Cannabis and Self-Regulation

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Abstract

Cannabis is one of the most used recreational substances, especially among adolescents and young adults. Two studies examined the relationship between cannabis use and self-regulation among undergraduates. The first study (*N* = 248), an online survey, found that cannabis, alcohol, and cigarette use were related to lower levels of self-regulation. Among these substances, multiple regression analyses showed that cannabis use uniquely predicted lower levels of self-control and executive functioning when controlling for impression management. The second study (*N* = 31) compared regular cannabis users (*n* = 11) to nonusers (*n* = 15) on self-regulation performance following an ego depletion task. The depletion manipulation task required participants to choose between many everyday products, recreational substances, and occupations. To ensure the depletion task was effective, depleted nonusers (*n* = 15) were compared to a control group of nonusers (*n* = 5). The ego depletion manipulation was unsuccessful. Cannabis users did, however, perform worse on the Stroop task and a handgrip endurance task. Additionally, reported self-control from study one did not predict performance on these tasks at study two when controlling for cannabis use. The findings demonstrate that cannabis use is uniquely linked to lower levels of self-control, however, the causal order of this relationship remains unclear. The failure to replicate the ego depletion effect is discussed.

Cannabis and Self-Regulation

Cannabis is one of the most used recreational substances, with its use being most prevalent among 15 to 24-year-olds (Statistics Canada, 2019). Undergraduate students are thus a prime demographic for examining the effects of the drug. As obvious as this point may be, cannabis users are not always acutely intoxicated. However, drugs can have nonacute effects on the brain and behavior that become increasingly apparent with frequent or problematic use. In the case of drug addiction, brain imaging studies have revealed that addiction is characterized by dysfunction in the brain's control circuits. Specifically, these are circuits that normally regulate reward and saliency (e.g., nucleus accumbens and ventral tegmental area), motivation and drive (e.g., orbitofrontal cortex and motor cortex), memory and conditioning (e.g., amygdala and hippocampus), and inhibitory control and executive functioning (e.g., dorsolateral prefrontal cortex and anterior cingulate gyrus) (Volkow, Wang, Fowler, Tomasi, & Telang, 2011). These same brain patterns are generally reflected in chronic cannabis users relative to healthy controls (Zehra et al., 2018). Thus, the long-term nonacute effects that cannabis may have on individuals' everyday behavior – for instance, performance at work or school – may warrant a greater public health concern than the acute effects of intoxication. What follows is a review of the literature that gives an overview of self-regulation and the resource model of self-control, a discussion of decision-making as a depletion task, an overview of the effects of cannabis, followed by the effects of ego depletion and cannabis use on the self-regulatory outcomes of inhibitory control and impulsivity.

Overview of Self-Regulation

Self-regulation (or self-control) is a personality process defined by one's ability to exert control over their thoughts, emotions, impulses, and task performances (Baumeister, Gailliot, DeWall, & Oaten, 2006). It is furthermore defined by the process of the self overriding a prepotent response in favor of an alternative response that allows one to attain a goal or conform to social norms (Vohs, Schmeichel, Nelson, Baumeister, Twenge, & Tice, 2008). The mechanisms rooted in the brain that are thought to drive self-regulation are called executive functions. Neuropsychology views executive functioning as being comprised largely of unobservable cognitive events that are accomplished by a network primarily under the control of the prefrontal cortex (Barkley, 2011). The component features of executive functioning include inhibition, working memory, planning, emotional or motivational regulation, strategy development and use, flexible sequencing of actions, maintenance of behavioral set, and resistance to interference (Barkley, 2011). The terms self-control and executive functioning are largely considered top-down processes, and both fall under the broad umbrella of self-regulation. Although there are theoretical distinctions between the constructs (see Nigg, 2017), the terms self-control, executive functioning, and self-regulation are often used synonymously. The present thesis also uses the terms interchangeably.

As mentioned, drug use has the potential to negatively influence some of these executive functioning domains. As Volkow et al. (2011) argue, addiction is not solely defined by the increase in dopamine that is associated with the rewarding effects of a drug, but also by deficits in the prefrontal cortex (PFC) and anterior cingulate cortex (ACC) that impair executive functioning and inhibitory control. Subsequently, the emotion and motivation regions of the brain are left uninhibited and have greater influence over behavior than is typical. These deficits in self-regulation that are presumably caused by drug use could not only lead to further drug use, but also many other maladaptive behaviors.

Failures of self-regulation, both related and unrelated to substance use, are regarded as a key factor in most personal and social problems that afflict modern societies (Baumeister, Heatherton, & Tice, 1994). Conversely, high levels of self-regulation contribute positively to success and well-being (Baumeister, Vohs, and Tice, 2007; De Ridder & Gillebaart, 2016). Such important outcomes beg the question of what exactly the underlying mechanisms of self-control are.

Muraven, Tice, and Baumeister's (1998) foundational work helped to partially uncover the nature of self-control, which is explained by a phenomenon coined *ego depletion.* Ego depletion refers to the reduction of self-regulatory resources as they are drawn from while exerting self-control. As the ego becomes depleted, the likelihood of successful exertion of further self-control decreases. In the same way muscles rely on a finite amount of energy (i.e., they can only be used to the point of exhaustion), self-control too can be thought of as relying on limited energy resources. Through repetition and practice, muscles become stronger in that a person can lift more weight and endure physical demands for longer periods. Similarly, as people are routinely faced with demands, their ability to successfully self-regulate can improve over time.

To illustrate, a young adult transitioning into their first full-time job may have difficulty performing chores, cooking healthy meals, or going to the gym following an eight-hour day. Instead, they avoid chores, buy fast food, and situate themselves on the couch watching Netflix for the evening. With practice, however, the young adult can improve their self-regulation in order to act in a healthier manner following a trying day at work.

In a series of studies employing ego depletion tasks administered to samples of introductory psychology students, Muraven et al. (1998) yielded support for the *strength* model of self-control. The ego depletion tasks were followed by various dependent outcomes intended to measure the effect on the ego depletion group when compared to a control group who had tasks that required little to no self-control. The aim of the studies was not only to show that the ego depletion group would perform worse on subsequent tasks (time two) than the control group, but also to show that different types of self-control demands draw from the same pool of resources. To demonstrate the latter, Muraven et al. (1998) used dependent measures that were conceptually distinct from the nature of the ego depletion task at time one.

In Muraven et al.'s (1998) first experiment, participants were asked to either increase or decrease their emotional responses to an upsetting movie, while a control group was simply asked to watch without exerting control over their emotions. Following watching the video, participants were asked to squeeze a handgrip for as long as possible. The two affect groups squeezed the handgrip for significantly less time than the control group (Muraven et al., 1998). So, the results showed that exerting self-control in one area (i.e., emotional regulation) subsequently diminished self-control in another area (i.e., physical endurance). The three additional studies using varying depletions tasks and dependent measures showed similar patterns of depletion (Muraven et al. 1998). Research since then has continued to show that the same resource is used for an array of behaviors whose only commonality is the process of the self-altering or overriding an initial response (Baumeister et al., 2006).

The pattern of ego depletion has been replicated in a variety of experimental settings. Following ego depletion tasks, people have been shown to be less successful at difficult reasoning problems (Schmeichel, Vohs, & Baumeister, 2003), demonstrate decreased attentional and inhibitory control (Wang, Wang, & Wang, 2014; Garrison, Finley, & Schmeichel), 2019, rely on simplistic strategies for making decisions and judgments (Amir, Dhar, Pocheptsova, & Baumeister, 2005), present themselves in unfavorable ways (Vohs, Baumeister, & Ciarocco, 2005), respond with higher levels of aggression (Stucke & Baumeister, 2006), be more prone to break diets (Vohs & Heatherton, 2000), and are more likely to spend money impulsively (Vohs & Faber, 2004).

It was also suggested that although repetitive exertions may lead to fatigue in the short-run, they may build self-regulatory strength in the long-run. Conversely, not exerting self-regulation may lead to less fatigue in the short-run, but a decreased ability to self-regulate in the long-run (Muraven et al., 1998). A series of studies by Oaten and Cheng (2004a; 2004b; 2006) demonstrated that self-regulation interventions involving physical exercise, money management, and study habit formation all yielded improvements in self-regulation. The improvements were seen not only in the related domain (e.g., exercise or money management), but also in unrelated spheres. For instance, students who completed a study program reported smoking fewer cigarettes, drank less alcohol and caffeine, exercised more, and reported less emotional and perceived stress during their examination period compared to the wait list control group (Oaten & Cheng, 2006).

The strength model of self-control has not gone without scrutiny, and rightfully so. Instances of replication and concerns of publication bias have brought the ego depletion effect into question (Dang, 2018). However, proponents of the model argue that the inconsistencies of the effect may have to do with the vagueness of the resource that self-control is dependent on. As elegant as this idea of a single resource shared among many behaviors may be, the analogy of an energy resource akin to a muscle is simply a metaphor that risks overshadowing other mechanisms that could give explanatory power to both the successes and failures of ego depletion effect.

Inzlicht and Schmeichel (2012) proposed an alternative called the process model of ego depletion. In this model, there is no resource, but rather an interplay between attention and motivation. As an individual performs an aversive ego depletion task, their motivation lessens and their attention shifts away from the task towards signs of rest or reward (Inzlicht & Schmeichel, 2012). This may explain why a participant's performance lessens from Time 1 to Time 2, because they lose motivation to continue to perform after completing one task. The crux of Inzlicht and Schmeichel's (2012) model is based on previous studies showing that motivation and incentives can counteract the ego depletion effect. On the other hand, studies have also shown that increasing the intensity of the depletion task overpowers the performance benefits of motivation (Vohs, Baumeister, & Schmeichel, 2012). Thus, although motivation can help in sustaining performance in tasks of self-control over time, it does not fully explain changes in self-control. In other words, no amount of motivation can overcome the complete exhaustion of self-regulatory resources. Since neither model debunks the other, it is likely that incorporating attention and motivation as mechanisms will add explanatory power to the ego depletion effect. Therefore, both models were used to inform the present study. The following discussed decision-making ego depletion task developed by Vohs et al. (2008) has been shown to have a powerful enough effect that it may override motivation.

Making Choices as an Ego Depletion Task

Making choices is an everyday part of life. Decisions range in seriousness from choosing the best piece of fruit at the supermarket to deciding on a career. With an increasing diversity in consumer product selection, seemingly trivial decisions over everyday products, such as choosing one of the 100 different models of smartphones, can become overwhelming (Huffman & Kahn, 1998). Iyengar and Lepper (2000) found that when consumers were given more options (24 versus 6), they were less willing to buy anything at all, and when they did, they were less satisfied with their purchase. Having no choice at all might be equally troubling, however, these findings suggest that excessive options may be taxing, as well as counterproductive (Vohs et al., 2008).

Based on this prior research that suggests the demanding nature of choices, Vohs et al. (2008) hypothesized that self-regulation and decision making may be driven by the same pool of resources in that making choices could reduce the capacity for subsequent self-regulation. The authors reasoned that any choice involves an intrapersonal act, that is, decisions are made in relation to the self regardless of their gravity. Evidently, serious life decisions are stressful and likely more depleting than choosing between buying a black or blue pen. Nonetheless, choosing the color of pen could still involve an endless amount of intrapersonal considerations such as color preference and professional standards. Thus, no decision is ever entirely independent of the self.

In Vohs et al.'s (2008) study, undergraduates were randomly assigned to a choice or no-choice task. Those in the choice condition made a total of 292 choices between everyday products and occupations. Some products were physically present in the lab, while other products, as well as occupations, were listed and described on paper. Participants in the choice condition were told they would be able to choose a gift based on their choices. Participants in the no-choice condition simply rated the same products and occupations, and were also told they would receive a gift, but that they could not choose what gift. After the task, participants entered a room and were seated at a table with 20 small paper cups filled with one ounce of an ill-tasting drink. Participants were told that the experiment concerned motivation and that they would be given a nickel for every cup they drank, but that how much they drank was up to them.

The choice condition drank significantly less of the ill-tasting drink than the no-choice condition. Vohs et al's (2008) findings are important for two reasons. First, their hypothesis that self-regulation and decision making rely on the same resources was supported. Second, the ego depletion effect was found even though participants were incentivized and motivated to perform well on the dependent measure (Inzlicht & Schmeichel, 2012). Thus, the task developed by Vohs and colleagues was shown to be a powerful ego depletion task and validated the demanding nature of repetitive choices within a short time frame.

Overall Effects of Cannabis

Before considering the effects of cannabis use on self-regulation specifically, here I consider the overall effects. Of more than 100 cannabinoids found in cannabis, tetrahydrocannabinol (THC) is the most well-understood and is recognized as the main source of psychoactive effects caused by its consumption (Ashton, 2001). The subjective effect of cannabis intoxication is associated with the phenomenon of feeling *high*, *baked*, or *stoned* (Jacquette, 2018). The most common form of administration is via inhalation (i.e., smoking or vaporizing), meaning absorption happens quickly and the resulting effects can be felt within minutes, with peak effects happening between 30 to 60 minutes, and a total duration of two to three hours. Oral administration (e.g., edibles) takes 30 to 90 minutes to absorb, with psychoactive effects lasting up to 12 hours (Hancock & McKim, 2018). Effects on the body include bloodshot eyes, drooping eye lids, dry mouth and feelings of hunger. Sleepiness and lack of alertness is a common side effect. Additionally, varying doses of THC can cause distortion in perception (Hancock & McKim, 2018).

Research on the more consequential effects of cannabis has generally examined cognition, motivation, and psychosis as outcomes. The most reliable findings related to cognition have shown cannabis to have acute impairment on learning, IQ, memory, and attention (Volkow et al. 2016). Such deficits in neuropsychological measures are unsurprising considering that acute intoxication produces changes in brain functioning and apparent subjective effects. However, whether there is enduring neuropsychological impairments beyond intoxication remains unclear (Gonzalez, 2007). The most reliable findings that show lasting neuropsychological cognitive deficits are observed among heavy users (i.e., those who either report using every day or meet criteria for problematic use) who report early onset of cannabis use, and whose symptoms align with addiction (Gonzalez, 2007).

Adolescence is a focus of this research because it represents a crucial stage in neurodevelopment. Emerging evidence suggests adolescents are particularly susceptible to the adverse effects of cannabis use (Volkow et al., 2016). However, longitudinal co-twin cohort studies suggest that deficits in executive functioning observed in adolescent cannabis users may be better explained by social and environmental factors. This conclusion arose because although cannabis may be associated with lower executive functioning, these longitudinal studies showed no significant long-term decreases in executive functioning over time related to cannabis use, suggesting that lower executive functioning precedes cannabis use (Meier et al., 2018; Jackson et al. 2016).

Amotivational syndrome, which is characterized by apathy, low energy, and a diminished ability to perform and follow routine has long been associated with cannabis use (Duncan, 1987). However, findings demonstrating a clear link between motivation and cannabis are mixed (Pacheco-Colón, Limia, & Gonzalez, 2018). One possible explanation for this ambiguity relates to the problem of circular reasoning, that is, individuals who use cannabis may be unmotivated to begin with. Nonetheless, there are some findings suggesting that cannabis use causes decreases in motivation (Pacheco-Colón et al., 2018; Volkow et al., 2016).

A systematic review on the nonacute effects of cannabis use on motivation found partial support from longitudinal research that cannabis use could reduce motivation (Pacheco-Colón et al., 2018). Two important explanations for the inconsistent results were brought forth by Pacheco-Colón et al. (2018). First, motivation is often poorly operationalized. For instance, there are cognitive definitions of motivation such as self-efficacy where one believes in their ability to complete a task, versus behavioral motivation such as persistence through a difficult task despite adverse effects. The second reason may have to do with how cannabis use is measured: through frequency or problematic use. Those studies using the DSM criteria for substance use and dependence were more likely to find significant negative effects of cannabis compared to those simply measuring frequency of use (Pacheco-Colón et al., 2018, Gonzalez, 2007). This appears to make sense when considering that frequency of use does not necessarily entail dependence or addiction (whose negative outcomes are clearer).

Finally, the link between cannabis and psychosis has focused on schizophrenia. High doses of THC can cause acute, transient, and dose-dependent psychosis that resemble the positive and negative symptoms of schizophrenia (Volkow et al., 2016). When controlling for the use of alcohol and other drugs, longitudinal and epidemiological studies consistently report that cannabis use precedes psychosis. Furthermore, early cannabis use, even when use has long been discontinued later in life, is linked to the onset of psychosis (see Volkow et al., 2016 for review). The large number of genetic and social factors that relate to schizophrenia make these findings controversial, but there is nonetheless legitimate reason for concern.

Cannabis and Self-Regulation

There is uncertainty regarding the causal order of cannabis use and self-regulation. Lower self-control and executive functioning are associated with increased drug use (Jackson et al., 2016; Meier et al., 2018), whereas drug use may lead to lower self-control. Thus, there is evidence of a negative reciprocal relationship. Some of the more consistent neuroimaging findings in addiction show dysregulation of frontal cortical regions involved in executive function such as the dorsolateral prefrontal cortex and anterior cingulate cortex (Zehra et al., 2018), suggesting that cannabis use may cause deficits in self-regulation. Neuropsychological and behavioral measures rather than neuroimaging, however, may be a better indicator of deficits resulting from drug use as changes in brain functioning and metabolism do not necessarily parallel functional impairments.

Cannabis and Delay Discounting

Discounting is the process by which the subjective value of an outcome is altered because the delivery of that outcome is either delayed or less probable (Madden & Bickel, 2010). Discounting is of interest to some psychologists because of its association with impulsiveness and emotional regulation which influences healthy behaviors and drug and alcohol use (Clark, Kassman, Derenne, & Weatherly, 2014). Discounting has become a popular method to assess impulsivity because of drug research. With the use of the monetary-choice questionnaire (MCQ; originally developed by Kirby & Marakovic, 1996), Kirby, Petry, and Bickel (1999) showed that heroin addicts had higher discounting rates for delayed rewards compared to non-drug using controls. As illustrated by Kirby et al., (1999), this means that monetary amounts lost their value almost twice as fast for heroin addicts compared to controls. For example, $50 for the heroin patients lost half its value in about 40 days, whereas it would require about 77 days for $50 to lose half its value for controls. Additionally, the scores on the MCQ correlated strongly with established self-report scales of impulsivity (Eysenck & Eysenck, 1978; Barratt, 1985). This seminal study provided strong initial evidence that drug addicts exhibit impulsive decision-making in that they tend to prefer smaller immediate rewards relative to larger delayed rewards.

In the past two decades, the MCQ and other similar delay discounting tasks have been used to examine a variety of drugs, most recently cannabis, with mixed results. Peters, LaPaglia, Petry, Reynolds, and Carroll (2013) found no association between pretreatment discounting rates and frequency of cannabis use, age of onset, or self-reported impulsivity in a sample of cannabis dependent adults. Stea, Hodgins, and Lambert (2011) assessed gambling, cannabis, and alcohol problem severity in university students by having them complete a computerized discounting task involving monetary rewards. Although the overall model that included all three predictors was significant, only gambling accounted for greater discounting rates above and beyond cannabis and alcohol use, suggesting that gamblers may discount money more than those with alcohol and cannabis problems. Strickland, Lile, and Stoops (2017) used discounting tasks that involved discounting money, alcohol, and cannabis, with the expectation that if, for example, cannabis users did not show greater discounting rates for alcohol or money, that they might show more impulsive decision-making when having to discount cannabis. However, no differences were observed in any of the discounting tasks between cannabis users and controls (Strickland et al., 2017). Heinz, Boden, Peters, and Bonn-Miller (2013) examined whether delay discounting rates predicted a series of cannabis-related outcomes in cannabis-dependent military veterans interested in quitting. The study found that higher delay discounting was associated with compulsive craving for cannabis, younger age of first Cannabis use, and earlier commencement of regular cannabis smoking (Heinz et al., 2013).

Overall, support for cannabis use increasing impulsivity as assessed via temporal discounting tasks is sparse and suggests that delay discounting may carry less relevance for Cannabis than other substances of abuse. Nonetheless, the limited number of studies suggest that the chronic use of cannabis and its association with discounting warrants further investigation.

Ego Depletion and Delay Discounting

A small number of studies have examined the effects of ego depletion on delay or temporal discounting. Discounting is generally associated with executive functioning (Weatherly & Ferraro, 2011). Weatherly and Ferraro (2011) had 156 university students discount four different delayed outcomes: money, cigarettes, finding the ideal partner, and obtaining one's ideal body image. Executive functioning was a significant predictor of delay discounting for the first three outcomes, while the fourth outcome approached significance, in that lower executive functioning was associated with higher levels of impulsivity, and vice versa.

Howlett, Kees, and Kemp (2008) examined the effect of ego depletion on university students' likelihood of contributing to a 401k plan. The decision not to participate in the retirement savings plan is considered a poor choice with serious long-term consequences. The reduction of self-regulatory resources was shown to decrease the likelihood of contributing to the 401k (Howlett et al., 2008). Joireman, Balliet, Sprott, Spangenberg, and Schultz (2008) yielded similar findings. Following ego depletion, participants were administered Kirby et al.'s (1999) temporal discounting task. Participants in the depletion group who scored high on the consideration of future consequences scale showed significantly more discounting than the control group (Joireman et al., 2008). That is, those participants with a greater concern for future consequences were more sensitive to ego depletion in that they tended towards the smaller immediate reward rather than the larger delayed reward compared to the non-depleted condition.

Cannabis and Inhibitory Control

Attention control is a form of self-control involving overriding a predominant attentional tendency (Garrison et al., 2019), which lends itself to behavioral inhibitory control). One of the standards for measuring inhibitory control that is thought to tap into neuropsychological functioning is the Stroop task where participants respond to nondominant aspects of a stimulus (font color) while ignoring dominant aspects (word content; Trenerry, Crosson, DeBoe, & Leber, 1989).

Studies employing the standard Stroop task with cannabis users have yielded mixed results. The focus in this thesis is on the *classical* Stroop task because I am only interested in the effect that cannabis may have on general cognitive control. This is worth mentioning because studies using a modified Stroop task that includes cannabis words to study whether attentional bias is present in regular users, are more numerous and have yielded more consistent results (Cousijn et al., 2013). Cousijn et al. (2013) used the classical and modified Stroop task on cannabis dependent undergraduates. Results from the modified Stroop showed that cannabis dependent participants demonstrated an attentional bias towards cannabis-related words compared to controls, however, there were no differences in performance on the classical Stroop.

Another study using Stroop performance as a dependent measure by Battisti et al (2010) assessed a community sample of adults (ages of 18 to 55 years), comparing chronic users to nonusers. Being a cannabis user meant using cannabis at least four times per month for a minimum of three years. The 21 cannabis users reported using cannabis at least 15 days per month, and an average of 16.4 years of nearly daily use. Those chronic users made significantly more errors on incongruent trials than the controls, whereas there was no difference on congruent trials. The findings indicate that chronic use can impede cognitive control. Furthermore, poor incongruent trial performance was predicted by earlier age of onset of regular cannabis use (Battisti et al., 2010). Similarly, Coullaut-Valera et al. (2011) found that adults (mean age of 40 years) who reported greater duration of cannabis and alcohol use had worse inhibition on the classical Stroop task. Their findings are suggestive of more permanent effects as participants were disqualified if they had consumed any substances in the month leading up to the study. However, it is unclear which substance (alcohol or cannabis) contributed most to the deficits.

Sagar et al. (2015) administered the Stroop task to a community of adults (age range: 17-46 years) and divided them into three groups: early onset heavy cannabis smokers (use prior to age 16), later onset heavy cannabis users (use after age 16), and nonusers. Users were well-characterized. Participants must have reported smoking a minimum of 2500 times in their lives, used cannabis at least five times in the last seven days, tested positive for urinary cannabinoids, and met the DSM-IV criteria for cannabis abuse or dependence to be included in the study (Sagar et al., 2015). Their findings were two-fold. First, heavy cannabis smokers displayed significantly poorer performance on the Stroop task compared to healthy controls. Second, early onset heavy cannabis users performed significantly worse than both the late onset and healthy control groups (Sagar et al., 2015). Overall, studies using the Stroop task have shown deficits in cognitive control among heavy cannabis users, especially those with early onset of use. However, more research is needed examining younger populations in order to further understand whether such inhibitory deficits may occur earlier on in life as a result of less prolonged cannabis use.

Ego Depletion and Inhibitory Control

The Stroop task has been shown to be both an effective depletion task (Dang, Liu, Liu, & Mao, 2017) as well as a dependent measure (Inzlicht & Gutsell, 2007; Wang et al., 2014; Garrison et al., 2019) in ego depletion research. Dang et al. (2017) had Chinese university students complete the Stroop task at Time 1, followed by an anti-saccade task at Time 2. The depletion condition was administered a Stroop task where 75% of the trials were incongruent, whereas all trials were congruent for the control condition. The depletion group performed worse on the anti-saccade task than the control group (Dang et al., 2017).

In a sample of university students, Inzlicht and Gutsell (2007) employed an emotional video depletion technique whereby participants in the experimental condition were asked to suppress their emotional responses to an emotionally arousing video, while the control group was not given such instructions. Following the video task, those in the suppression condition had significantly slower response times (RTs) in the Stroop task, indicating poorer attentional control, compared to controls. There was no difference in the amount of errors made. Wang et al. (2014) employed the same video technique and found that university students in the depletion group made more errors in the Stroop task than controls, whereas there was no difference in RTs. Garrison et al. (2018) employed a writing depletion technique (Finley, Crowell, Harmon-Jones, & Schmeichel, 2017) and found that those undergraduates in the depletion condition made more errors in the Stroop task, whereas no difference was detected in RTs. Being in a state of ego depletion thus appears to negatively influence the ability to detect errors and effectively inhibit dominant responding.

The Present Study

Drug research has demonstrated that drug use and abuse can physically alter the brain as well as cause deficits in neurological functioning related to executive functioning and ultimately self-regulation. Research comparing heavy and problematic cannabis users to healthy controls has suggested similar negative outcomes. Volkow et al.'s (2016) model of addiction is not only explained by the dopaminergic reward system, but also by deficits in brain circuits that are associated with self-control. Furthermore, lower self-control itself may predict cannabis use (Jackson et al., 2016; Meier et al. 2018). Given these findings, I expect that cannabis users generally have less self-regulatory resources than nonusers.

The general purpose of the present study was to examine the links between cannabis use (as well as alcohol and cigarette use) and self-regulation (including attention and motivation). First, I examined the relationships between cannabis use and self-regulation using an online study. In Study 2, I focused on the link between cannabis use and ego depletion using an experimental design.

Study 1

The purpose of Study 1 was to examine the relationships between substance use and self-regulation. Using an online survey, participants were asked to complete measures of self-regulation and motivation and report their substance use (alcohol, cannabis, and cigarettes). I hypothesized that increases in cannabis, alcohol, and cigarette use would be negatively associated with self-regulation and motivation.

Method

Participants

Two-hundred and seventy-two participants entered the online survey. Six percent (*n* = 16) of these participants were removed for failing to complete the survey beyond consent or failing to respond to at least 60% of the items. Two identical surveys were advertised in the online participation system with different titles tailored for cannabis users versus nonusers. Due a technical error in the participation system, 6 participants answered the survey twice. In this case, both entries were deleted, resulting in an additional two percent of participants being removed (*n* = 6). The final sample comprised of 248 undergraduates (29% men [*n* = 72], 70% women [*n* = 174], and 0.01% non-binary [*n* = 2]), primarily Caucasian (74.60 % Caucasian [*n* = 185], 9.3% did not answer [*n* = 23], 6.0% African Canadian/American [*n* = 15], 4.8% Asian [*n* = 12], and 5.2% Other [*n* = 10]) from a small Atlantic Canadian university participated in exchange for either course credits or five dollars. The mean age was 20.25 years (*SD* = 2.48). Table 1 shows the number of cannabis users versus non-users, with accompanying demographic and substance use information. Cannabis users were identified as those who reported using cannabis at least one day per week.

Procedure and Materials

Participants were recruited through the university's participation system SONA, and through posters around campus. Participants completed an online survey that measured self-control, executive functioning, social desirability, motivation, temporal discounting, depression severity, cannabis and alcohol use and dependence, and

Table 1

Demographics of cannabis users and non-users

	Users	Nonusers	*F (df)*	X^2 (*df*)	*p*
Total *n*	85	163			
Age	*M* = 20.07 (3.51)	*M* = 20.60 (1.67)	2.55 (2, 242)		.111
Gender	57 Fem., 27 Males	118 Fem., 45 Males		2.48 (2)	.290
Year of Study	*M* = 1.70 (1.02)	*M* = 1.58 (0.88)		1.74 (4)	.784
Cigarette Use	31	216		**20.98 (2)**	.001
Weekly Can.	2.58 (2.12)				

Note. Significant effects are in bold. One nonuser did not answer cigarette use question. Weekly Can. = Weekly Cannabis Use (i.e., 1 to 7 days per week), Fem. = Females. In the user group, 67% are females and 32% are males. In the nonuser group, 73% were female and 28% were male.

demographic information. Following informed consent, participants were presented with the following scales in the following order.

Self-Control. The Brief Self-Control Scale (BSCS, Tangney, Baumeister, & Boone, 2004) is a 13-item measure that focuses on processes that directly involve self-control. The authors reported evidence supporting its validity and re-rest reliability from a similar sample. The scale is designed to assess four domains of self-control: thoughts, emotion, performance, and impulses. Participants are asked to indicate “how much each of the following statements reflects how you actually are”. Items include “I am good at resisting temptation” and “I have trouble concentrating”. Responses are given on a five-point Likert scale ranging from one “not at all” to five “very much”, with a total score range from 13 to 65.

Executive Functioning. Participants were asked to complete the short-form 20-item Barkley Deficits in Executive Functioning Scale (BDEFS-SF Barkley, 2011) that assesses Self-Management to Time, Self-Organization, Self-Restraint (inhibition) (e.g., “Make impulsive comments to others), Self-Motivation (e.g., “Inconsistent in the quality or quantity of my work performance), and Self-Regulation of Emotion. Responses are given on a four-point scale: ranging from one "Never or rarely" to four "Very often". All scores were added to generate an overall executive functioning score with a possible range from 20 to 80 such that higher scores reflect greater deficits.

Impulsiveness. Impulsiveness – which is characterized by a lack of emotional regulation – was measured through a monetary-choice questionnaire (MCQ) developed by Kirby and Marakovic (1996). Participants are presented with 27 hypothetical choices between a smaller immediate monetary reward and larger delayed monetary reward and asked to indicate which they prefer. For example, the first question states "Would you prefer $54 today, or $55 in 117 days?". Typically, delay decreases the reinforcement value of the reward. Thus, the further away the delayed reward is in time, the greater value the delayed reward must have to increase the likelihood that the individual will delay gratification and choose it rather than the smaller immediate reward. A participant's rate of discounting (i.e., their discounting curve) was calculated using the formula from Mazur (1987), where the *k* value is considered an impulsiveness parameter. The greater the *k* value, the greater preference the individual has towards the smaller immediate reward. Conversely, the smaller the participants *k* value, the less impulsive (i.e., the more indifferent) the participant is towards the two choices. The present study relies on SPSS syntax provided by Gray, Amlung, Palmer, and MacKillop (2016) to generate *k* values based on small, medium, and large monetary rewards.

Motivation. The Apathy Evaluation Scale (AES) is an 18-item scale developed by Marin, Biedrzycki, and Firinciogullari (1991) that measures apathy, which is defined as the lack of motivation. Participants responded on a four-point scale from one "not at all" to four “a lot” to statements such as “I put little effort into anything” or conversely, “Seeing a job through to the end is important to me”. All 18 items were summed for a total, with a possible range from 18 to 64, where a greater score reflects greater apathy.

Depression. The Patient Health Questionnaire-9 (PHQ-9) (Kroenke, Spitzer, & Williams, 2001) measures depression severity. Participants responded to eight items on a four-point scale from zero “not at all” to three “nearly every day” to items that include “Little interest or pleasure in doing things” and “Trouble concentrating on things, such as reading the newspaper or watching tv”. The ninth item from the standard PHQ-9 was removed as it pertains to self-harm and suicide. Evidence demonstrates excellent agreement between the PHQ-8 and PHQ-9 (Cohen’s kappas, .966-.974) (Wells, Horton, LeardMann, Jacobson, & Boyko, 2013). Items were summed for a total depression score.

Social desirability. The Balanced Inventory of Desirable Responding (BIDR; Paulhus, 1988) was employed to control for socially desirable responding. Participants responded to 40 items on a seven-point scale from one “not true” to seven “very true”. Items one to 20 assess self-deceptive positivity (e.g., “I am fully in control of my own fate”), whereas items 20 to 40 assess impression management (e.g., “I never swear). Negatively worded items were reversed scored. Each subscale was summed individually, where higher scores reflect a tendency to answer in a socially desirable way.

Cannabis and Alcohol Use. Both frequency of use and dependency were measured for cannabis and alcohol use. Participants were first asked whether they had ever used the substance (Yes or No). If they answered ‘Yes”, they were asked at what age they first tried the substance, when was the last time they consumed the substance (e.g., today, yesterday, six months ago), as well as how many days per week they used the substance. To assess how intoxicated participants typically got, participants responded on a scale from 1 (light buzz) to 7 (very drunk or very high) (Barnwell et al., 2005). Lastly, alcohol and cannabis dependence were assessed by asking participants to indicate their relationship with the substance by selecting how many of the 11 items from the DSM-V's substance criteria disorder applied to them. For cannabis use only, participants were asked what their common form of administration was (e.g., joints, bongs, vaporized oils). Finally, participants were asked attention check questions asking about the honesty of their responses, as well as demographic information regarding gender, year of birth, ethnicity, and year of university.

Results

In addition to those participants removed for incomplete responding and duplication (as mentioned previously), two participants were removed for reporting that their given answers were not entirely honest as assessed by two attention check items. The purpose of the online survey for Study 1 was to examine the associations between substance use, self-regulation, depression, motivation, and social desirability. To examine the presence of these relationships, descriptive statistics and Pearson correlations were computed. These findings are presented in Table 2.

As can be seen in Table 2, use of cannabis, alcohol, and cigarettes show significant relationships with either one or both measures of self-regulation (self-control and deficits in executive functioning). Only alcohol dependence and cigarette use showed a significant positive relationship with depression. Cigarette use was the only substance

Table 2

Descriptives and correlations between self-regulation, depression, motivation, social desirability, and substance use.

Measure	**Self-Control**	**BDEF**	**Depression**	**Apathy**	**IM**	**SDP**
M(SD)	42.15(8.41)	38.69(10.15)	10.74(6.40)	31.22(8.25)	6.11(3.66)	7.57(3.95)
α	***.82***	***.89***	***.89***	***.88***	***.76***	***.80***
Weekly Cannabis Use	**-.23**	.09	.07	.09	.09	**-.21**
0.88(1.59)	[-0.35, -0.11]	[-0.21, 0.03]	[-0.06, 0.19]	[-0.04, 0.21]	[-0.04, 0.21]	[-0.33, -0.09]
Cannabis Dependence	**-.194**	.13	.03	-13	.08	**-.28**
0.99(1.89)	[-0.35, -0.03]	[-0.28, 0.04]	[-0.13, 0.19]	[-0.04, 0.28]	[-0.13, 0.20]	[-0.42, -0.12]
Cannabis Intoxication Level	**-.20**	.14	.13	.15	-.10	-.11
3.59(1.68)	[-0.35, 0.04]	[-0.29, 0.02]	[-0.03, 0.28]	[-0.02, 0.30]	[-0.26, 0.06]	[-0.26, 0.06]
Alcoholic drinks per week	**-.24**	.09	.02	-.02	-.05	**-.20**
4.67 (5.32)	[-0.35, -0.11]	[-0.21, 0.04]	[-0.10, 0.15]	[-0.14, 0.11]	[-0.17, 0.08]	[-0.31, -0.08]
Alcoholic drinks per occasion	**-.24**	.12	.02	.03	-.09	**-.19**
4.08(2.56)	[-0.35, -0.12]	[-0.01, 0.24]	[-0.11, 0.14]	[-0.39, 0.16]	[-0.21, 0.04]	[-0.31, -0.07]
Alcohol Dependence	**-.38**	**.25**	**-.23**	.06	-.08	**-.24**
1.31(1.88)	[-0.49, -0.27]	[0.12, 0.37]	[0.01, 0.35]	[-0.18, 0.08]	[-0.21, 0.05]	[-0.36, -0.11]
Cigarette use (Yes or No)	**-.24**	**.15**	**.13**	**.15**	-.06	**-.18**
	[-0.36, -0.12]	[0.02, 0.27]	[0.01, 0.25]	[0.02, 0.27]	[-0.18, 0.07]	[-0.29, -0.05]

Note. n = 248. 95% CI in brackets. IM = Impression Management, SDP = Self Deceptive Positivity. All significant correlations are in bold.

to show a significant positive relationship with apathy. The correlations confirm the predicted relationships between substance use and self-regulation in that increased substance use was associated with lower self-regulation. Furthermore, substance use was not significantly associated with depression and motivation. Interestingly, all substance use variables (except for cannabis intoxication level) showed a significant negative relationship with self-deceptive positivity, suggesting that those reporting greater substance use were less self-deceptive. Alternatively, impression management showed no relationship with cannabis or any other substance use. Table 3 shows the relationships between substance use and temporal discounting.

Table 3

Correlations between substance use and the temporal discounting rates

Measure	**Small Reward**	**Medium Reward**	**Large Reward**
M(SD)	0.04(0.05)	0.02(0.03)	0.02(0.03)
Weekly Can. Use	.05	.08	**.164**
0.88 (1.59)	[-0.08, 0.18]	[-0.05, 0.20]	[0.04, 0.28]
Can. Dependence	-.05	-.02	.04
0.99 (1.89)	[-0.11, 0.21]	[-0.18, 0.14]	[-0.12, 0.20]
Can. Intoxication Level	-.02	.02	.06
3.59(1.68)	[-0.18, 0.14]	[-0.14, 0.18]	[-0.10, 0.22]
Alc. drinks per week	.04	.02	-.03
4.67 (5.32)	[-0.09, 0.17]	[-0.11, 0.14]	[-0.10, 0.16]
Alc. drinks per occasion	.05	.04	-.05
4.08(2.56)	[-0.08, 0.18]	[-0.09, 0.17]	[-0.17 0.08]
Alc. Dependence	-.001	-.06	.03
1.31(1.88)	[-0.13, 0.14]	[-0.19, 0.07]	[-0.10, 0.16]
Cig. (Yes or No)	-.08	.02	-.004
	[-0.05, 0.20]	[-0.11, 0.14]	[-0.13, 0.12]

Note. 95% CIs presented in brackets. Significant findings in bold. Can. = Cannabis, Alc. = Alcohol, Cig. = Cigarette. The size of the reward reflects monetary values, where small rewards are lower amounts that have less differences between the smaller immediate reward and larger delayed reward (e.g., $22 now or $25 in 136 days), whereas larger rewards reflect greater monetary amounts and have bigger difference between the smaller immediate reward and larger delayed reward (e.g., $31 now or $80 in 14 days). The greater the number, the quicker the delayed reward loses its subjective value.

As demonstrated, and contrary to my prediction, substance use showed almost no relationship with temporal discounting. The one exception in this case is weekly cannabis use. Weekly cannabis use was associated with greater discounting rates for the larger rewards, meaning increased cannabis use was associated with greater impulsivity in relation to larger monetary rewards (i.e., as cannabis use increased, there was a tendency for participants to choose the smaller immediate reward).

Given the support for concurrent use of substances in the literature, a one-way analysis of variance was conducted comparing cannabis users to non-users based on their use of alcohol. These findings are presented in Table 4.

Table 4
Comparing cannabis users to non-users on alcohol use.

	Users (n = 64) Mean (SD)	Non-Users (n = 129) Mean (SD)	*df*	*F*	*p*	R^2
Alcoholic drinks per week	5.95 (6.17)	3.26 (4.42)	1, 246	**15.69**	.001	0.06
Alcoholic drinks per occasion	4.47 (2.91)	3.10 (2.54)	1, 246	**14.71**	.001	0.06
Alcohol Dependence	1.78 (2.17)	1.04 (1.67)	1, 217	**7.82**	.006	0.04

Note. Significant *F* scores are bolded.

As demonstrated, number of alcoholic drinks per week, number of alcoholic drinks per occasion, and alcohol dependence were all significantly higher among cannabis users. The sample size was much less for the alcohol dependence variable as those who reported never using alcohol did not respond to the dependence items.

The analyses thus far have demonstrated that all considered forms of substance use have a negative relationship with self-regulation. Furthermore, alcohol use and dependence, as well as cigarette use, is more prevalent among cannabis users than nonusers. Thus, it is unclear to what degree cannabis use uniquely predicts lower self-regulation when considering these other factors. Therefore, a two-step hierarchical regression was conducted with self-control as the dependent variable. Reported weekly cannabis use was entered at stage one, and alcoholic drinks per week, cigarette use (dummy coded with one = yes and zero = no), and impression management were added at step two. Despite the correlations between self-deceptive positivity and substance use, Paulhus and John (1998) recommend controlling for impression management rather than self-deceptive positivity when considering self-reporting bias, as the former reflects conscious bias meant to impress an audience, whereas the latter reflects unconscious bias in how one perceives themselves. Therefore, impression management was the variable controlled for in step two of the hierarchical multiple regression. These findings are presented in Table 5.

Table 5

Summary of hierarchical regression analysis for variables predicting self-control

Step	Predictor	*B*	*SE*	CI	r^2	Δr^2	ΔF	*p*
1								
	Weekly Can. Use	-1.10	0.30	[-1.70, -0.51]	0.05	0.05	**13.53**	.001
2								
	Weekly Can. Use	-1.03	0.26	[-1.55, -0.50]	0.35	0.29	**35.71**	.001
	Alc. drinks per week	-0.21	0.09	[-0.39, -0.04]				
	Cigarette Use	-2.96	1.44	[-5.78, -0.13]				
	Imp. Management	1.13	0.12	[0.89, 1.37]				

Note. n = 246. *B* and *SE* are unstandardized. Cigarette use was dummy coded such that 0 represented a non-user and 1 a user. Can = Cannabis, Alc. = Alcoholic, Imp. = Impression Management.

The hierarchical regression revealed that at step one, reported weekly cannabis use contributed significantly to the prediction of self-control. Importantly, in step two, when controlling for the other variables, cannabis uniquely predicted self-control. Whereas the correlations from Table 2 show that alcoholic drinks per week and cigarette use showed a significant relationship with self-control, these variables did not predict self-control when combined with cannabis use and impression management. Moreover, although impression management itself uniquely predicted self-control, it did not alter the relationship between cannabis use and self-control.

Although the correlational analysis showed a nonsignificant relationship between cannabis use and deficits in executive functioning, a second hierarchical regression was conducted with this as the dependent variable to examine its effect when controlling for alcohol, cigarette use, and impression management. Reported weekly cannabis use was entered at stage one, and alcoholic drinks per week, cigarette use (dummy coded), and impression management were added at step two. These findings are presented in Table 7.

Table 7

Summary of hierarchical regression analysis for variables predicting deficits in executive functioning

Step	Predictor	*B*	*SE*	CI	r^2	Δr^2	ΔF	*p*
1								
	Weekly Can. Use	0.49	0.37	[-0.23, 1.21]	0.01	0.01	1.84	.176
2								
	Weekly Can. Use	0.65	0.31	[0.03, 1.27]	0.36	0.35	**33.72**	.001
	Alc. drinks per week	-.003	0.11	[-0.21, 0.20]				
	Cigarette Use	2.75	1.69	[-0.58, 6.07]				
	Imp. Management	-1.60	0.14	[-1.88, -1.32]				

Note. n = 235. B and SE are unstandardized. Cigarette use was dummy coded such that 0 represented a non-user and 1 a user. Can = Cannabis, Alc. = Alcoholic, Imp. = Impression Management.

The hierarchical regression revealed that at step one, weekly cannabis use failed to significantly contribute to the regression model. However, when adding alcohol and cigarette use, and impression management at step two, the model was significant. Cannabis use rose to significance and predicted self-control independently of impression management and other substance use. These results suggest that cannabis use uniquely predicts both self-control and executive functioning when controlling for other substance use, as well as impression management.

Discussion

The purpose of Study 1 was to examine the relationships between substance use and self-regulation, motivation, depression, and social desirability using self-reports from an undergraduate sample. Study 1 showed that cannabis users are more likely to drink alcohol and smoke cigarettes than nonusers, providing support for concurrent use of substances. As predicted, cannabis use was negatively associated with self-control, such that as weekly cannabis use, cannabis dependence, and reported cannabis intoxication levels increased, self-control decreased. Similarly, as alcohol and cigarette use increased, self-control decreased. The association between substance use and executive functioning was not as clear, with only cigarette use and alcohol dependence predicting deficits. Motivation and depression did not show a relationship with cannabis use. Given the inconsistency in the literature regarding the association between cannabis use and motivation and depression (Gonzalez, 2007; Walsh et al., 2017, respectively), these results were not unusual.

Perhaps the most crucial findings from Study 1 was that cannabis use uniquely predicted lower levels of self-control and executive functioning when controlling for the use of alcohol and cigarettes, as well as impression management. In sum, there appears to be a clear link between cannabis use and lower levels of self-regulation.

Study 2

The aim of Study 2 was to compare the self-regulation performance of cannabis users to nonusers following ego depletion. Given that the literature suggests that cannabis use is associated with lower self-control (Zehra et al., 2018) the general hypothesis for the second study predicted that cannabis users would perform worse on indicators of self-regulation following ego depletion relative to nonusers. The assumptions underlying this hypothesis is that cannabis users have less self-regulatory resources to begin with than nonusers.

Method

Participants and Procedure

Participants were asked at the end of Study 1 whether they were interested in participating in Study 2. Those who were interested, and who qualified as either a regular cannabis user or nonuser, were contacted via email. Cannabis users were classified as those who reported using cannabis at least once per week. Of the 248 participants, roughly 60% agreed to be contacted for Study 2, while the remaining participants either were not willing to be contacted or failed to indicate their preference. Of the hundreds of emails sent out to those willing to be contacted, however, only 26 participated in Study 2 (not including controls). The resulting sample were thirty-one undergraduate students (9 men, 22 women), primarily Caucasian (80.80%, [n = 21], 11.40% other [n =3]) from a small Atlantic Canadian university participated in exchange for either course credits or five dollars. The mean age was 19.85 years (SD = 2.22). Fifteen nonusers, 11 users, and five controls participated in Study 2. Due to technical difficulties, ethnicity and age were not obtained from the five control participants.

Participants were tested individually to complete the ego depletion task. As a depletion task, a decision-making task was adopted from Vohs et al. (2008). Participants were asked to make a long series of choices between products that were both within and across categories. The types of products for Study 2 included t-shirts, coffee mugs, water bottles, socks, pens (among others). The products used in Study 2 were largely similar to that used by Vohs et al. (2008). In addition to the types of products used by Vohs et al. (2008), types of alcohol and cannabis were included. Alcohol and cannabis products were included because of potential attentional bias for users that may increase the ego depletion effect. Participants chose products within the same categories (e.g., between two t-shirts) and across different categories (e.g., between t-shirt and candle). Participants' choices are guided by questions regarding their preferences (e.g., "Would you prefer Product A or Product B?"). Some of the choices were displayed on a table in the laboratory, whereas others were listed on paper. Following product choices, participants were then asked to make choices between different occupations (e.g., "Would you rather become a teacher or lawyer?"). There was a total of 250 choices. To ensure that participants took their decisions seriously, they were told that the consistency of their choices would influence their chances of winning their preferred choices in a series of draws for the products displayed.

For the control group, participants were asked to rate products based on how often they used them and the likelihood of buying these products for themselves and others. Similarly, they were asked to rate occupations based on how likely they would be to want to have that occupation as their career. Those in the control group were not told that their ratings mattered. All participants completed the materials described in the next section in the same order as presented here and were then debriefed and thanked.

Materials

Manipulation Check. Four items served as manipulation check for the depletion task. One item asked to what extent the depletion task involved deliberation and careful consideration, the second question asked if the task reflected the participants' choices. A third question asked participants to rate the difficulty of the task, and, lastly participants were asked to rate how fatigued they were. Responses were on a scale from one "Not at all" to 10 "Very much".

Inhibitory Control. The classical Stroop was used in Study 2 because it is thought to assess neuropsychological functioning of error detection and inhibition (Trenerry et al., 1989). For the standard Stroop task, participants saw the color words red, blue, green, and yellow displayed in red, blue, green, or yellow font and were instructed to respond to the color of the font by pressing keys corresponding to each color. On congruent trials the color word matched the font color, whereas on incongruent trials the color word did not match the font color. The number of milliseconds it took to respond to congruent trials was subtracted from the time it took to respond to incongruent trials for a final score, where a greater number reflects less successful inhibitory control. The number of errors were also recorded (e.g., pressing the blue key when the word was red). Participants completed the Stroop task online through the psytoolkit.org platform on a desktop computer (Stoet, 2020). There were 80 trials.

Physical endurance. The handgrip task was adopted as a behavioral index of self-control to assess the effectiveness of the depletion task (Muraven et al., 1998). A Camry digital hand dynamometer was used to control for differences in physical strength. Participants' maximum grip strength was established by asking them to squeeze the handgrip as hard as possible for three seconds. The maximum grip was recorded in kilograms and multiplied by 0.70 to calculate 70% of their maximum grip (e.g., 40kg x 0.70 = 28kg). Participants were told the number reflecting 70% of their maximum grip (e.g., 28kg), and were asked to squeeze the handgrip for as long as possible at that intensity (Xu et al., 2014). The total number of seconds the grip was held was used as an index of endurance.

Impulsiveness. To index impulsiveness, the monetary choice questionnaire (Kirby et al. 1991) as described in Study 1 was used.

Approach motivation. The behavioral inhibition scale (BIS) and behavioral activation scale (BAS) developed by Carver and White (1994) measures the behavioral inhibition and behavioral activation systems, where BAS is sensitive to rewards, and the BIS is sensitive to punishment or aversive outcomes. Participants responded to 24 items on a scale from one "very true for me" to four "very false for me". Of the 24 items, 13 (present sample, $\alpha = 0.73$) are broken down into three BAS subscales: drive (e.g., "When I want something I usually go all-out to get it", fun seeking (e.g., "I often act on the spur of the moment"), and reward responsiveness (e.g., "When I get something I want, I feel excited and energized"). For the purposes of this study, all BAS items were summed for a total BAS score, which is a supported method (Ross, Millis, Bonebright, & Bailley, 2002). The remaining 12 items (present sample, $\alpha = 0.70$) assessed BIS (e.g., "I worry about making mistakes"). Participants were asked to answer the questions based on how they felt in the present moment, reflecting prior research (Schmeichel, Harmon-Jones, & Harmon-Jones, 2010).

Mood. The Positive and Negative Affect Schedule (PANAS) developed by Watson, Clark, and Tellegen (1988b) is a 20-item self-report measures of positive and negative affect. The 20 items are adjectives that describe feelings and emotions (e.g., nervous, proud, distressed, etc.). Participants were asked to indicate on a five-point scale from one "slightly or not at all" to five "extremely" how much they feel that way "at the present moment. Positive and negative affect items (10 each) were computed separately for two independent scores. Scores for each mood ranged from 10 to 50. Cronbach's alphas in the present sample were .82 and .86 for the positive mood and negative mood, respectively.

Results

The purpose of the second study was to compare self-regulation performance of cannabis users and nonusers following an ego depletion task involving decision making. To determine the validity of participants' responses, I first calculated means and standard deviations of the six manipulation check questions as seen in Table 7.

Table 7
Descriptive statistics for manipulation check questions for depleted cannabis users and nonusers

	Choices	Engagement	Deliberation	Preferences	Effort	Fatigue
Mean	8.69	8.07	9.04	8.73	7.46	4.34
SD	1.91	2.06	1.31	1.43	2.68	2.23

Note. Items answered on a scale from one (Not at all) to 10 (Very much)

Table 7 shows that all participants subject to depletion were highly active in deliberating and making choices, and that they took their decisions seriously, as reflected in questions one through four. However, questions five and six, which assessed effort and fatigue level, respectively, fell closer to the midpoint. For this reason, I compared users to nonusers on these two items. Assumptions of ANOVA were met. The first one-way analysis of variance revealed no significant differences in effort between users (M = 7.91, SD = 2.70) and nonusers (M = 7.13, SD = 2.70), F(1, 24) = 0.53, p = .476, n^2 = .02. The second one-way analysis of variance revealed no significant differences in reported fatigue between users (M = 4.27, SD = 2.05) and nonusers (M = 4.40, SD = 2.41), F(1, 24) = .02, p = .889, n^2 < .001.

Despite small group sizes, a one-way analysis of variance was undertaken which compared a control group (*n* = 5) to the depleted nonusers (*n* = 15) to ensure that the depletion task was effective. To limit the number of analyses, the two groups were compared on those dependent variables that other researchers (e.g., Garrison et al., 2019; Joireman et al., 2008 Muraven et al., 1998) have used. These findings are shown in Table 8.

Table 8

Comparison of control versus depleted nonusers on the outcomes of mood, handgrip endurance, and Stroop Performance

	Control	*Nonusers*			
Outcome Variable	*M(SD)*	*M(SD)*	*F* (df)	*p*	*η2*
Positive Affect	24.00 (5.24)	29.93 (8.66)	2.05 (1, 18)	0.17	0.1
Negative Affect	16.40 (10.69)	13.07 (3.84)	1.13 (1,18)	0.302	0.06
Handgrip Time (seconds)	30.60 (5.32)	52.40 (17.58)	18.10 (1, 17.99)	**0.015**	0.29
Stoop Interference (ms)	48.40 (64.58)	55.87 (62.39)	0.05 (1, 18)	0.821	0.002
Stroop Errors	3.40 (1.82)	2.73 (3.81)	0.14 (1, 18)	0.714	0.007

Note. Significant relationships are bolded. The initial difference in handgrip endurance was not significant, however, the Levene's test of homogeneity was violated in this case. Brown-Forsythe and Welch correction yielded a significant difference between controls and nonusers on handgrip endurance.

As can be seen, the number of seconds squeezing the handgrip following depletion was significantly different between groups, although in the opposite direction than predicted, that is, the depleted group squeezed the handgrip for longer than the controls. Otherwise, there were no significant differences between the two groups on any other outcomes. Contrary to the predictions of the resource model, the nondepleted group performed worse on all measures except for the Stroop interference difference, although the differences were not statistically significant. In sum, these findings (albeit small sample sizes) failed to yield support for an ego depletion effect.

Self-regulation performance of cannabis users and nonusers

Despite the findings when comparing non-users to a control group, I undertook a series of one-way ANOVAs to compare the self-regulation performance of cannabis users to nonusers following an ego depletion task. All assumptions were met. The results are shown Table 9.

Table 9
One-way ANOVA results comparing self-regulation of users to nonusers following ego depletion

Outcome Variable	Nonusers *M(SD)*	Users *M(SD)*	*F* (df)	*p*	η2
Positive Affect	29.93 (8.66)	26.36 (6.14)	1.36 (1, 24)	.255	0.05
Negative Affect	13.07 (3.84)	14.73 (3.95)	1.16 (1, 24)	.293	0.05
Handgrip Time (seconds)	52.40 (17.58)	35.62 (12.52)	7.28 (1, 24)	**.013**	0.23
Stoop Difference (ms)	55.87 (62.40)	124.91 (82.49)	5.92 (1, 24)	**.023**	0.20
Stroop Errors	2.73 (3.81)	2.27 (2.05)	0.13 (1, 24)	.720	0.005
Behavioral Inhibition	13.13 (3.74)	12.18 (3.46)	0.44 (1, 24)	.515	0.02
Behavioral Approach	22.40 (5.01)	23.90 (3.82)	0.70 (1, 24)	.412	0.03
MCQ Small Reward	0.033 (0.044)	0.027 (0.031)	0.14 (1, 24)	.703	<.01
MCQ Medium Reward	0.025 (0.026)	0.015 (0.020)	1.10 (1, 24)	.306	0.07
MCQ Large Reward	0.010 (0.010)	0.006 (0.008)	1.55 (1, 24)	.225	<.01

Note. Significant findings in bold. MCQ = Monetary choice questionnaire. The values for the MCQ items reflect discounting curves, with the greater numbers reflecting steeper discounting curves (i.e., greater impulsivity). Reward sizes reflect the difference between the immediate and delayed reward.

These analyses reveal two notable results. First, nonusers squeezed the handgrip for significantly longer than cannabis users. Second, cannabis users were more susceptible to the interference effect in the Stroop task, that is, they took significantly longer to respond to incongruent trials. Although there were no other significant differences, three of the other five means were in the expected directions such that nonusers showed more positive and less negative affect, greater behavioral inhibition and users showed greater behavioral activation. Conversely, the means for Stroop errors and temporal discounting curves were in the opposite direction as expected. The results from

Table 9 show promising patterns in that cannabis users performed worse on many indicators of self-regulation; however, they appear to be a result of pre-existing differences rather than the ego depletion effect.

Given that some participants from Study 2 were recruited from Study 1, I examined whether reported self-control levels at Study 1 predicted performance on the handgrip and Stroop tasks (i.e., the interference difference) following depletion. Two simultaneous multiple regressions for each outcome were undertaken with self-control scores from Study 1 as one predictor, with the second predictor being dummy coded where users were given the value of one and non-users were given zero.

The first simultaneous multiple regression employed handgrip persistence as the outcome. A normal probability plot and scatterplot show that the assumptions of normality and homoscedasticity were clearly violated, respectively. Multicollinearity was not an issue. The overall regression equation was significant, $F(2,23) = 3.49$, $p = .048$, and accounted for 23% of the variability in handgrip endurance. Only the partial regression coefficient for group membership (user vs. non-user) was significant, $b = -16.80$, $SE = 6.38$, [-29.99, -3.60]. Thus, when controlling for self-control, $b = 0.01$, $SE = 0.36$, [-0.75, 0.73], cannabis use predicted less handgrip endurance following depletion.

The second simultaneous multiple regression employed the Stroop interference difference as the outcome with self-control and dummy coded group membership as predictors. All assumptions were met, and multicollinearity was not an issue. The overall regression equation was significant, $F(2,23) = 4.52$, $p = .022$, and accounted for 28% of variability in the Stroop task. The partial regression coefficient of cannabis was significant such that cannabis use, $b = 64.94$, $SE = 27.53$, [7.99, 121.90] predicted a greater latency when responding to incongruent trials. In contrast, when controlling for cannabis use, self-control, *b* = -2.52, *SE* = 1.53, [-5.70, 0.66], did not significantly predict performance on the Stroop task. The two described regression analyses show that self-control levels from Study 1 did not predict handgrip endurance or Stroop performance following ego depletion at Study 2.

Discussion

In Study 2, the self-regulation performance of cannabis users to nonusers following ego depletion was examined. Given the discussed link between cannabis use and deficits in self-control, the hypothesis for the Study 2 predicted that cannabis users would perform worse on indicators of self-regulation following ego depletion relative to nonusers. To be able to draw such a conclusion, however, the ego depletion effect must be clear. Study 2 did not support the effectiveness of the choice task to deplete resources. When comparing the self-regulation performance of depleted nonusers to a small group of controls, the handgrip task was the only significant difference, and this was in the opposite direction as hypothesized. In this case, nonusers in the depletion group squeezed the handgrip for longer than the controls.

Despite not yielding an ego depletion effect, support was found for the link between cannabis use and lower self-control. Cannabis users were more susceptible to the Stroop interference effect and squeezed the handgrip for less time than nonusers following the depletion task. Furthermore, reported self-control levels from Study 1 did not predict Stroop or handgrip performance in Study 2 when controlling for cannabis use. Thus, the findings suggest that cannabis use alone explains poorer performance on these tasks.

General Discussion

Cannabis is one of the most used recreational substances, especially among 15 to 24-year-olds (Statistics Canada, 2019). Given cannabis's popularity and the recent movements toward legalization, it is important not only to understand the acute but also the nonacute effects of the drug. Regular users are, of course, not always intoxicated, which raises the concern of whether cannabis use may show similar residual effects as other drugs. In the case of drug addiction, brain imaging studies have revealed that addiction is characterized by dysfunction in the brain's self-regulation (or self-control) circuits (Volkow et al., 2011), with similar brain patterns emerging in chronic cannabis users (Zehra et al., 2018). Self-regulation – the process of controlling one's own thoughts, behaviors, and emotions – is crucial to well-being and success (Baumeister et al., 1993; Baumeister et al., 2007; De Ridder & Gillebaart, 2017). Therefore, cannabis's potential negative nonacute effects on self-regulation warrant further exploration.

The purpose of the present thesis was two-fold. First, Study 1 examined the links between substance use and self-regulation with a focus on cannabis use. Second, an experimental design in Study 2 compared the self-regulation performance of cannabis users to non-users following an ego depletion task. In both studies, cannabis use was hypothesized to be negatively related to self-regulation before and after ego depletion.

Relationship between cannabis use and self-regulation

Study one hypothesized that substance use would be negatively associated with all measures of self-regulation. This hypothesis was largely supported. Cannabis use and dependence, alcohol use and dependence, and cigarette use were all negatively associated with self-control. These findings are consistent with implications from brain imaging research suggesting that cannabis use may lead to dysfunction in the brain mechanisms responsible for self-control (Zehra et al., 2018). The relationship between substance use and executive function is less clear, with only alcohol dependence and cigarette use demonstrating a negative association. It is possible that dependence may be a better predictor of deficits in executive functioning than frequency of use as alcohol dependence was significant, and cannabis dependence approached significance.

Study one also provided partial support for the link between cannabis use and impulsivity as measured through the MCQ (Kirby et al., 1999). Although not the case for small and medium sized monetary rewards, increased weekly cannabis use was associated with higher delay discounting of larger rewards. Large rewards in this case reflect monetary amounts between $31 and $85; and these items have the largest differences between the immediate smaller amount and larger delayed amount. Thus, increased cannabis use was associated with choosing the smaller immediate reward over the larger delayed reward for these items. This finding adds to the literature as previous studies have failed to find a relationship between cannabis use and temporal discounting (Peters et al., 2013; Stea et al., 2011; Strickland et al., 2017), apart from Heinz et al. (2013) who found that compulsive craving for cannabis and earlier commencement of use were associated with higher delay discounting.

Regarding motivation and depression, Study 1 did not yield any association between these factors and cannabis use, which is both consistent and inconsistent with the literature. Pacheco-Colón et al. (2018) provided partial support that cannabis use led to decreased motivation over time, however, this is the only study to my knowledge to demonstrate this causal order. Likewise, research investigating cannabis use and depression has failed to illuminate the causal order of the exchange, as people with depression may be more likely to seek cannabis to alleviate symptoms (Walsh et al., 2017). Ultimately, the lack of a link between cannabis use and these variables was promising in that it is unlikely that motivation and depression contributed to the link between cannabis and self-control.

An unexpected finding in Study 1 was the relationship between cannabis use and social desirability. As cannabis use increased, self-deceptive positivity decreased, meaning that cannabis users unknowingly presented themselves more favorably. This was true of alcohol and cigarettes as well. Impression management, on the other hand, was not an issue for reported substance use.

Because concurrent substance usage was supported in that cannabis users reported drinking more alcoholic drinks per week and per occasion, had higher alcohol dependence, and were more likely to smoke cigarettes than nonusers, I examined the association between cannabis use and self-control when controlling for alcohol, cigarette, and impression management. As mentioned, impression management is more of a concern when it comes to consciously biasing self-reports than self-deceptive positivity (Paulhus & John, 1988). When considering these variables together, cannabis use uniquely predicted self-control, while alcohol and cigarette use did not. Although impression management also uniquely predicted self-control, it did not alter cannabis use as a predictor. Thus, this provides notable support for the idea that cannabis users have less self-control than nonusers. The link between cannabis use and executive functioning is less clear such that cannabis use alone failed to predict deficits in executive functioning. However, when controlling for impression management, cannabis use uniquely predicted self-control, while alcohol and cigarette use did not. In sum, Study 1 provided support for a unique relationship between the use of cannabis and lower self-regulation.

Cannabis use and self-regulation performance following ego depletion

Previous studies that employed self-control tasks have found that regular and chronic cannabis users show poorer performance than healthy controls (Battisti et al., 2010; Coullan-Valera et al., 2011; Cousjin et al., 2013; Heinz et al., 2013; Sagar et al., 2015). Furthermore, cannabis users have displayed dysfunction in the self-control circuits of the brain (Zehra et al., 2018). For these reasons, the present study assumed that cannabis users have less of the finite self-regulatory resource described by the resource model of self-control (Muraven et al., 1998). This model posits that performing a demanding self-control task (i.e., an ego depletion task) at time one leads to poorer performance at time two due to the limited nature of the resource that self-control relies on. Therefore, in Study 2, I hypothesized that cannabis users would perform worse on self-control tasks following ego depletion relative to nonusers. Although cannabis users performed worse on two measures of self-control, the hypothesis was not supported due to the lack of an ego depletion effect.

Being that both cannabis users and nonusers were subject to ego depletion, a control group was recruited to have their self-regulation performance compared to nonusers in order to test the depletion manipulation. The findings provided no support for the decision-making task adopted by Vohs et al. (2014) as a depletion manipulation. That is, there was largely no difference on subsequent performance between controls and nonusers. The one notable difference was on the handgrip endurance task, which showed the opposite effect in that nonusers performed better than controls. The reason for the opposite effect is unclear, however, Xu et al. (2014) yielded similar findings whereby the depletion samples squeezed the handgrip for longer than controls, although the difference was nonsignificant. It is possible that the decision-task used in the present study, and the modified Stroop used by Xu et al. (2014), were both ineffective depletion tasks. In the case of the present study, the small sample sizes make it difficult to be sure the ego depletion task was ineffective. However, Vohs et al. (2014) yielded an effect with only 30 participants between both groups. Thus, it is surprising that most of the self-regulation performances trended in the opposite direction as predicted.

The responses to the manipulation questions revealed that the users and nonusers in the depletion group took the decision-task seriously in that they reported being engaged and active in deliberating between choices. However, when asked how much effort they put forth, as well as how fatigued they felt, their responses fell closer to the midpoint of the scale. There was no difference between cannabis users and nonusers on these two items. The issue here may be the nature of the manipulation questions. For example, participants were not explicitly made aware they were completing a demanding task. Hence, even if they expended much effort and were mentally fatigued, they may not have realized it. A better manipulation question might have been how difficult they found the task (Muraven et al., 1998).

Despite the lack of a depletion effect, cannabis users showed worse Stroop and handgrip performance than nonusers. Regarding the Stroop task, the difference between the response times to the incongruent trials minus the congruent trials was larger for the users, meaning nonusers were quicker to inhibit and override the interference effect produced by the incongruent trials, whereas there was no difference in the amount of errors made. This finding is consistent with previous studies examining the effect of cannabis use on Stroop performance (Battisti et al., 2010; Coullan-Valera et al., 2011; Cousjin et al., 2013; Sagar et al., 2015). Regarding the handgrip task, nonusers squeezed the handgrip for longer than users. To my knowledge, no ego depletion research has assessed cannabis use and, therefore, there are likely no studies that have shown the effect of regular cannabis use on handgrip endurance.

Considering the failure of the depletion manipulation, these differences in performance are the result of either pre-existing levels of self-control and/or cannabis use. When examining whether self-control in Study 1 predicted performance on these tasks at Study 2, when controlling for cannabis use, the findings only strengthened the link between cannabis use and lower self-control performance. That is, cannabis use uniquely predicted lower performance on the Stroop and handgrip task, while pre-existing levels of self-control did not. In this way, Study 2 added to Study 1 in demonstrating the unique contribution of cannabis use on lower levels of self-regulation.

Limitations

The present thesis is not without limitations. First, the lack of an observed ego depletion effect was extremely problematic in testing the hypothesis for Study 2. To argue that cannabis users have less self-regulatory resources, the depletion effect had to be clear. Otherwise, any differences found can be assumed to reflect the individual and not the experimental manipulation. The decision-making task adopted by Vohs et al. (2014) was chosen because it was shown to have a notable depletion effect on a small sample of 15 participants. Also, the taxing nature of decision-making, and the length of the task (making hundreds of choices takes some time), made it appear as a good option for depletion. There are, however, a couple of reasons the decision task may not have been as effective as anticipated. First, it is possible that the options given were not relevant to the sample of undergraduates. Study 2 used everyday items such as t-shirts, coffee mugs/water bottles, pens, and key chains (among others) as the options to choose from. Most of the items were university logoed. It is possible the subjective value of these products made the decision easy or without meaning for participants. Likewise, when choosing between future occupations, participants may not have had interest in many of the given careers or, alternatively, the prospect of considering different careers at this early stage of university may have had little meaning to them. Although the decision options in the current study approximated those given by Vohs et al. (2014), it is possible the slight differences in products explain the lack of effect observed in Study 2.

Second, the decision-task is relatively new and less-evidenced based than some of the traditional tasks used in the ego depletion literature. A meta-analysis by Dang (2018) demonstrated that the emotional video technique typically yields the most consistent depletion effects, following by the crossing out letters exercise invented by Muraven et al. (1998), and the Stroop task (Dang et al., 2017). However, the lack of power from the small sample sizes in Study 2 may have still rendered these depletion tasks ineffective (Dang, 2018; Hagger, Wood, Stiff, & Chatzisarantis, 2010).

Another limitation of the present thesis is being able to show the causal order of cannabis use and self-regulation. The evidence I reviewed in the introduction largely suggests that cannabis use interferes with, or decreases, self-regulation. However, it is also plausible that low self-control and executive functioning may lead to cannabis use

(Jackson et al., 2016; Meier et al. 2018). This methodological conundrum cannot be addressed with the current design and is an inherent flaw of drug research on human participants because of its necessary reliance on self-reporting past drug use. More studies with longitudinal designs are required to shed light on the causal order of cannabis use and self-regulation.

Finally, the most evident limitation of the current studies is the size and characteristics of the attained samples for Study 2. Small samples sizes may have contributed to both the lack of an ego depletion effect, as well as the lack of differences in self-regulation performance between regular users and nonusers. Attrition from the first to second study was an issue. Due to the lack of heavy cannabis users who were willing to return for Study 2, the minimum usage threshold was changed from four to one time per week, whereas the studies mentioned in the literature review typically had higher usage requirements. The many levels of cannabis use seen in the online survey at Study 1 show that university students are a target demographic to examine the effects of the drug. Of the 85 participants who reported using cannabis at least one day a week, 26 of them reported using at least four times per week, however, only one participant who reported using cannabis more than once a week participated in Study 2. A more hands-on approach to recruiting cannabis users on a university campus, such as networking with students familiar with others who use cannabis, may improve attrition in future studies.

Conclusion

The popularity of cannabis, as well as the movements towards its legalization in many countries, warrant public health concern regarding the potential nonacute effects resulting from overuse of the drug. The present thesis provides evidence of cannabis's negative association with self-regulation, a process that is integral to well-being and success. Furthermore, these findings contribute to the uncertainty of the ego depletion phenomenon. Future research should continue to test the effect with appropriate sample sizes, and even more so, endeavor to elucidate the underlying factors that help explain the great variability in self-control following depletion.

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