g., autonomy support). For instance, it could be determined how much effect autonomy support or conservation has on self-control depletion relative to no depletion.

Implications

The present study offers novel insights and has numerous implications for future studies on self-regulation and self-control strength as well as more generally for the design of experiments involving self-control tasks. In terms of general experimental design, the present research highlights numerous procedural considerations, in particular the wording of instructions to ensure consistent performance. For example, the no autonomy support script used within the present study is very similar to how many researchers provide instructions for various tasks. Although there were only minor differences in the wording of instructions in the present study, there were significant differences in performance, suggesting that manipulating autonomy support would be advantageous in order to get maximal performance or effort from participants. Therefore, it is important for future studies to be uniform in the description of the study tasks and instructions to their participants so that everyone receives the same autonomy supportive or no autonomy supportive instruction sets. .

Caution should also be taken for the wording of instructions when explaining what participants will be performing during the experiment. Results of the present study, and previous research, suggest that when participants anticipate future self-control tasks their performance suffers on interim tasks. Therefore, for studies involving multiple tasks it would be methodologically prudent for researchers to consider whether or not to inform participants of the exact tasks and order of the tasks they will be performing, especially if these tasks require levels of self-control, as their performance on each task leading up to the final task may not be performed to maximum potential or effort.

Within the area of exercise psychology there are numerous implications for naturalistic settings involving exercise self-regulation. The findings may have particular relevance for exercise initiates who are planning their exercise sessions or for trainers who are instructing individuals in a gym setting. For instance, from a conservation standpoint, it would be worthwhile for people who are in the early stages of exercise adoption to avoid planning their exercise sessions before they have to exert self-control on other tasks. If they anticipate high self-control demands following their planned exercise session, they may be motivated to conserve their resources for those future self-control tasks. As a consequence, they may chose to not partake in the exercise session, cut it short, or lessen the effort they might otherwise commit to exercising. As well, from an autonomy support standpoint, it would be worthwhile for trainers to present their exercise instructions in an autonomously supportive way and provide as much choice as possible in order to motivate their clients to perform the exercises at the desired intensity and potentially to increase future adherence. Providing autonomy support may be especially important towards the end of an exercise session, when self-control for exercise may be depleted. Thus, at the end of a workout, trainers could encourage greater autonomy by providing their clients with their (the client's) choice of a favorite exercise tasks (e.g., bicep curls on a machine, bicep curls with dumb bells, or bicep curls with a barbell) rather than giving them direction on those exercises.

Strengths and Limitations

There are important strengths and limitations that deserve discussion and interpretation. Among the limitations is the absence of an effect for autonomous motivation. Although, differences were found between the autonomy support and no autonomy support conditions on the second endurance trial, ratings of autonomous regulation were not found to be different. This finding raises questions about the generalizability of assertion that autonomous motivation can override the effects of self-control depletion. However, as noted above, the instrument used to assess autonomous regulation in this study may not have been the most appropriate measure for a physical endurance task. Therefore, caution should be taken when measuring autonomous regulation between different types of self-control tasks (i.e., cognitive, physical, or emotional). Nevertheless, this finding supports previous research highlighting the beneficial effects of autonomy support on performance and the necessity to exercise caution in the wording of instructions to participants.

Also, it is possible that a portion of the autonomy support findings could be attributed to altruism, specifically, a desire to help others. In the present study the researcher stated "*Advancing knowledge through research is an important undertaking and your willingness to put forth your best effort on the next task will assist our research the most*". This statement was originally designed to instill a feeling of perceived choice; however, a sense of altruism may have arisen within the participants in the autonomy support conditions. Thus, a measure of altruism should be included within future studies manipulating autonomy support in order to control for, or independently account for the effects of, altruistic behaviour that may present in the findings.

Another limitation is that the sequence and types of self-control tasks used within the present study differ from past studies. Although the present study used a novel assessment of physical endurance self-control performance, it was rather unpleasant to perform to maximal exhaustion and was perhaps limited by biological demands in addition to self-control. Therefore, assessing complete self-control resource exhaustion may not be as sensitive when utilizing physical tasks, and as discussed above, investigating the conservation effect on a third task using a physical self-control task may not be directly comparable to self-control of cognitive or emotional tasks.

A final limitation is the generalizability of the tasks performed in the present study to actual exercise tasks, such as running on a treadmill or lifting weights. Although the handgrip task was a physical self-control task, there is no way to determine whether the positive effects of autonomy support could generalize to other exercise tasks. As well, the conservation effects involving the Stroop task may not be generalizable to self-control tasks that comprise peoples' daily activities. Future studies incorporating ecologically valid exercise and self-regulation tasks are clearly needed.

Balanced against these limitations are a number of strengths. For instance, by following Hagger et al.'s (2010) recommendation to integrate the separate perspectives of conservation and motivation, this study was the first to show that manipulating autonomy support is more beneficial to self-control performance than conserving resources. In the emerging literature on self-control depletion, research investigating the independent and combined effects of potential moderating variables stands to be more informative than studies that investigate only independent effects.

An additional strength is the use of a physical self-regulation task to investigate conservation and motivation effects. Self-control depletion effects are implicated in numerous problematic health behaviours including tobacco smoking, unhealthy eating, unsafe sex, and exercise non-adherence (Baumeister et al., 1994; Hagger et al., 2009). Generating new knowledge of the effects of conservation and autonomous motivation on self-control of a physically-demanding exercise task provides an effective starting point for future research that should seek to understand these effects on more complex exercise behaviours.

Conclusions

In summary, the present study provides additional support to the limited research investigating the effect of autonomy support and conservation on self-control strength depletion. Autonomy support has a significant effect that preserves or enhances performance on physical endurance tasks. When people anticipate future self-control tasks they are motivated to conserve their resources for those tasks by holding back on their performance on interim tasks. Importantly, this study was the first to examine the interaction between autonomy support and conservation on self-control strength depletion and it is apparent that when individuals are autonomously supported, it may not matter a great deal whether they are aware of future self-control tasks as they outperform individuals who are not autonomously supported regardless of their conservation of self-control strength.

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Appendix A

Email Screening Questionnaire/Inclusion Criteria

Letter of Information/Consent Form

Brief Mood Introspection Scale

Intrinsic Motivation Inventory – Task Evaluation Questionnaire

Self-Control Scale

Demographics/Godin-Leisure Time Questionnaire

Visual Analogue Scale

Ratings of Perceived *Physical* Exertion

Ratings of Perceived *Mental* Exertion

2-Item Manipulation Check

4-Item Manipulation Check

Stroop Task

Debriefing Script

EMAIL SCREENING QUESTIONNAIRE PACKAGE

If you answer NO to the following questions and are between the ages of 17-30 years then you are eligible for the study.

1. Do you have a medical condition that requires you to avoid strenuous exercise?
2. Has your doctor ever said that you have a **heart condition** <u>and</u> that you should only do physical activity recommended by a doctor?
3. Do you feel **pain in your chest** when you do physical activity?
4. In the past month, have you had **chest pain** when you were not doing physical activity?
5. Do you lose balance because of **dizziness or do you lose consciousness**?
6. Do you have a **bone or joint problem** (for example, back, knee or hip) that could be made worse by a change in your physical activity?
7. Is your doctor currently prescribing **drugs** (for example, water pills) for your **blood pressure** or heart condition?
8. Do you know of <u>any other reason</u> why you should not do physical activity?
9. Are you colour blind?

DATE: ________

LETTER OF INFORMATION / CONSENT

A Study of/about Understanding cognitive and physical performance

Investigators: Jeff Graham and **Dr. Steven Bray**

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Purpose of the Study
The purpose of this study is to examine the performance of physical endurance exercise and mental challenges under a variety of conditions.

Procedures involved in the Research
This study will take approximately 30 minutes to complete. Participation involves squeezing a handgrip as hard as possible and holding a submaximal (medium intensity) handgrip squeeze for as long as possible. You will also be asked to perform a mentally challenging task (reading different coloured words). Prior to and after these tasks you will complete some questions about yourself and your personality on a survey. While performing these tasks your arm muscle (EMG) activity will be monitored. This will require you to wear 3 small stickers on your arm.

Potential Harms, Risks or Discomforts:
You might find the handgrip exercises to be tiring and experience some minor muscle soreness. If you experience any pain while doing the exercises you should tell the researcher immediately and stop the exercise. You might find some of the questions about your personality to be stressful. You can skip any question you wish and still remain in the study. Removing the 3 recording electrode stickers will be similar to removing 3 bandages, which may cause some minor discomfort.

Potential Benefits
There are no direct benefits to you from taking part in this study. The results from this preliminary study will help the scientific community better understand the effects of cognitive tasks and physical tasks on physical endurance task performance.

Payment or Reimbursement
You will be paid $5 cash for completing this study. If you drop out before completing the study, you will still be compensated. All compensation will be given at the end of the lab session.

Confidentiality
Any information that is obtained during this study and that can be identified with you will remain confidential and will be disclosed only with your permission. The questionnaires are completely private and will be kept in a locked filing cabinet in The Health and Exercise Laboratory for a period of five years. Your name will not be recorded on any of the study documents. Only the researchers and research assistants will have access to this information. Your identity will <u>never</u> be revealed in any reports of this study.

Participation and Withdrawal
You can decide whether to take part in this study or not. If you volunteer for this study you may withdraw at any time without penalty. You can choose to remove your data from the study at any time. You may also refuse to answer any questions you don't want to answer while remaining in the study.

Information about the Study Results
I expect to have this study completed by approximately by August, 2011. If you would like a brief summary of the results, please leave your email contact _________________.

Questions about the Study
If you have questions or require more information about the study itself, please contact me.
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 Office of Research Services
E-mail: ethicsoffice@mcmaster.ca

CONSENT

I have read the information presented in the information letter about a study being conducted by Jeff Graham of McMaster University. I have had the opportunity to ask questions about my involvement in this study and to receive additional details I requested. I understand that if I agree to participate in this study, I may withdraw from the study at any time. I have been given a copy of this form. I agree to participate in the study.

Signature: ______________________________________
Name of Participant (Printed) ___________________________________

BMIS

The next items are statements about your mood. Please circle the response on the scale below that indicates how well each adjective describes your present mood.

	1	2	3	4	5	6	7
	Definitely Do Not Feel						**Definitely Do Feel**
1. Lively	1	2	3	4	5	6	7
2. Peppy	1	2	3	4	5	6	7
3. Active	1	2	3	4	5	6	7
4. Happy	1	2	3	4	5	6	7
5. Loving	1	2	3	4	5	6	7
6. Caring	1	2	3	4	5	6	7
7. Drowsy	1	2	3	4	5	6	7
8. Tired	1	2	3	4	5	6	7
9. Nervous	1	2	3	4	5	6	7
10. Calm	1	2	3	4	5	6	7
11. Gloomy	1	2	3	4	5	6	7
12. Fed up	1	2	3	4	5	6	7
13. Sad	1	2	3	4	5	6	7
14. Jittery	1	2	3	4	5	6	7
15. Grouchy	1	2	3	4	5	6	7

16. Content	**1**	**2**	**3**	**4**	**5**	**6**	**7**

IMI - TASK EVALUATION QUESTIONNAIRE

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

1	2	3	4	5	6	7
Not at all true			**Somewhat true**			**Very true**

1. While I was working on the task I was thinking about how much I enjoyed it. ___
2. I did not feel at all nervous about doing the task. _________
3. I felt that it was my choice to do the task. _________
4. I think I am pretty good at this task. _________
5. I found the task very interesting. _________
6. I felt tense while doing the task. _________
7. I think I did pretty well at this activity, compared to other students. _________
8. Doing the task was fun. _________
9. I felt relaxed while doing the task. _________
10. I enjoyed doing the task very much. _________
11. I didn't really have a choice about doing the task. _________
12. I am satisfied with my performance at this task. _________
13. I was anxious while doing the task. _________
14. I thought the task was very boring. _________
15. I felt like I was doing what I wanted to do while I was working on the task. _____
16. I felt pretty skilled at this task. _________
17. I thought the task was very interesting. _________
18. I felt pressured while doing the task. _________
19. I felt like I had to do the task. _________
20. I would describe the task as very enjoyable. _________
21. I did the task because I had no choice. _________

22. After working at this task for awhile, I felt pretty competent. _________

TRAIT SELF-CONTROL SCALE

Please answer the following items as they apply to you. There are no right or wrong answers. Please choose a number (1 – 5) that best represents what you believe to be true about yourself for each question. Use the following scale to refer to how much each question is true about you.

1	2	3	4	5
Not at all like me		**Sometimes like me**		**Very Much like me**

1. I have a hard time breaking bad habits. _____
2. I am lazy. _____
3. I say inappropriate things. _____
4. I never allow myself to lose control. _____
5. I do certain things that are bad for me, if they are fun. _____
6. People can count on me to keep on schedule. _____
7. Getting up in the morning is hard for me. _____
8. I have trouble saying no. _____
9. I change my mind fairly often. _____
10. I blurt out whatever is on my mind. _____
11. People would describe me as impulsive. _____
12. I refuse things that are bad for me. _____
13. I spend too much money. _____
14. I keep everything neat. _____
15. I am self-indulgent at times. _____
16. I wish I had more self-discipline. _____
17. I am good at resisting temptation. _____
18. I get carried away by my feelings. _____
19. I do many things on the spur of the moment. _____
20. I don't keep secrets very well. _____

21. People would say that I have iron self-discipline. _____
22. I have worked or studied all night at the last minute. _____
23. I'm not easily discouraged. _____
24. I'd be better off if I stopped to think before acting. _____
25. I engage in healthy practices. _____
26. I eat healthy foods. _____
27. Pleasure and fun sometimes keep me from getting work done. _____
28. I have trouble concentrating. _____
29. I am able to work effectively toward long-term goals. _____
30. Sometimes I can't stop myself from doing something, even if I know it's wrong. ____
31. I often act without thinking through all the alternatives. _____
32. I lose my temper too easily. _____
33. I often interrupt people. _____
34. I sometimes drink or use drugs to excess. _____
35. I am always on time. _____
36. I am reliable. ____

DEMOGRAPHICS

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)

Visual Analogue Scale

Make a line through the bar to indicate how energized or tired you feel at this moment

Extremely tired		Extremely energized

RATINGS OF PERCEIVED PHYSICAL EXERTION (RPE)

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

RATINGS OF PERCEIVED MENTAL EXERTION (RPME)

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

2-item Manipulation Check

These items are statements about your reactions to the task you just completed. Please read each statement and circle your response using the scales below.

1. How much energy were you trying to <u>conserve</u> for the last endurance trial?

1	2	3	4	5	6	7
Minimal Energy						**Maximum Energy**

2. How <u>important</u> was it for you to conserve your energy for the final endurance trial?

1	2	3	4	5	6	7
Not Important						**Very Important**

4-item Manipulation Check

These items are statements about your reactions to the task you just completed. Please read each statement and circle your response using the scales below.

1. How much effort did you exert while doing the task?

1	2	3	4	5	6	7
Little Effort						**Extreme Effort**

2. How tired do you feel after doing the task?

1	2	3	4	5	6	7
Not Tired						**Extremely Tired**

3. How frustrated do you feel after doing the task?

1	2	3	4	5	6	7
Not Frustrated						**Extremely Frustrated**

4. How pleasant did you find doing the task?

1	2	3	4	5	6	7
Extremely Unpleasant						**Extremely Pleasant**

Stroop Task (Sheet 1 of 3)

RED	RED
BLUE	GREEN
GREEN	GRAY
BLUE	YELLOW
BLACK	PINK
YELLOW	ORANGE
GREEN	BLUE
ORANGE	GREEN
GREEN	BLUE
RED	RED
PINK	GREEN
BLACK	YELLOW

Debriefing Script

Thank you for taking part in this investigation. I realize that performing the endurance exercise tasks may have been challenging for you. Many people think that certain motivational incentives (i.e., autonomy support) can increase physical performance on subsequent exercise tasks. In this study we are comparing the physical performance and muscular activation of groups of people who are provided with autonomy support compared to people who are not provided with autonomy support to see their effects on a subsequent physical performance. In addition, we were also investigating how individuals conserve their resources when they are informed about future demanding tasks and how autonomy support affects this conservation process. If you were in the non-conservation condition then you were exposed to a form of deception. Sorry if this made you feel uncomfortable in any way but this was necessary in order for us to test the hypothesis that people will conserve or not conserve their resources when they anticipate the end of the study or future tasks.

We are also investigating how certain aspects of people's personalities might affect the types of responses we see. Some people have a lot of willpower, while others have less. We wanted to see if scores on a measure of willpower would make a difference in the results.

We do not know how the results of the study will work out until we have analyzed the data. If you are interested in receiving an executive summary of the findings, please provide a contact email address on the sheet where you sign for having received your honorarium for the study and we will send it to you when it is available.