COGNITIVE TRAINING FOR REDUCING CANNABIS USE IN YOUNG ADULTS: COMPARING THE APPROACH-AVOIDANCE TASK AND EVALUATIVE CONDITIONING

by

Jill Marie Robinson

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The following individuals certify that they have read, and recommend to the College of Graduate Studies for acceptance, a dissertation entitled:

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Dr. Marvin Krank, Irving K. Barber School of Arts and Sciences

Supervisor

Dr. Paul Davies, Irving K. Barber School of Arts and Sciences

Supervisory Committee Member

Dr. Zach Walsh, Irving K. Barber School of Arts and Sciences

Supervisory Committee Member

Dr. Robert Campbell, Okanagan School of Education

University Examiner

Dr. Alan Stacy, School of Community and Global Health

External Examiner

Abstract

Substance use may be influenced by a combination of both reflective and impulsive cognitions (Wiers, Van Woerden, et al., 2002). Traditional prevention programs typically focus exclusively on reflective cognitions while impulsive cognitions are often left unexamined. Cognitive bias modification (CBM) has been proposed as an innovative method of reducing substance use in a variety of populations. Existing literature suggests that the Approach-Avoidance Task (AAT) and Evaluative Conditioning (EC) procedures have effectively altered cognitions and have also produced behaviour changes. However, most of the studies examining AAT and EC training for substance use have focused on alcohol and nicotine use. Research is needed to determine the effectiveness of these procedures for cannabis use. The aim of this study was to examine whether AAT and EC training was able to alter cognitions about cannabis and produce changes in behaviour. This study drew participants (n=293) from the undergraduate research pool at the University of British Columbia Okanagan. Participants completed six sessions of cognitive training over several weeks and a follow-up session one month after the sixth training session. This study used a 2x2 factorial design by randomizing participants into one of four conditions – EC, AAT, combination, or sham. Results indicated that the AAT training produced changes in cognition over 6 sessions, F (1.58, 135.06) = 6.97, p = .003, partial η2 = .08, while the EC training did not, F (5.3, 151.95) = .33, p = .90, partial η2 = .01. No changes in cannabis use behaviour were observed over time for those in the EC training group (all *p's* > .05). Cannabis use was higher at the 1-month follow-up for those in the AAT training group (p = .03). Motives to use cannabis and cravings for cannabis predicted frequency of cannabis use and problems associated with use (*p's* < .05) at Session 1 and Session 6. Gender and mental health diagnosis predicted frequency of cannabis use and problems associated with cannabis use at Session 1 (*p's*

< .05). This study is the first to examine the efficacy of the AAT and EC procedures to alter cognitions about cannabis use and associated behaviour.

Lay Summary

Cannabis is a commonly used substance throughout the world, especially among young people. Research has shown that individuals have thoughts and attitudes that influence their substance use behaviour. For instance, those who frequently use cannabis often have a bias toward approaching cannabis-use stimuli and may look at cannabis photos longer or take longer to shift their attention to other photos. Individuals may be aware of these cognitions or may be unaware that they hold certain beliefs or attitudes about substances. These maladaptive cognitions can impact our behaviour and can lead to increased substance use. Cognitive bias modification techniques have been used to change unhealthy cognitions that lead to increased substance use. Results of the present study suggest that a cannabis Approach-Avoidance Task changed cannabis cognitions but did not change cannabis use behaviour while a novel Evaluative Conditioning task did not produce changes in cognition or cannabis use behaviour.

Preface

Jill M. Robinson, MA was the primary contributor to the work presented in this dissertation, and was responsible for all study design, data analysis, and writing of the manuscript. The Behavioural Research Ethics Board of the University of British Columbia's Okanagan Campus granted ethics approval for this research. The certificate approval number for the project is H19-02395. To date, the results of this study have not been published.

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Dedication

To my two Husky dogs, who have been by my side (literally and figuratively) throughout my graduate school journey. Diesel and Raine have been my anchor of self-care and my unparalleled love for them has carried me through the past 5 years.

To my family and friends.

CHAPTER 1 Introduction

Daily use of cannabis is a popular activity among adolescents and young adults (Johnson et al., 2017). Despite large movements across the world to decriminalize medical and recreational cannabis use, many countries strictly prohibit the use of cannabis. In several countries (e.g., Pakistan, Brazil, Russia), significant legal ramifications exist for those possessing and using cannabis. However, in 2018 the federal government of Canada passed legislation decriminalizing recreational cannabis use for adults. Coupled with decreased legal restrictions on use, cannabis use has become a notable political and public health issue in Canada. Research suggests that early, heavy cannabis use can impact mental health (Coffey & Patton, 2016; Degenhardt et al., 2013; Moore et al., 2007) and lead to a heightened risk of problematic substance use (Chen et al., 2005; Rubino & Parolaro, 2008). Given that adolescent and young adult populations are at increased risk for harm from cannabis and substances in general, important initiatives focus on methods of reducing such risk to young people. One means of doing so is to intervene on the cognitions that underlie young adult cannabis use (Krank & Robinson, 2017). Research suggests that cognitions about substance use precede and predict initiation and increase in substance use over time (Fulton et al., 2012; Loijen et al., 2020; Robinson & Krank, 2018). To this end, the development and validation of cognitive interventions to prevent or reduce harmful cannabis use may be a useful method for preventing harm to young people.

Cognitive research posits that human behaviour is influenced by both reflective (controlled) and impulsive (automatic) cognitive processes (Wiers, Stacy, et al., 2002). Reflective cognitions are those that are relatively slow, goal-oriented, easily reported, and operate at a conscious level. Reflective cognitions are often process-driven and unfold in serial or patterned steps that reflect the controlled manipulation of memory representations which guide behaviour (Gladwin et al., 2016). In contrast, impulsive cognitions are characterized as spontaneous, associative, automatic, outside of awareness, and operate without the need to consciously deliberate and are often highly influential in decision making, especially with regard to substance use behaviour (Stacy & Wiers, 2010). This two-system model of cognition is often referred to as the dual-process theory. Even if individuals rationally ponder positive and negative consequences of each decision, dual-process models of cognition suggest that individuals are significantly influenced by automatic cognitive processes, contextual effects, and priming influences that occur without conscious awareness (Krank & Robinson, 2017; Stacy & Wiers, 2010).

Often, impulsive cognitions are established over time through conditioning processes that individuals may or may not be aware of (e.g., positive and negative reinforcement patterns; Gladwin & Wiers, 2012). Impulsive cognitive processes may develop and take the form of cognitive biases such as the approach bias which refers to the automatic tendency to approach a specific and relevant cue after it has been exposed. When cognitive biases occur that are maladaptive or lead individuals toward unhealthy behavioural outcomes, they are considered a risk factor for psychopathology including problematic substance use and addiction (Mathews & MacLeod, 2005). These biases exist in several areas of human behaviour (e.g., sex, eating, purchasing goods) but have particular importance in the realm of substance use behaviour. From a dual-process standpoint, addiction is likely perpetuated by strong approach, attention, and appetitive biases that have become associated with drug use and may be activated outside of an individual's awareness (Stacy & Wiers, 2010). Reflective cognitive processes are said to exert little control over the implicit cognitive biases that operate automatically in addiction (Stacy &

Wiers, 2010), setting in motion a vicious cycle of drug-seeking and drug-taking behaviour that can appear out of control.

Incentive-salience models of addiction assume that cognitive biases come about from repeated exposure to substance use and substance-related cues which lead to behaviours that become strongly associated with addiction (Berridge, 2007). In addition, the behaviours of addiction may stem from a hypersensitivity to the motivational factors associated with drug use and related stimuli (Berridge & Robinson, 2016). Given the neurobiological reinforcing features of some substances, the automatic cognitions that have been repeatedly associated with substance use become difficult to control at a conscious level. As such, compulsive drug-taking and addiction may occur despite a person being able to report that their addiction is detrimental to their life. This process can be understood as a product of strong impulsive associations between the reward system and the drug-taking behaviour that are difficult to override with reflective cognition when an individual is presented with stimuli, craving, or environments that encourage drug-taking behaviour (Berridge & Robinson, 2016). Not surprisingly, an abundance of literature has demonstrated the critical role of approach, attentional, and evaluative cognitive processes in the development and maintenance of addiction (Field et al., 2006, 2008; Waters & Feyerabend, 2000).

Cognitive biases towards substance use cues are particularly important to examine in young adults as this population has been shown to participate in increased levels of risky substance use behaviours (Everitt & Robbins, 2013; Peeters et al., 2012; Thush et al., 2008). Several studies have shown that approach biases correlate with consumption levels (Barkby et al., 2012; Wiers et al., 2010) and are associated with maintaining addictive behaviours (Baird et al., 2017; Waters et al., 2003). For instance, individuals who smoke cigarettes hold approach biases that correlate with nicotine craving (Field et al., 2009). Similarly, heavy cannabis users show an approach bias toward cannabis images compared to control images (Cousijn et al., 2011). Cognitive biases towards cannabis have also been related to increased rates of cannabis use and more cannabis-related problems in those dependent on cannabis (Cousijn et al., 2011, 2012). Relative to non-cannabis users, heavy cannabis users look at cannabis cues longer and rate these cues as more pleasant, suggesting an attentional and evaluative bias (Field et al., 2006). Taken together, this research suggests a strong relationship in support of the notion that substance use is heavily impacted by impulsive cognition. Despite this, substance use prevention and treatment approaches that incorporate this research are only beginning to be explored and adequately developed.

1.1 Substance Use Prevention and Treatment Approaches

Several approaches have been taken to prevent and reduce substance use, typically beginning with programming for youth. Explicit, universal approaches (e.g., Drug Abuse Resistance Education [D.A.R.E.]) have been implemented with varying levels of success. These programs often target the dangers of using substances and attempt to use instruction and scare tactics as a means of reducing substance use among adolescents (Boendermaker et al., 2015). However, the efficacy of these programs has been called into question (Werch & Owen, 2002). Further, many of these approaches must be implemented within the school system, taking considerable time away from scholastic pursuits. These programs can also be very costly to maintain. For example, D.A.R.E. is estimated to cost three quarters of a billion dollars to provide in schools in the United States annually (West & O'Neal, 2004).

In older adolescents and emerging adults, preventative drug programming often comes in the form of brief education in health-related high school or college curricula. However, adolescents do not typically consider their substance use problematic during their teenage years (Wiers et al., 2005) and they often do not exhibit high levels of motivation to change their risky behaviour. As such, prevention and intervention programs that target reflective cognitions and suggest abstinence often fall on deaf ears and may not be the most efficacious method of substance use prevention for young people (Wiers et al., 2005).

Though many adolescents and young adults mature out of risky substance use, some youth will maintain and increase their levels of substance use. As young people age, addressing substance use may shift from prevention to treatment of problematic substance use. Substance use may be treated in emergency departments, disciplinary school settings, the justice system, or mental health settings. Treatment of substance use in mental health settings has varying degrees of success (Cutler & Fishbain, 2005), with poor outcomes being the norm rather than the exception. Twelve-month rates of relapse after alcohol and nicotine cessation range between 80% and 95% (Brandon et al., 2007). Following treatment, rates of relapse are similarly high for individuals using cannabis (Sherman & McRae-Clark, 2016). Even the most efficacious treatments for cannabis use (e.g., cognitive behavioural therapy [CBT] and motivational enhancement therapy) have low rates of success, with abstinence rates of 23% at 4-month follow-up that decline to 15% at 9 months (Babor et al., 2004). High rates of relapse that occur long after the acute effects of withdrawal have subsided suggest that other factors may be maintaining addictive processes (e.g., cognition; Gladwin et al., 2016).

It is evident that the current approaches to treating problematic substance use have a low degree of success and limited durability (Brandon et al., 2007; Sherman & McRae-Clark, 2016). In response, several novel cognitive approaches to substance use prevention and treatment are under development. As previously mentioned, these models suggest that over time, substance use leads to maladaptive changes in cognition including changes in attentional (Field et al., 2007) and approach biases (Wiers et al., 2009) towards substances as well as the formation of new automatic memory associations (Frigon & Krank, 2009). Approach tendencies toward alcohol have been shown to be present in adolescent drinkers soon after they initiate alcohol use, highlighting the need to address these biases before harmful drinking ensues (Pieters et al., 2010) and biases become more solidified.

Cognitive biases have also been shown to play a significant role in maintaining problematic substance use and are associated with poorer treatment outcomes (Cox et al., 2007; Marhe et al., 2013). As such, identifying and modifying maladaptive cognitive biases may be beneficial as an adjunct treatment method in addition to current well-established explicit approaches (e.g., CBT). Some authors have suggested that treatment for substance use should include techniques to modify both the reflective and impulsive cognitions that drive substance use behaviour rather than focusing exclusively on one set of cognitions (Heitmann et al., 2017; M. Krank & Robinson, 2017). Further, the automatic, impulsive, and associative cognitive system has been proposed to be the default cognitive processing system that influences many of our thoughts and behaviours (Kahneman, 2003). Given this theory, it makes intuitive sense then to target the impulsive processes when intervening in potentially life-threatening situations (e.g., addiction; Stacy & Wiers, 2010).

1.2 Cognitive Bias Modification

Given the ample research suggesting that impulsive cognition impacts behaviour, it follows that techniques to target impulsive maladaptive cognitions may be useful in reducing harmful behaviours. Recently, techniques to modify impulsive cognitive biases have gained attention in substance use research. Because cognitive biases have the potential to produce or exacerbate mental health problems, recent literature has examined the ability of cognitive bias modification (CBM) procedures to modify, reverse, or gain increased control over problematic biases that may underlie risky behaviour and psychopathology (C. E. Wiers & Wiers, 2017).

Originally developed to examine and assess impulsive cognition, cognitive bias assessment procedures have evolved into CBM paradigms. These modification techniques have been used to change biases related to anxiety (Amir et al., 2009; Linetzky et al., 2015; Schmidt et al., 2009), depression (Peckham et al., 2010), food intake (Dickson et al., 2016), and substance use (Eberl et al., 2013; Manning et al., 2016; Schoenmakers et al., 2010; Wiers et al., 2013). CBM for alcohol and cigarette use has been explored broadly in the literature, although the same cannot be said for cannabis use. To date, only three studies have examined the effectiveness of CBM methods for reducing cannabis use (Heitmann et al., 2017; Jacobus et al., 2018; Sherman et al., 2018).

CBM methods typically use computerized tasks that capture automatic cognitive processes (e.g., approach or attention bias) and attempt to manipulate pathological biases such as those found in anxiety or addiction (C. E. Wiers & Wiers, 2017). The varied methods used in CBM interventions are targeted at changing the impulsive cognitions which have proved challenging to alter with explicit interventions (Eberl et al., 2013). The goal of these training procedures is to change the behaviour that is associated with the cognitive bias. Participants retrain these cognitive biases, often by viewing numerous trials of photograph or word stimuli. CBM methods for substance use seek to modify the impulsive biases that individuals hold towards substance use cues (Eberl et al., 2013, 2014; Wiers et al., 2010), frequently by training participants to approach or avoid selected features of a substance (e.g., avoiding a photo of a wine glass or approaching a glass of water; C. E. Wiers & Wiers, 2017). Training that causes people to form strong biases toward a substance typically increases the substance use behaviour while the opposite is true for those who have been trained to avoid the substance (Field & Eastwood, 2005; MacLeod et al., 2002). Many methods of CBM are used in various fields of study, however, one principle is similar in all methods – the training that occurs must be indirect (Stacy & Wiers, 2010). That is, the participant is not aware that their implicit processes are at work when they are responding to the task. When using indirect methods of measuring or training cognition, the characteristics of reflective cognition are said to be avoided or engaged to a minimal extent, thereby producing a spontaneous, automatic approximation of the cognitive processes that operate outside of awareness (Stacy & Wiers, 2010).

Despite some efficacious training effects, the question remains as to what mechanisms underlie the effects of CBM. Although most of the research has only just begun to posit potential mechanisms of change, some theoretical underpinnings have been identified to help explain the impacts of CBM. Some authors suggest that the effects of CBM on rates of relapse are in fact mediated by changes in approach biases that were present before the CBM training (Eberl et al., 2013; Wiers et al., 2011). Additionally, change in avoidance biases over the course of training has also been measured and suggested as a potential mediator as well (Gladwin et al., 2015). Taken together these findings propose that one potential underlying mechanism of CBM is its ability to alter cognitive biases in desired directions.

Though CBM has often shown positive training effects on cognition and behaviour, some studies and a recent meta-analysis have shown less-than-favourable outcomes (e.g., Cristea et al., 2015, 2016). While it is important for all research to examine study failures or contradictory opinions, the field of CBM is relatively new and highly varied in terms of technique, parameter choice, and follow-up length used in each study (Gladwin et al., 2016). Further, moderators of

CBM are beginning to be explored (e.g., motivation, attention, working memory) and research has just begun to examine mechanisms of change. As such, claims that render CBM ineffective at this developmental stage of the field may be prematurely limiting the potential positive outcomes of this adjunct treatment modality. To this end, the most important question that is being asked is, “What works for whom?” The answer to this theoretical question is rapidly expanding and the present research sought to contribute to the broader understanding of CBM.

1.2.1 Approach-Avoidance Task (AAT)

The AAT is a relatively new CBM technique that was originally developed to assess impulsive cognitions (Rinck et al., 2018) and later adapted as a tool for retraining biases associated with alcohol (Wiers et al., 2009, 2010, 2011). This technique is cost effective, easily administered, and accessible for patients and service providers as it does not rely on language (Aguinaldo et al., 2019). The AAT is conducted on a computer and requires participants to use a computer mouse or joystick to push a stimulus away (reducing the size) which simulates avoidance or pull a stimulus towards them (increasing the size) which simulates approach (Rinck et al., 2018). The extension or flexion of the arm using the mouse or joystick during this task is analogous to approach or avoidance of the stimuli. Although the arm movements that simulate approach or avoidance have been called into question, evidence has suggested that flexion of the arm is more likely to be paired with the acquisition of an object that is desired than is extension of the arm (Cacioppo et al., 1993; Neumann & Strack, 2000). Over the lifetime, arm flexion then becomes conditioned to an approach bias while arm extension becomes conditioned to an avoidance bias (Cacioppo et al., 1993). Further, evidence suggests that arm flexion is initiated quicker to a positive stimulus than to a negative stimulus (Chen & Bargh, 1999). Conversely, arm extension is initiated faster to a negative stimulus than to a positive stimulus.

Recent research has found that AAT training changes approach biases towards substances which then may result in behavioural changes (Wiers et al., 2011). The AAT trains the participant to avoid stimuli of the problematic substance thereby attenuating the approach bias and reducing the incentive salience of the substance. This is done by configuring the AAT so that participants push away substance use stimuli (e.g., alcohol or cannabis photos) and pull neutral stimuli (e.g., soft drink or plant photos) towards themselves. To do so implicitly, the participant is trained to push away the stimuli that are oriented in one format (e.g., landscape photos) and pull the stimuli that are oriented in the opposite format (e.g., portrait photos). The CBM training that takes place using the AAT is indirect as it requires the participant to respond to the orientation of the stimulus instead of the content of the photograph. By doing so, the participant is not likely to be consciously aware that their biases may change due to this training given that they are responding to each trial based on an irrelevant feature of the task (Wiers et al., 2011).

An early study of the AAT indicated that heavy drinkers who were trained in a single session to avoid alcohol stimuli subsequently consumed less alcohol in an alcohol taste test relative to those who were trained to approach alcohol stimuli (Wiers et al., 2010). This study trained participants to avoid alcohol stimuli by presenting 90% of the alcohol photos in the orientation that required a push movement and only 10% that required a pull movement. The opposite pattern was required for those who were trained to approach alcohol, with 90% of the photos of alcohol being pulled and 10% being pushed. Interestingly, participants did not report any awareness of these two training contingencies (Wiers et al., 2010).

Following this, a clinical trial was conducted where inpatient individuals seeking alcohol treatment received either four sessions of AAT, sham training, or no training (Wiers et al., 2011). Those in the active AAT training group changed their alcohol approach bias to an avoidance bias and showed 13% less relapse one year after being discharged. Additionally, the effects of training generalized to other photos of alcohol that were not used in the training AAT, suggesting that a general construct of alcohol was being accessed during the AAT training (Wiers et al., 2011). Similarly, one randomized control trial involving 509 patients being treated for alcohol use disorder reported that participants receiving 12 sessions of AAT training in addition to CBT reported a significantly lower rate of relapse one year later (51.2% abstinent) relative to those who only received CBT (42.7% abstinent; Eberl et al., 2013). The AAT training group in this study also showed an increase in alcohol avoidance bias after receiving the training. Several additional studies have examined the effect of AAT training on individuals with alcohol dependence and many have found that AAT training has led to decreases in alcohol consumption or relapse rates (Manning et al., 2016; Rinck et al., 2018; Wiers et al., 2011). One important theoretical outcome of these studies is that six or more sessions are likely needed to produce better results (Eberl et al., 2014).

Studies with cigarette smokers have found promising results as well (e.g., (Machulska et al., 2016; Wittekind et al., 2015). One study of online AAT training showed decreased cigarette use at 1-month follow-up in those who received the training (Wittekind et al., 2015). However, this study was limited by the lack of a sham training condition. A later study by the same authors found that a nicotine AAT training program reduced daily cigarette use immediately after training when compared to the control group, but these effects did not persist at the 6-month follow-up (Wittekind et al., 2019). In a sample of inpatient psychiatric patients with nicotine dependence, the addition of AAT training for smoking had no effect on approach-avoidance tendencies above and beyond a smoking cessation program (Machulska et al., 2016). Interestingly though, at the 3-month follow-up, those in the AAT training group smoked fewer cigarettes than those in the sham training group suggesting an added long-term benefit of avoidance training for those in the active training condition.

1.2.1.1 Cannabis Approach-Avoidance Task. Approach biases of cannabis have been found in cannabis users in several studies (e.g., Cousijn et al., 2011, 2012) and these biases have been shown to predict increased cannabis use 6 months later (Cousijn et al., 2012). These studies highlight the need to address these biases as they present as a possible risk factor for increased cannabis use. Although AAT training paradigms have been used with alcohol- and cigarette-using populations, they have been evaluated substantially less in those who use cannabis. A recent proof-of-concept study used the AAT method but adapted the procedure for use with cannabis (Sherman et al., 2018). Thirty-three non-treatment-seeking adults who met Diagnostic and Statistical Manual of Mental Disorders-5 criteria for moderate to severe Cannabis Use Disorder were randomized to four sessions of AAT training or sham training over a 2-week period. Results indicated that AAT training did not reduce cannabis approach bias after training ended. However, men in the AAT training condition reported significantly fewer days of cannabis use than women in the same condition. The authors suggest that the null bias modification findings could have been due to the lack of standardized treatment protocol for this new cannabis intervention (i.e., uncertainty about parameters needed for effectiveness), the non-treatment-seeking population, and the small sample size.

Another proof-of-concept study tested the AAT with a sample of non-treatment-seeking 17- to 21-year-old frequent cannabis users (Jacobus et al., 2018). Eighty participants were randomized to receive either six sessions of AAT training or six sessions of sham training twice per week for 3 weeks. Although change in approach bias did not reach significance, the change trended towards reductions in approach of cannabis stimuli. Further, those in the AAT training group reported a 7% reduction in days of cannabis use over the period of the study relative to a 0% change in the sham group, although this difference was not statistically significant. Interestingly, those in the AAT training group reported a 10% increase in days using alcohol compared to a 3% increase in the sham group, highlighting the importance of measuring the use of these two substances simultaneously. These findings are somewhat consistent with the alcohol AAT literature, suggesting that six sessions of training may produce modest reductions in behaviour and approach biases (Eberl et al., 2013; Wiers et al., 2011). The authors suggest that a small sample size may have contributed to their null findings.

1.2.1.2 AAT Moderators. An area of interest that is currently under consideration is the conditions under which AAT training is most effective. Little is known about the choice of stimuli, number of trials, number of training sessions, spacing of training sessions, and other parameters that lead to effective AAT training. Multiple sessions of training have been reported to work more effectively in anxiety and heavy-drinking populations (Amir et al., 2009) and research does indicate that more than one session of training is necessary to produce successful outcomes in the area of substance use (Field et al., 2007; Schoenmakers et al., 2007). However, it is unclear as to whether more sessions translate to increased behavioural or cognitive changes (Fadardi et al., 2009; T. M. Schoenmakers et al., 2010; Wiers et al., 2011) and how many sessions are optimal and feasible.

Since the AAT training paradigm is relatively new and still being evaluated in several populations, little is known about the mechanism of change that drives success or about the predictors of successful training (Eberl et al., 2013). Previous studies (e.g., Wiers et al., 2010, 2011) have shown an effect of alcohol avoidance training on subsequent drinking behaviour but neither examined the mechanism that produced the effects, nor did they determine if the change was due to changes in alcohol approach biases. Some authors hypothesize that another mechanism altogether may be responsible for decreases in substance use behaviours in those who received the AAT training. However, others maintain that the effects could be due to participants learning to attend less to the alcohol stimuli throughout the task (Sharbanee et al., 2014). To examine this, one study assessed whether the effect of AAT training on alcohol use was mediated by selective attention or by alcohol approach biases (Sharbanee et al., 2014). Results suggest that a significant indirect effect of training was not mediated by changes in selective attention but was instead mediated by changes in approach bias. Although this line of research is in its infancy, these results suggest preliminary evidence that the AAT training method produces changes in behaviour that are preceded by changes in approach biases.

1.2.2 Evaluative Conditioning

EC is another promising cognitive approach to reducing substance use. EC is a form of Pavlovian conditioning where the goal of the task is to change the valence associated with a stimulus by repeatedly pairing one stimulus (CS; conditioned stimuli) with another subsequent stimulus (US; unconditioned stimuli; De Houwer et al., 2001). Some of the earliest evidence of EC was demonstrated by a simple experimental task that paired nonsense words (CS) with negative or positive valence words (US; Staats & Staats, 1957). Consequently, the nonsense words acquired the valence of the word with which they had been paired. Nonsense words that were paired with positive words acquired positive associations and vice versa. As such, the goal of EC procedures is often to change the valence of one stimulus by associating it with another stimulus with a different desired affective quality (De Houwer, 2007). This change may then modify the affect, cognition, or behaviour associated with the original stimulus in the direction of the US stimulus. Interestingly, research suggests that the affective change is often stronger when stimuli are paired with negative USs than with positive USs (Levey & Martin, 1975).

Dual-process models of cognition suggest that cognitions and preferences related to an object or action develop through repeated pairings of the object or action with positive or negative affect (Olson & Fazio, 2001). As such, the impulsive cognitions that are associated with an object may be changed by introducing a new affective object pairing (Olson & Fazio, 2001). EC has been demonstrated with visual (De Houwer et al., 2000; Hammerl & Grabitz, 1993), gustatory (Baeyens et al., 1995, 1996), and haptic stimuli (Hammerl & Grabitz, 2000). More recent visual EC methodology has proven effective in several domains including: reducing non-suicidal and suicidal self-injury behaviours (Franklin et al., 2016), modifying cognitions related to food consumption (Hollands et al., 2011), and reducing prejudices toward homelessness (Balas & Sweklej, 2013).

Another emerging area of research has begun to examine the utility of EC for reducing maladaptive substance use biases, cognitions, and related behaviour in young adults. Positive impulsive cognitions have been shown to correlate with increased substance use (Houben & Wiers, 2008; Jajodia & Earleywine, 2003) and the EC paradigm has been proposed as a method of reducing positive associations that are related to substance use. To test this, several studies have examined the EC procedure with undergraduate student samples. An early study examined the effect of a single session EC task that paired pictures of beer (CS) with negative words and photos (US) in an undergraduate sample (Houben, Schoenmakers, et al., 2010). Results suggested that participants had more negative attitudes about beer, had less explicit cravings for beer, and drank less beer immediately after they completed the task and in the week after the experiment. These results propose that drinking behaviour and cognition can be altered by using

EC procedures (Houben, Schoenmakers, et al., 2010). A similar study examined the effectiveness of a single session of EC in another undergraduate sample (Houben, Havermans, et al., 2010). Results suggest that those in the experimental condition, which paired alcohol photos with negative stimuli, reported more negative implicit attitudes towards alcohol and consumed less alcohol during the week following the experiment (Houben, Havermans, et al., 2010). In another study of college students, one session of EC was effective in reducing drinking behaviour by 31% in the experimental group relative to 4% in the control group at 2-week follow-up (Tello et al., 2018). This study suggested that the cognitive changes that occurred after completing an EC task do translate into subsequent behaviour changes. However, the authors caution that lengthier follow-up periods should be employed in future studies. An additional recent study paired 10 alcohol photos with 10 negatively valenced images in an EC task with students (Zerhouni et al., 2018). Results of this study suggested that cognitive associations with alcohol were reduced immediately after participation and 1 week later.

Additional evidence comes from a study that examined the effect of EC on reducing reflective alcohol-related cognitions (Choi & Lee, 2015). To do so, the authors recruited heavily drinking male undergraduates and showed them several alcohol-related photos paired with negatively valenced photos. Results found that participants reported decreased explicit attitudes about alcohol expectancies and decreased cravings for alcohol after completing the EC task compared to their baseline assessment. In a related study, an EC task was effective at changing cognitions towards cigarette smoking which then led to decreased smoking behaviour (Məgurean et al., 2016). However, these changes only occurred when the participants’ affective reaction was explicitly noticed. This caveat calls for more research examining the conditions and parameters impacting the effectiveness of EC procedures for substance use. Nevertheless, preliminary studies suggest that EC tasks are effective for changing impulsive cognitions and producing behavioural changes toward some substances (e.g., alcohol and cigarettes). However, no studies exist that examine EC procedures for the purpose of reducing cannabis use. Moderators of the EC tasks for substance use have also not been well researched and the boundary conditions are still being determined (De Houwer et al., 2001).

1.2.2.1 Evaluative Conditioning with the Affect Misattribution Procedure (AMP). Although many EC procedures have been used over the past several decades, some research suggests that the effect of the EC tasks are due to the obvious demand characteristics of the experimental task (De Houwer et al., 2001). To mediate this problem and ensure that outcomes are due to true conditioning, researchers have suggested that indirect affective priming tasks be used (Fazio, 2001). As such, the AMP was chosen to facilitate the EC in this study as it requires that participants make affective judgements based on very fast presentations of stimuli. The AMP relies on the premise that individuals are often unable to determine the source of their affect when two events occur closely together in space and time (Payne et al., 2010), rendering the task indirect in nature. During each trial of the standard AMP, participants are instructed to make ratings of the trial based on a neutral stimulus (e.g., a Chinese pictograph) rather than rating the target stimulus in the trial (e.g., a cannabis photo). However, a series of studies (Murphy & Zajonc, 1993; Payne et al., 2005) has shown that when a valenced stimulus precedes the neutral stimulus, the valenced stimulus influences the affective rating of the neutral stimulus even after explicit instructions have been given to avoid this error. The repeated pairing of two stimuli is central to the AMP and this pairing facilitates the transfer of valence that takes place when a substance use stimulus is presented in close time proximity to a negative stimulus.

1.3 Modifiers of Cognitive Bias Modification

Previous research has identified various potential modifiers that may impact CBM training. Explicit, reflective cognitive associations have been found to predict substance use behaviour immediately and longitudinally (Fulton et al., 2012; Thush et al., 2008). Specifically, explicitly stated substance use outcome expectancies have been particularly successful in predicting substance use behaviour (Treloar et al., 2016). These outcome expectancy tasks often ask participants to generate several explicit outcomes that they expect to occur if they use a particular substance (Fulton et al., 2012; Krank et al., 2010). Participants are then asked to rate how much they would like each outcome. In these outcome expectancy measures, the responses given by participants are reflective in nature; however, research suggests that the response is influenced by impulsive cognitive processes (Ames et al., 2012; Krank et al., 2005; Krank et al., 2010). In addition, dual-process models of cognition suggest that reflective cognitions interact with impulsive cognitions to produce behaviour. As such, reflective cognitions have the potential to impact the effectiveness of both explicit and implicit cognitive training programs.

Craving for substances has been widely identified as an influence that has significant impact on substance use behaviour (Cavicchioli et al., 2020). Cravings have been explored in several large-scale studies and have been incorporated in many models of substance use and addiction over the past several decades (Skinner & Aubin, 2010; Smart et al., 1983). Further, craving for cannabis has been strongly associated with subsequent cannabis use (Gray et al., 2011; Lundahl & Johanson, 2011) and level of craving has predicted severity of withdrawal in individuals with heavy cannabis use (Cousijn & van Duijvenvoorde, 2018). Craving for cannabis also predicts treatment outcome in adolescents who present for treatment of heavy cannabis use (Cousijn et al., 2015). Thus, high levels of unaddressed cannabis cravings may be expected to impact the effectiveness of CBM.

Similarly, motives for using cannabis have been found to interact with treatment outcome and cannabis use behaviours (Fox et al., 2011; Simons et al., 1998). Research suggests that coping motives among individuals using cannabis to manage their negative affect predicted problematic cannabis use as well as cannabis dependence (Fox et al., 2011). Motives for cannabis use have also been shown to predict frequency of cannabis use in a sample of adolescents (Blevins et al., 2016). This study also found that motives were malleable and changed over the course of a brief cognitive intervention, indicating that motives may respond to interventions that target cognitive aspects of addiction.

Several demographic characteristics have also been considered when designing prevention and intervention strategies for cannabis use. Notably, a strong positive association between cannabis use and mental health problems has been documented in the literature (Lev-Ran & Feingold, 2017; Schlossarek et al., 2016; van der Pol et al., 2013). Comorbid mental health disorders have been found to hinder and moderate treatment outcomes in those seeking treatment for cannabis use disorders (Lees et al., 2021; Raphael et al., 2005), suggesting that the presence of mental health problems may moderate or impact the effectiveness of cannabis use interventions. Relatedly, differences exist in the patterns of cannabis use among men and women, where men typically use cannabis more frequently and in larger quantities than women (Cuttler et al., 2016). Research also suggests that cannabis use is highest among individuals between the ages of 20 and 24 (Health Canada, 2020). The impact of these demographic variables on CBM programs for substance use has not been adequately explored but given their potential to modify outcomes, these variables are important to examine.

Finally, previous research has examined motivation as a significant moderator of the effect of CBM for alcohol use (Wiers et al., 2013, 2015). Several studies suggest that when participants have limited or no motivation to change their alcohol use behaviour, alcohol consumption is not reduced after participating in a CBM program (Wiers et al., 2013, 2015). Further, in a sample of cigarette smokers, low motivation to change resulted in no changes in smoking behaviour despite significant changes in attentional bias after CBM training (Kerst & Waters, 2014). These findings suggest that desire to change behaviour is an important factor to consider when designing substance use prevention and intervention programs.

CHAPTER 2 Methods

2.1 Present Research and Objectives

Cognitions about substance use in adolescence have been shown to predict substance use behaviours, even before substance use is initiated (Robinson & Krank, 2018; Stacy & Wiers, 2010). Substance use may also be influenced by a combination of both reflective and impulsive cognitions (Wiers, Stacy, et al., 2002). Although substance use prevention programs have been widely used in schools, adolescent substance use remains high and typically increases into young adulthood (Jajodia & Earleywine, 2003). Prevention and treatment programs often focus exclusively on reflective cognitions that are reportable while impulsive cognitions are often left unexamined. This problem calls for innovative substance use prevention and treatment techniques. To address this, CBM procedures have been proposed as a method of reducing substance use in a variety of populations.

Overall, the trend in the existing literature suggests that CBM, specifically the AAT and EC procedures, have effectively altered cognitions. Further, these methods have also produced changes in behaviour. This evidence of change is promising for those studying, preventing, and treating problematic substance use given that CBM methods may act as an adjunct treatment method that can easily be added to a more formal substance use program. However, most of the studies examining AAT and EC training for substance use have focused on alcohol and nicotine use. Research is needed to determine the effectiveness of these procedures for other substances (e.g., cannabis). Moreover, most studies of CBM have focused on treatment-seeking populations. As most individuals with substance use problems do not seek treatment (Bowers et al., 2017), it is important to consider the potential effectiveness of CBM in a non-treatment-seeking population. Therefore, the primary aim of this study was to examine whether the AAT and EC training procedures produce changes in cognitions about cannabis use as well as changes in cannabis use behaviour after six sessions of training. In addition, we sought to examine AAT and EC training in a general population of undergraduate students who use cannabis and were not seeking treatment for their cannabis use. This study informs intervention efforts to reduce harm to young adults by examining the use of cognitive training to reduce substance use and problems in this population. Further, this novel research informs the CBM literature as to the consequences of training on substance use behaviour and the use of cognitive training methods with young adult cannabis-using populations. We also sought to examine and describe potential moderators of CBM (e.g., craving, motives, gender, age, and mental health diagnosis) in a university population. This study will describe the moderator's relationship with level of use and with problems associated with cannabis use.

2.2 Conditions and Methodology

This study used a 2x2 factorial design (see Figure 1). Participants were randomized into one of four conditions – EC training, AAT training, combination training, or sham training. Each condition received two tasks during all the training sessions. The EC training group received EC training and the sham version of AAT training. The AAT training group received AAT training and the sham version of EC training. Those in the combination training group received both EC and AAT training. Those in the sham training group received sham versions of the EC and AAT training. Longitudinal follow-up data was collected one month after participants completed the sixth session of training.

Figure 1

Experimental Conditions

		Approach-Avoidance Training: No	Approach-Avoidance Training: Yes
Evaluative Conditioning	No	Sham	AAT
	Yes	EC	Combination

2.3 Hypotheses

2.3.1 Primary Hypotheses

First, to determine predictors of cannabis use behaviour and frequency, we examined the predictive ability of several variables including measures of cognition, cravings, and motives for cannabis use. We hypothesized that the cognitive measures in our study would predict levels of cannabis use and problematic cannabis use such that those with increased bias towards cannabis would report higher levels of cannabis use and more problems related to cannabis. We hypothesized that cravings and motives would also predict cannabis use such that those with high scores on measures of cravings and motives would report higher levels of cannabis problems and use.

Second, to determine immediate training effects, we examined whether participants in the active training groups had significantly different scores on the AAT and EC measures, respectively, by comparing their Session 1 scores to their final scores at Session 6 and Session 7 when training was complete. We hypothesized that those in the AAT training group would push cannabis photos away faster relative to those who did not participate in AAT training immediately after training was completed. We hypothesized that those in the active EC training group would make less positive affective ratings of cannabis trials immediately after training was completed relative to those who did not participate in EC training.

Third, we examined whether cannabis use frequency changed after participating in AAT and EC training by examining frequency of use after six sessions of training and at 1-month follow-up. Although research suggests that cognitive and behavioural changes related to substance use in undergraduates have lasted at least one week (Houben, Schoenmakers, et al., 2010) and have persisted to one year in a clinical sample (Eberl et al., 2013), very little research has examined the durability of CBM programs with an undergraduate cannabis-using sample. We hypothesized that cannabis-using participants in the AAT and EC training conditions would decrease their cannabis use at each timepoint. This hypothesis sought to inform the need for booster sessions or changes to the training parameters.

2.3.2 Secondary Hypotheses

To date, no study has examined the comparative effects of cognitive training paradigms. Research has typically examined the effects of cognitive training by comparing an experimental group to a control group (Cousijn et al., 2011; Olson & Fazio, 2006). First, we sought to examine if any training group (i.e., AAT, EC, combination) showed greater reduction in bias towards cannabis stimuli and greater reduction in cannabis use after training was complete and at 1-month follow-up. We expected that all training groups would show reductions in cannabis bias and rate of consumption, but the comparative magnitude of training effects was determined to be the primary outcome variable. We expected that receiving two cognitive training tasks would have a synergistic effect and lead to greater reductions in bias toward cannabis stimuli and greater reductions in cannabis use after training was complete and at 1-month follow-up. This was an exploratory hypothesis as no previous research has examined the comparative magnitude of training paradigms.

Second, contingency awareness was measured with an open-ended question asking participants whether they noticed anything about the presentation of the photographs (e.g., pushing 90% cannabis photos in the AAT condition or repeated pairings of negative stimuli with cannabis photos in the EC condition) or whether they were able to report the purpose of the study. Previous research suggests that participants are generally unaware of the contingencies of the training tasks (Houben, Schoenmakers, et al., 2010; Schoenmakers et al., 2007) and that contingency awareness did not impact the training effects (Baeyens et al., 1988, 1992; Houben, Schoenmakers, et al., 2010). We hypothesized that participants would not be aware of the training parameters in both training conditions and that lack of awareness would not impact training effects.

2.4 Participants

This study drew participants from the undergraduate research pool at the University of British Columbia Okanagan. Students were offered course credit or entries into a draw for several gift cards in exchange for their participation. Students of all ages were invited to participate. Participants were awarded one credit or gift card entry when they completed Session 1, an additional credit or gift card entry for the following five sessions of training, and a final credit or gift card entry for completing the 1-month follow-up assessment. Participants were excluded from participation if they were able to read Chinese characters as these characters were used as stimuli throughout the training. Participants were also excluded if they had visual or upper limb impairments that precluded them from seeing the stimuli or using the computer mouse, if they had not used cannabis in the last 6 months, or if they were undertaking any form of treatment for problematic substance use. Data were collected across seven timepoints. Session 1 served as the baseline and first session of training while training sessions 2 through 6 occurred in successive 3-day intervals until six sessions of training were complete. Session 7 occurred 30 days after Session 6 was complete. Data collection occurred over 7 months during two university semesters.

2.5 Measures

2.5.1 Affect Misattribution Procedure (AMP; Payne et al., 2005)

Indirect measures are based on the premise that if a behaviour or cognition is strongly associated with the presentation of a stimulus (i.e., cannabis photographs), then the underlying affect, attitude, or bias towards that stimulus will be spontaneously triggered and be reflected in the participant's responses (Ames et al., 2007). The AMP measures impulsive cognitions by eliciting affective responses of which the participant cannot accurately determine the source (Payne & Lundberg, 2014). In this study, prime images were presented for 75ms and target images were presented for 150ms. A 175ms lag occurred between the two presentations. An inter-trial interval of 500ms was included to deter participants from randomly responding. The reliability and validity of this procedure is well-established with other stimuli, including alcohol- (Cameron et al., 2012) and cannabis-related images (Robinson & Krank, 2018). The duration of this task is short yet remains a powerful test of impulsive cognitions (Cunningham et al., 2001). Photograph stimuli were drawn from the International Affective Picture System (IAPS; Lang et al., 2008) and from online public domain sources (see Appendix A).

2.5.2 Alcohol Use Disorders Identification Test (AUDIT; Saunders et al., 1993)

The AUDIT is a brief screening questionnaire for alcohol use problems (Saunders et al., 1993). The measure consists of 10 self-report items to assess problematic alcohol use, drinking behaviours, and alcohol-related problems (see Appendix B). The AUDIT has been shown to be internally consistent, reliable, and valid (de Meneses-Gaya et al., 2009). In the current study, the Cronbach's alpha coefficient was .72.

2.5.3 Cannabis Approach-Avoidance Task (AAT; Sherman et al., 2018)

The first condition of CBM training was carried out using the AAT procedure established in previous research (Jacobus et al., 2018; Sherman et al., 2018). In this procedure, participants respond with a computer mouse to the presentation of a neutral or cannabis photo. Photographs used as target stimuli included cannabis-related imagery. Control photos included photos of neutral plants and inanimate objects. Photograph stimuli were drawn from the IAPS (Lang et al., 2008) and from online public domain sources. Photo presentation was randomized and counterbalanced. Methodology of the AAT is described in the AAT training section below. This procedure has been used previously in two proof-of-concept studies (Jacobus et al., 2018; Sherman et al., 2018). Reaction time was the variable of interest in this procedure.

2.5.4 Cannabis Evaluative Conditioning Task

The second condition of CBM training was carried out using a new cannabis EC procedure that was embedded within the AMP. This procedure is novel but draws on the principles of well-established EC training protocols (Măgurean et al., 2016; Olson & Fazio, 2006). Participants were shown a series of cannabis and neutral photographs and then asked to make evaluative judgements of each trial as pleasant or unpleasant. Methodology of the EC is described in the EC training section below. Photograph stimuli consisted of cannabis-related imagery. Control photos included photos of neutral plants and inanimate objects. Photograph stimuli were drawn from the IAPS (Lang et al., 2008) and from online public domain sources.

Photo presentation was randomized. Higher proportions of pleasant ratings on cannabis trials indicate a bias toward cannabis photos.

2.5.5 Cannabis Outcome Expectancy Liking (COEL; Fulton et al., 2012)

Explicit cannabis cognitions were assessed with the COEL which uses an open-ended question asking what participants anticipated happening to them if they used cannabis (Fulton et al., 2012; see Appendix C). Participants were asked to generate four expectancies. After completing this self-generated task, participants coded their responses according to how much they would like the respective outcome. This measure was used to capture the perceived hedonic quality of the outcome. COEL scores range from 1 to 5 with higher scores indicating a greater liking score for that outcome. The mean was calculated for each set of outcomes. This score reflects the average liking score for cannabis outcomes. This procedure has been shown to have strong concurrent and prospective predictive validity and good test-retest reliability (Fulton et al., 2012; Robinson & Krank, 2018).

2.5.6 Cannabis Use

To assess frequency of cannabis use, participants were asked, "*When was the last time you smoked cannabis or used other THC products?*" Responses were given on a 5-point scale: *never, more than a year ago, in the past year, in the past month*, and *in the past week*. If participants indicated that they had used cannabis in the last 30 days, they were queried as to how many days out of the last 30 days they have used and how many times per day they used on average.

2.5.7 Cannabis Use Disorders Identification Test - Revised (CUDIT-R; Adamson et al., 2010)

Problematic cannabis use within the past 6 months was examined using the CUDIT-R (see Appendix D; Adamson et al., 2010). This measure is a derivative of the AUDIT (Saunders et al., 1993) that mirrors the parent measure but refers to cannabis rather than alcohol in the self-report questions. Recently, four additional items have been added to the scale to enhance the validity and reliability of the test. This measure has been found to be a valid and reliable screening measure of cannabis use problems (Adamson et al., 2010). In the current study, the Cronbach's alpha coefficient was .83.

2.5.8 Comprehensive Marijuana Motives Questionnaire (CMMQ; Lee et al., 2009)

The CMMQ consists of 36 items that examine motives for using cannabis (see Appendix E). These motives include enjoyment, conformity, coping, experimentation, boredom, alcohol, celebration, altered perception, social anxiety, relative low risk, sleep/rest, and availability. Participants were instructed to respond using a 5-point Likert scale ranging from *almost never/never* to *almost always/always.* Adequate validity has been found with this measure (Lee et al., 2009). In the current study, the Cronbach's alpha coefficient was .92.

2.5.9 Desire to Discontinue Cannabis Use

Desire to discontinue using cannabis was measured with a single-item change ladder (Amodei & Lamb, 2004). Participants were asked to rate their current motivation to discontinue cannabis use with the question, "*On a scale from 1 to 10, with one representing no desire to quit, give yourself a rating. Choose the number between 1 and 10 that best describes your own desire to stop using cannabis at this time. Remember, the higher the number, the greater your desire.*" This measure has been validated in a sample of smokers considering cessation (Biener & Abrams, 1991). Wording was adapted to be consistent with cannabis use.

2.5.10 Marijuana Craving Questionnaire-Short Form (MCQ-SF; Heishman et al., 2001)

The MCQ-SF is a 12-item questionnaire that assesses cannabis cravings on four dimensions: compulsivity, emotionality, expectancy, and purposefulness (see Appendix F). The compulsivity scale refers to the inability to control use of cannabis. The emotionality scale refers to using cannabis for relief from negative mood states or withdrawal. The expectancy scale refers to the anticipation of positive effects from using cannabis and the purposefulness scale refers to the intention and plan to use cannabis for positive effects. The MCQ-SF also produces a total craving score. The MCQ-SF has demonstrated good validity and reliability estimates (Heishman et al., 2001; Singleton et al., 2002). In the current study, the Cronbach's alpha coefficient was .90.

2.5.11 Mental Health History

Diagnosis of any mental disorders was queried with an open-ended question, "*Have you ever been diagnosed with any mental health disorder/condition? If so, what was the diagnosis?"*

2.5.12 Substance Use

Using both formal and street names, participants were asked how often they used each of the following substances in the past year: alcohol, nicotine, psilocybin mushrooms, lysergic acid diethylamide (LSD), inhalants (glue, whiteout, nail polish remover, gasoline), ecstasy, gamma-hydroxybutyrate (GHB), rohypnol, methamphetamine, cocaine, and opioids. Responses were given on a 5-point scale: *never, more than a year ago, in the past year, in the past month*, and *in the past week*. If participants indicated that they had used any drugs in the last 30 days, they were queried as to how many days out of the last 30 days they have used.

2.6 Procedure

At each training session, participants used a computer or laptop to complete the study. Participants were given time to review the consent form at Session 1. Participants were then directed to begin an online survey using the Qualtrics platform. At Session 1, participants completed demographics and substance use questionnaires. Participants were then randomized into the EC training, AAT training, combined training, or sham training groups. Sham training followed the same procedures as the experimental training. However, AAT sham training included 50% pull trials and 50% push trials instead of the 90% positive and 10% neutral training contingency used in the experimental conditions. EC sham training was modified so that the same 90% and 10% contingency applied; however, cannabis photos were always paired with neutral USs. The AAT and EC training tasks were facilitated by Inquisit© online software. The first and last training session lasted approximately 1 hour while all other training sessions were completed in less than 15 minutes. Consistent with past literature (Eberl et al., 2014; Jacobus et al., 2018; Wiers et al., 2010), participants received six sessions of training.

For 60.4% of participants (*n*=177), the first session took place in-person on the UBCO campus. The subsequent training sessions took place online at the participants convenience (e.g., in their home). For 39.6% of participants (*n*=116), the first session took place online after all research endeavours moved online in response to the COVID-19 social distancing protocols. In both instances, participants were instructed to complete the training in a quiet room with minimal distraction. Participants completed one training session every 3 days. One month later the participants were contacted to complete follow-up measures again in an online survey.

2.6.1 Cannabis Approach-Avoidance Training

Participants in this condition were trained with the AAT procedure. They were instructed to respond with a push or a pull motion depending on the orientation of the photo. Participants were explicitly told to "*push the photo away from your body*" or "*pull the photo toward your body.*" Landscape photos were pushed while portrait photos were pulled. The participants used the computer mouse to simulate a pushing or pulling movement during the trials. Twenty practice trials were given with neutral stimuli which oriented the participant to push or pull the stimuli depending on the portrait or landscape orientation of the photo. This served to train the participants to push the landscape orientation stimuli and pull the portrait orientation stimuli. Following the practice trials, a baseline assessment occurred with 40 trials that included 20 cannabis and 20 neutral stimuli that were pushed and pulled with equal frequency. All participants received this baseline assessment. Participants were instructed to respond as quickly and as accurately as possible.

Following this, participants in the active training group unknowingly began a training phase in which 90% of 20 new cannabis photos were presented in the push-format while only 10% of those photos were presented in the pull-format. This format has been shown to be undetectable by participants (Jacobus et al., 2018). Participants in the control group received an equal number of push and pull photos. The total number of push and pull trials remained at 50% for each training group. Consistent with previous literature, the training phase consisted of 192 trials (Dickson et al., 2016; Wiers et al., 2015). Then, again without awareness, the AAT moved into an assessment phase where the presentation of stimuli mirrored the baseline phase, with 40 images presented, 20 being cannabis photos, and 20 neutral images. This assessment phase determined if any avoidance-biases generalized to stimuli outside of the training phase. Approach bias scores were calculated by subtracting the median time it took to pull cannabis-related images from the median time it took to push away these images. Reaction time is defined as the total time to make the push or pull motion until the photo disappears. Median reaction times have been used previously to compute approach bias scores to avoid outlier influence.

2.6.2 Cannabis Evaluative Conditioning Training

Participants in this condition completed CBM training using a new cannabis EC procedure that was embedded within the AMP. This procedure uses forward conditioning where the CS is presented before the US on each trial. In this procedure, the participant viewed a series of photograph stimuli on a computer screen. The participant first saw a photograph of cannabis-related stimuli (experimental trials) or neutral-matched plant and inanimate object stimuli (control trials) for 75ms. Immediately after this, a valenced stimulus drawn from the IAPS picture repository (Lang et al., 2008) appeared for 75ms. Photos considered positively valenced are those that have an average valence rating of 5.5 or more while those with negative valence are those that have an average valence of 4.5 or less; photos between 4.5 and 5.5 are considered neutral (Choi & Lee, 2015). Following this, the participant was presented with a Chinese pictograph for 150ms, and the trial concluded with a black and white visual mask that stayed on the screen until the participant responded. The participant was asked to respond to each trial by indicating whether they found the Chinese pictograph to be more or less pleasant than the average pictograph. Stimuli presentation was randomized and counterbalanced to reduce artifactual bias.

Participants were presented with 40 practice trials including 20 cannabis images and 20 neutral images. Previous research suggests that the conditioning effect increases with number of critical pairings and as such, we choose to include 20 cannabis images that would form the pairings. After the practice trials, the EC training trials began. In the training condition, 90% of the cannabis trials were presented with negatively valenced photos paired with the target photo while 10% were presented with neutrally valenced photos paired with the target photo. Participants received 192 training trials. EC scores were calculated by subtracting the proportion of pleasant responses on control trials from the proportion of pleasant responses on cannabis trials.

2.6.3 Combination Training

Participants in this condition completed both the AAT and the EC training. Participants were presented with both training conditions in succession, counterbalanced for each participant.

2.6.4 Sham Training

Participants in this condition served as the control group. Previous literature suggests that no difference between sham training or no training was found (Wiers et al., 2010) and as such, the sham training condition was chosen to increase comparability across conditions.

2.7 Analytical Procedure

Data analysis occurred in six stages. First, the data was cleaned and examined for errors and impossible values. Analyses for outliers and missing data were conducted. Second, descriptive statistics including means and standard deviations were computed for all study variables to characterize the study data. Attrition was also examined at this step. Third, Pearson correlations were computed between study variables to assess for significant associations present in the data.

Fourth, negative binomial regressions (SPSS generalized linear models) were used to assess the predictors of cannabis use frequency and problematic cannabis use at each timepoint. This analysis is used when the outcome variables are count in nature (e.g., number of days of cannabis use in the previous month), when overdispersion is present, and when the data best fit a negative binomial distribution (see goodness-of-fit data from each analysis below). Cannabis use frequency and problematic cannabis use scores at each timepoint were input as the categorical dependent variable and cognitive variables, demographic characteristics, cravings for cannabis, and motives for cannabis use were input as predictors in the various models. All models were conducted in a progressive manner with cognitive variables included first, demographic variables included second, and craving and motive variables included third. Several models were tested and are presented in the results section below.

Fifth, to examine change in cannabis use frequency and change in cognitions about cannabis use, a Wilcoxon Signed Rank test and a repeated measures analysis of variance (ANOVA) were conducted, respectively. Regarding the Wilcoxon Signed Rank test, cannabis use frequency at each timepoint was input into the analyses and tested for significant differences. To examine change in cognitions about cannabis use over time, group and time were input as the independent variables and cannabis cognition scores (i.e., AAT and EC score) were input as the dependent variables in independent analyses. To determine if cravings, motives, presence of mental health diagnosis, or motivation to quit moderated the training effects of AAT and EC, we conducted repeated measures ANOVAs with group and time input as the independent variables, cannabis cognition scores input as the dependent variables, and cravings, motives, diagnosis, and motivation to quit were input as covariates in independent analyses. Sixth, to examine the impact of contingency awareness (e.g., knowing the purpose of the study) on cognitive outcomes, independent-samples *t*-tests were conducted with the dichotomous contingency awareness variable as the grouping variable and cognitive score at Session 6 and Session 7 (i.e., EC or AAT score) as the test variables.

CHAPTER 3 Results

3.1 Data Cleaning

3.1.1 Missing Data

Little's Missing Completely at Random (MCAR) test was conducted to determine if there was a pattern to the missing data (Little, 1988). Results for all variables in the analyses were non-significant, χ^2 (454) = 500.96, p = .063, indicating that there was no pattern to the missing data in the current study.

3.1.2 Outliers

Univariate outliers were examined by computing standardized residuals (z-scores) on all study variables at each timepoint. Standardized residuals were inspected to determine if any cases fell outside of the absolute value of 3.29. Two univariate outliers were found that fell outside the absolute value. Main analyses were conducted with and without the outliers in the dataset and no differences were found. As such, the outliers were removed for the remainder of analyses.

3.2 Sample Characteristics

At baseline, 293 students participated in Session 1. All participants completed the baseline demographics, substance use, and cognitive measures. Table 1 contains information about the full sample.

Table 1

Sample Characteristics for Full Sample

	N = 293
Age, M(*SD*)	20.72 (3.23)
Range	18 to 42 years

Gender, *n* (%)	
Female	220 (75.1%)
Male	66 (22.5%)
Other	4 (1.4%)
Missing	3 (1.0%)
Ethnicity, *n* (%)	
Caucasian	176 (60.1%)
Asian	65 (22.2%)
Mixed	23 (7.8%)
African	9 (3.1%)
First Nations	8 (2.7%)
European	4 (1.4%)
Latin America	3 (1.0%)
Missing	5 (1.7%)
Undergraduate program year, *n* (%)	
1st	82 (28.0%)
2nd	63 (21.5%)
3rd	81 (27.6%)
4th	53 (18.1%)
5th	9 (3.1%)
Missing	5 (1.7%)
Mental Health Diagnosis, *n* (%)	81 (27.6%)
Anxiety	18 (22.2%)

Depression	9 (11.1%)
Attention deficit/hyperactivity disorder	4 (4.9%)
Post-traumatic stress disorder	2 (2.5%)
Obsessive-compulsive disorder	2 (2.5%)
Eating disorder	2 (2.5%)
Dual diagnosis	44 (54.3%)

Note. *M* = mean. *SD* = standard deviation.

3.2.1 Attrition

Attrition was observed in this study across time. To calculate attrition rate, we first examined the number of participants who completed Session 1 and all other timepoints throughout the study. Of the 293 participants at Session 1, 257 (87.7%) completed Session 2, 243 (82.9%) completed Session 3, 227 (77.5%) completed Session 4, 215 (73.4%) completed Session 5, 210 (71.7%) completed Session 6, and 96 (32.8%) completed Session 7.

Differential attrition was assessed by examining differences between those who completed the entire study (i.e., six training sessions and 1-month follow-up) and those who completed six or fewer sessions. No differences were observed between those who completed all study sessions when compared to those who completed six or fewer sessions on variables including: experimental group allocation, age, gender, ethnicity, desire to quit using cannabis, substance use frequency, problematic cannabis or alcohol use, cannabis cravings, presence of mental health diagnosis, or year of undergraduate program (all *p*'s >.05).

Attrition was further explored by assessing differences between those who completed only the six training sessions of the study and those who completed the six training sessions and

1-month follow-up assessment. A significant association between undergraduate year of study and completion of the entire study was found such that those who completed the entire study were more junior in their degree than those who did not, χ^2 (4, n=217) = 11.0, p = .02, Cramer's V = .23. Apart from undergraduate year, no differences were observed between those who completed six sessions when compared to those who completed the 1-month follow up on variables including: experimental group allocation, age, gender, ethnicity, desire to reduce cannabis use, substance use frequency, problematic cannabis or alcohol use, cannabis cravings, or presence of mental health diagnosis (all p's > .05).

To determine if any variables predicted the retention of participants throughout the entire study, a logistic regression was conducted with a dichotomous-completion variable (i.e., complete or incomplete) as the dependent variable and group, gender, age, year of undergraduate degree, number of days of cannabis use, problematic cannabis and alcohol use, mental health diagnosis, and motivation to quit using cannabis as independent predictors. The model containing all predictors was not significant, χ^2 (14, n=270) = 21.36, indicating that no variables significantly predicted retention of participants throughout the entire study including the 1-month follow-up.

3.2.2 In-Person and Online Participant Differences

Given that approximately 60% of participants received in-person instruction during the first session while approximately 40% of participants received online instruction, differences between these two groups were explored. No differences were observed between those who completed the first session in-person when compared to those who completed the first session online on variables including: experimental group allocation, gender, ethnicity, presence of mental health diagnosis, desire to reduce cannabis use, problematic alcohol use, motives and cravings for cannabis use, and substance use frequency (excluding alcohol use; all *p's* > .05). However, differences were found between those receiving in-person and online first sessions on several variables. More participants completed the entire study from the in-person first-session group than those in the online first-session group, χ^2 (1, N=293) = 9.24, p = .002. Differences were also observed regarding year of undergraduate education such that more participants in their 1st and 2nd years of study completed the first session in-person than online, while more participants in their 3rd, 4th, and 5th years of study completed the first session online, χ^2 (4, n = 288) = 62.61, p < .001, Cramer's V = .247. Additionally, those who completed the first session in-person were found to be significantly younger than those who completed the first session online. Those completing the first session in-person were found to report significantly more cannabis-related problems than those who completed the first session online. Finally, the in-person group was also found to have used significantly less alcohol over the past 30 days than those in the online group. Table 2 describes demographic differences between groups.

Table 2

In-Person and Online Participant Differences

	In-Person Participants		Online Participants				
	M	*SD*	*M*	*SD*	*t*	*df*	*Sig.*
Age	19.97	2.51	21.87	3.81	- 4.72	178.59	.001
CUDIT-R Score	7.91	5.87	5.41	5.18	3.69	285	.001
Alcohol Use	5.69	4.44	7.99	7.22	- 2.71	122.08	.008

Note. *M* = mean. *SD* = standard deviation. *t* = t-statistic. *df* = degrees of freedom.

3.2.3 Cannabis Use

At Session 1, almost half (46.8%) of all participants reported having used cannabis within the last week. Under half (44.7%) of participants used cannabis on average once per month or less while just under one-fifth (18.4%) of the sample reported using cannabis on average 4 or more times per week. Additional results describing cannabis use in the sample are reported in Table 3.

Table 3

Cannabis Use Behaviour Descriptive Statistics

Last Cannabis Use, n (%)	
In the past 6 months	82 (28.0%)
In the past month	74 (25.3%)
In the past week	137 (46.8%)
Cannabis use frequency, n (%)	
Monthly or less	131 (44.7%)
2-4 times/month	66 (22.5%)
2-3 times/week	36 (12.3%)
4 or more times/week	54 (18.4%)
Never	5 (1.7%)
Missing	1 (0.3%)
Number of days using cannabis in the last 30, *M(SD)*	8.38 (9.65)
Number of times using cannabis per day, *M(SD)*	1.80 (1.57)

Note. *M* = mean. *SD* = standard deviation.

3.2.4 Problematic Cannabis Use

Problematic cannabis use was measured using the CUDIT-R (Adamson et al., 2010) at Session 1. As shown in Table 4, the sample had a total average CUDIT-R score of 6.9. Of the sample, approximately one quarter (27.6%) of participants endorsed responses that may indicate hazardous cannabis use when using a cut score of ≥ 9, while approximately one-sixth (15.7%) of participants endorsed responses that may indicate problematic cannabis use that requires clinical intervention when using a cut score of ≥ 13. These cut scores have been suggested as useful scores to detect hazardous and problematic cannabis use (Bonn-Miller et al., 2016).

Table 4

CUDIT-R Scores among the Full Sample

CUDIT-R Score, *M*(*SD*)	6.9 (5.7)
Participants exceeding CUDIT-R score ≥ 9, n (%)	81 (27.6%)
Participants exceeding CUDIT-R scores ≥ 13, n (%)	46 (15.7%)

Note. *M* = mean. *SD* = standard deviation.

3.2.5 Other Substance Use

Other substance use was measured at Session 1 and is reported in Table 5. Many participants consumed alcohol during the past month (84.6%) and almost half of all participants (48.1%) used nicotine (e.g., cigarettes, vaping, chewing tobacco) in the past month. Use of illicit drugs in the past month was low (< 5%).

Table 5

Count and Percentage of those Using Each Substance

	Never	More than a year ago	Past year	Past month	Past week	Missing
Alcohol	5 (1.7%)	7 (2.4%)	31 (10.6%)	81 (27.6%)	167 (57%)	2 (0.7%)
Mushroom	211 (72%)	25 (8.5%)	40 (13.7%)	11 (3.8%)	4 (1.4%)	2 (0.7%)
LSD	259 (88.4%)	14 (4.8%)	15 (5.1%)	0 (0%)	3 (1.0%)	2 (0.7%)
Inhalants	281 (95.9%)	5 (1.7%)	3 (1.0%)	2 (0.7%)	0 (0%)	2 (0.7%)
Ecstasy	212 (72.4%)	36 (12.3%)	29 (9.9%)	13 (4.4%)	1 (0.3%)	2 (0.7%)
GHB	279 (95.2%)	7 (2.4%)	4 (1.4%)	1 (0.3%)	0 (0%)	2 (0.7%)
Rohypnol	288 (98.3%)	2 (0.7%)	1 (0.3%)	0 (0%)	0 (0%)	2 (0.7%)
Methamph-etamine	285 (97.3%)	4 (1.4%)	2 (0.7%)	0 (0%)	0 (0%)	2 (0.7%)
Cocaine	246 (84%)	16 (5.5%)	20 (6.8%)	7 (2.4%)	2 (0.7%)	2 (0.7%)
Opiates	273 (93.2%)	11 (3.8%)	3 (1.0%)	3 (1.0%)	1 (0.3%)	2 (0.7%)
Nicotine	67 (22.9%)	25 (8.5%)	58 (19.8%)	41 (14.0%)	100 (34.1%)	2 (0.7%)

3.2.6 Problematic Alcohol Use

Problematic alcohol use was measured using the AUDIT (Saunders et al., 1993) at Session 1. The sample had an average AUDIT score of 8.1 (*SD* = 4.3). Of the sample, over half of all participants (54.8%) endorsed responses that may indicate hazardous alcohol use when using a cut score of ≥ 8, while under one-tenth of all participants (7.8%) endorsed responses that may indicate moderate to severe alcohol use when using a cut score of ≥ 15. These cut scores have been suggested as useful scores to detect hazardous and problematic alcohol use (Conigrave et al., 1995; Saunders et al., 1993).

3.2.7 Cravings

Participant cravings for cannabis were assessed along four dimensions using the MCQ-SF (Heishman et al., 2001). Full and subscale scores were calculated by summing responses to the items that load on each scale. Participants reported cravings related to expectancy (*M*=10.1, *SD*=4.9), purposefulness (*M*=9.3, *SD*=5.6), emotionality (*M*=7.9, *SD*=4.6), and compulsivity (*M*=4.8, *SD*=3.0). Total cravings scores were also computed across the sample (*M*=32.20, *SD*=15.21).

3.2.8 Motives to Use

Participants rated the frequency of their motives for using cannabis using the CMMQ (Lee et al., 2009). Full and subscale scores were calculated by summing responses to the items that load on each scale. Results from the measure of motives for cannabis use are reported in Table 6. Participants reported enjoyment, sleep, and availability as the top three most prominent motives for cannabis use.

Table 6

Mean and Standard Deviation of Cannabis Use Motives

	M	*SD*
Enjoyment	9.9	3.6
Conformity	4.4	2.2
Coping	5.5	3.2
Experimentation	6.0	3.2
Boredom	6.8	3.4
Alcohol	5.5	3.0
Celebration	6.9	3.2

Altered Perceptions	6.9	3.6
Social Anxiety	5.3	2.9
Relative Low Risk	6.5	3.3
Sleep	7.2	4.0
Availability	7.1	3.1
Total Motives Score	78.08	22.77

Note. *M* = mean. *SD* = standard deviation.

3.2.9 Desire to Discontinue Cannabis Use

Participants rated their motivation to stop using cannabis on a 1 to 10 scale with 1 being no desire to stop using. In the full sample, average motivation to change was rated as 3.7 (*SD* = 2.83). Over 70% of the participants reported some desire to stop using cannabis (i.e., ratings above 1). About one quarter of the sample endorsed a desire to stop using cannabis as indicated by responses above the midpoint of the scale. Frequencies for each rating are reported in Table 7.

Table 7

Frequency of Desire to Discontinue Cannabis Use

Rating	Frequency (*n*, %)
1 – No Desire	85 (29.2)
2	48 (16.5)
3	44 (15.1)
4	22 (7.6)
5	22 (7.6)
6	11 (3.8)
7	15 (5.2)

8	15 (5.2)
9	13 (4.5)
10 – Complete Desire	16 (5.5)

3.3 Pearson Correlations

3.3.1 Cognitive and Cannabis Use Variable Correlations

Correlation analyses between cognitive measures and cannabis use variables are reported in Table 8. As shown, the problematic cannabis use measure (CUDIT-R) was highly correlated with cannabis use at each timepoint. The explicit cannabis cognition measure (COEL) at Session 1 and Session 6 was weakly and moderately correlated with Session 1 and Session 6 cannabis use, respectively. COEL at Session 7 did not correlate with cannabis use at Session 7. The EC score at Session 1 weakly correlated with cannabis use at Session 1 and the EC score at Session 7 weakly correlated with cannabis use at Session 7. Surprisingly, the AAT score at each session did not correlate with cannabis use at any timepoint.

Table 8

Pearson Correlation Analyses – Cognitive and Cannabis Use Variables

	Mean (*SD*)	CUDIT-R Score	Cannabis Use S1	Cannabis Use S6	Cannabis Use S7	COEL S1	COEL S6	COEL S7	EC Score S1	EC Score S6	EC Score S7	AAT Score S1	AAT Score S6
CUDIT-R Score	6.9 (5.7)	1.00											
Cannabis Use S1	8.4 (9.6)	**.68****	1.00										
Cannabis Use S6	7.8 (9.2)	**.61****	**.86****	1.00									
Cannabis Use S7	9.7 (9.7)	**.58****	**.75****	**.75****	1.00								
COEL S1	3.6 (.9)	.07	**.23****	**.23****	-.05	1.00							
COEL S6	3.6 (.8)	**.22****	**.27****	**.38****	.20	**.61****	1.00						
COEL S7	3.8 (.8)	-.04	.14	.15	.10	**.57****	**.72****	1.00					
EC Score S1	.55 (.18)	.07	**.16****	.13	.02	.11	.09	-.01	1.00				
EC Score S6	.53 (.24)	.11	.11	.09	.11	.02	.04	.02	**.40****	1.00			
EC Score S7	.50 (.23)	.05	.13	.16	**.23***	-.02	.05	.08	**.38****	**.73****	1.00		
AAT Score S1	-49.52 (239.21)	.08	.05	.09	-.01	-.03	.01	.03	.07	.02	-.10	1.00	
AAT Score S6	-147.89 (297.11)	.05	.05	.03	-.06	-.13	-.11	-.14	.04	.13	.16	**.27****	1.00
AAT Score S7	-126.68 (242.10)	-.15	-.14	-.07	-.20	-.06	-.05	-.04	-.10	.13	.12	.09	**.67****

Note: * $p < .05$; ** $p < .01$; S = session

3.3.2 Motives for Cannabis Use Correlations

Correlation analyses between the CMMQ subscales and cannabis use variables are reported in Table 9. Problematic cannabis use, as measured by the CUDIT-R, was moderately correlated with the full motive for cannabis use scale. Problematic cannabis use was weakly correlated with celebration, altered perception, low risk, and ease of availability motives. Problematic cannabis use was moderately correlated with enjoyment, boredom, social anxiety, and sleep motives while it was highly correlated with coping motives. Cannabis use at Session 1 and Session 6 were moderately correlated with the full motive for cannabis use scale, but this correlation was not significant at Session 7.

Table 9

Pearson Correlation Analyses – Motives for Cannabis Use (CMMQ - Full Scale and Subscales) and Cannabis Use Variables

	Mean (*SD*)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1. CUDIT-R Score	6.9 (5.7)	1.00															
2. Cannabis Use S1	8.4 (9.6)	**.68****	1.00														
3. Cannabis Use S6	7.8 (9.2)	**.61****	**.86****	1.00													
4. Cannabis Use S7	9.7 (9.7)	**.58****	**.75****	**.75****	1.00												
5. CMMQ Full Scale***	78.1 (22.8)	**.44****	**.34****	**.38****	.18	1.00											
6. CMMQ Enjoyment	9.9 (3.6)	**.41****	**.37****	**.40****	**.27***	**.69****	1.00										
7. CMMQ Conformity	4.4 (2.2)	-.09	**-.21****	**-.18****	**-.25***	**.32****	-.05	1.00									
8. CMMQ Coping	5.5 (3.2)	**.57****	**.42****	**.36****	**.23***	**.60****	**.34****	**.12***	1.00								
9. CMMQ Experimentation	6.0 (3.2)	-.07	**-.18****	-.13	**-.30****	**.44****	**.12***	**.45****	.04	1.00							

10. CMMQ Boredom	6.8 (3.4)	**.46****	**.41****	**.35****	**.35****	**.71****	**.52****	.10	**.52****	**.13***	1.00						
11. CMMQ Alcohol	5.5 (3.0)	-.08	**-.18****	-.06	-.13	**.31****	.04	**.33****	-.02	**.23****	.11	1.00					
12. CMMQ Celebration	6.9 (3.2)	**.14***	.06	.12	-.17	**.60****	**.45****	**.19****	.11	**.37****	**.28****	**.14***	1.00				
13. CMMQ Altered Perception	6.9 (3.6)	**.29****	**.23****	**.29****	**.29****	**.65****	**.56****	.03	**.36****	**.25****	**.39****	-.03	**.39****	1.00			
14. CMMQ Social Anxiety	5.3 (2.9)	**.36****	**.29****	**.37****	.14	**.71****	**.36****	**.16****	**.58****	**.17****	**.41****	**.22****	**.28****	**.40****	1.00		
15. CMMQ Relative Low Risk	6.5 (3.3)	**.27****	**.29****	**.28****	.11	**.71****	**.52****	.09	**.34****	**.26****	**.40****	.09	**.41****	**.44****	**.50****	1.00	
16. CMMQ Sleep	7.2 (4.0)	**.41****	**.48****	**.43****	**.32****	**.57****	**.32****	-.06	**.52****	-.03	**.41****	-.07	**.16****	**.37****	**.53****	**.38****	1.00
17. CMMQ Availability	7.1 (3.1)	**.22****	**.13***	**.15***	.12	**.64****	**.40****	**.28****	**.22****	**.26****	**.56****	**.34****	**.38****	**.21****	**.32****	**.39****	**.19****

Note: * $p < .05$; ** $p < .01$; *** CMMQ measured at Session 1; S = session

3.3.3 Cravings for Cannabis Correlations

Correlation analyses between the MCQ-SF subscales and cannabis use variables are reported in Table 10. Problematic cannabis was moderately correlated with the full craving for cannabis use scale. Problematic cannabis use was also moderately correlated with compulsivity, emotionality, expectancy, and purposefulness craving scales. Cannabis use at Session 1 and Session 6 was highly correlated with the full craving for cannabis use scale. This correlation remained significant but moderate for cannabis use at Session 7. Cannabis use at each timepoint was correlated with all scales of the craving measure.

Table 10

Pearson Correlation Analyses – Cravings for Cannabis (MCQ-SF - Full Scale and Subscales) and Cannabis Use Variables

	Mean (*SD*)	CUDIT-R Score	Cannabis Use S1	Cannabis Use S6	Cannabis Use S7	MCQ-SF Full Scale	MCQ-SF Compulsivity	MCQ-SF Emotionality	MCQ-SF Expectancy
CUDIT-R Score	6.9 (5.7)	1.00							
Cannabis Use S1	8.4 (9.6)	**.68****	1.00						
Cannabis Use S6	7.8 (9.2)	**.61****	**.86****	1.00					
Cannabis Use S7	9.7 (9.7)	**.58****	**.75****	**.75****	1.00				
MCQ-SF Full Scale***	32.2 (15.2)	**.47****	**.51****	**.54****	**.35****	1.00			
MCQ-SF Compulsivity	4.8 (3.0)	**.36****	**.25****	**.32****	**.32****	**.58****	1.00		
MCQ-SF Emotionality	7.9 (4.6)	**.35****	**.38****	**.41****	**.26***	**.89****	**.40****	1.00	
MCQ-SF Expectancy	10.1 (4.9)	**.39****	**.45****	**.49****	**.26***	**.90****	**.34****	**.84****	1.00
MCQ-SF Purposefulness	9.3 (5.6)	**.45****	**.55****	**.53****	**.36****	**.88****	**.41****	**.68****	**.71****

Note: * $p < .05$; ** $p < .01$; *** MCQ-SF measured at baseline; S = session

3.3.4 Desire to Discontinue Cannabis Use Correlations

Correlation analyses between the desire to discontinue cannabis use and other cannabis use variables are reported in Table 11. Problematic cannabis was weakly correlated with desire to discontinue cannabis use. Cannabis use at Session 1 and 6 was weakly negatively correlated with desire to discontinue cannabis use. Cannabis use at Session 7 was not correlated with desire to discontinue cannabis use.

Table 11

Pearson Correlation Analyses – Desire to Discontinue Cannabis Use and Cannabis Use Variables

	Mean (*SD*)	CUDIT-R Score	Cannabis Use S1	Cannabis Use S6	Cannabis Use S7
CUDIT-R Score	6.9 (5.7)	1.00			
Cannabis Use S1	8.4 (9.6)	**.68****	1.00		
Cannabis Use S6	7.8 (9.2)	**.61****	**.86****	1.00	
Cannabis Use S7	9.7 (9.7)	**.58****	**.75****	**.75****	1.00
Desire to Discontinue***	3.7 (2.83)	**.14***	**-.16****	**-.19****	-.01

Note: * $p < .05$; ** $p < .01$; *** Desire to discontinue cannabis use measured at baseline; S = session

3.4 Frequency of Cannabis Use Prediction

3.4.1 Negative Binomial Regression

The assumptions of negative binomial regression were tested for before conducting the procedure (Hilbe, 2014). The distribution of the count outcome data fit the negative binomial distribution. The conditional mean was much smaller than the conditional variance, indicating that overdispersion was present in the data and that a negative binomial model would be appropriate given its additional ancillary parameter to model the overdispersion. At each timepoint, three negative binomial regressions were conducted with cannabis use frequency (e.g., frequency at Session 1, Session 6, and Session 7) as the dependent variable. Cognitive variables (e.g., AAT score, EC score, COEL score), demographic variables (e.g., gender, age, and presence of mental health disorder), and craving and motives variables (e.g., craving and motive scores) were input as independent variables in each of the three regression models. Analyses were run with and without age and gender covaried in all models. The addition of age and gender did not change the outcome of any analyses of cognitive variables and as such, the models without age and gender are reported.

3.4.2 Session 1 Frequency of Cannabis Use Prediction

Variables specific to the Session 1 regression analyses are reported in Table 12. A Pearson Chi-Square goodness-of-fit test suggested that the data fit the negative binomial model, $\chi^2(267) = 335.54$, value/df = 1.26. The model containing the cognitive variables at Session 1 was significant, $\chi^2(3) = 22.04$, $p < .001$. In this model, the COEL score predicted frequency of cannabis use at Session 1, suggesting that individuals with more positive explicit cannabis expectancies had a 33% higher rate of cannabis use for each point higher on the scale. Scores on the AAT and EC measures did not predict frequency of cannabis use at Session 1.

The model containing the demographic variables at Session 1 was significant, $\chi^2(3) = 21.36$, $p < .001$. A Pearson Chi-Square goodness-of-fit test suggested that the data fit the negative binomial model, $\chi^2(282) = 327.07$, value/df = 1.16. In this model, gender predicted the frequency of cannabis use at Session 1, suggesting that males had a 40% higher rate of cannabis use. Similarly, presence of mental health disorder diagnosis also predicted frequency of cannabis use at Session 1, indicating that those who reported a mental health diagnosis had a 78% higher rate of cannabis use. Age did not contribute significantly to the model.

The model containing the cravings and motives scale variables at Session 1 was significant, $\chi^2(2) = 88.31$, $p < .001$. A Pearson Chi-Square goodness-of-fit test suggested that the data fit the negative binomial model, $\chi^2(288) = 360.97$, value/df = 1.25. In this model, motives for using cannabis (as measured by the full scale CMMQ score) significantly predicted frequency of cannabis use at Session 1, suggesting that those reporting more motives for cannabis use had a 1% higher rate of cannabis use for each point higher on the scale. Similarly, craving for cannabis (as measured by the full scale MCQ-SF score) significantly predicted cannabis use at Session 1, indicating that those reporting greater craving for cannabis use had a 3% higher rate of cannabis use for each point higher on the scale.

Table 12

Frequency of Cannabis Use Prediction at Session 1

	B(SE)	95% CI		Wald	Exp(B)	*p*
		Lower	Upper			
			Cognitive Variables [a]			
AAT Score	.01 (.001)	.00	.001	.47	1.00	.49
EC Score	.68 (.07)	-.007	1.36	3.77	1.97	.052
COEL Score	.28 (.07)	.14	.43	15.25	1.33	.001
			Demographic Variables [b]			
Gender	.34 (.15)	.05	.63	5.19	1.40	.02
Age	-.02 (.02)	-.06	.02	.98	.98	.32
Mental Health Diagnosis	.58 (.14)	.30	.85	16.37	1.78	.001
			Scale Variables [c]			
CMMQ Score	.01 (.004)	.003	.02	7.31	1.01	.007
MCQ-SF Score	.03 (.005)	.02	.04	37.61	1.03	.001

Note. CI = confidence interval; SE = standard error. [a] Model $\chi^2(3) = 22.04$, $p < .01$. [b] Model $\chi^2(3) = 21.36$, $p < .001$. [c] Model $\chi^2(2) = 88.31$, $p < .001$.

3.4.2.1 Motives and Cravings. To further examine which motive and craving factors were important in predicting the rate of cannabis use at Session 1, a negative binomial regression was conducted with the subscales from the CMMQ and MCQ-SF independently. Significant variables specific to these regression analyses are reported in Table 13. The full table including all variables is reported in Appendix G.

In the regression examining motives, a Pearson Chi-Square goodness-of-fit test suggested that the data fit the negative binomial model, χ^2 (278) = 278.63, value/df = 1.00. The model containing the CMMQ subscales was significant, $\chi^2(12) = 155.46$, $p < .001$. In this model, enjoyment, conformity, boredom, alcohol use, and sleep motives predicted frequency of cannabis use at Session 1. Individuals with higher scores on the enjoyment, sleep, and boredom subscales had a 7%, 8%, and 9% higher rate of cannabis use for each point higher on the scale, respectively. In contrast, individuals with higher scores on the conformity and alcohol use subscales had an 8% and 7% lower rate of cannabis use for each point higher on the scale, respectively. No other subscales of the CMMQ were significant in the model (all *p*'s > .05).

In the regression examining cravings, a Pearson Chi-Square goodness-of-fit test suggested that the data fit the negative binomial model, χ^2 (286) = 344.65, value/df = 1.21. The model containing the MCQ-SF subscales was significant, $\chi^2(4) = 109.00$, $p < .001$. In this model, emotionality, expectancy, and purposefulness craving subscales predicted frequency of cannabis use at Session 1. Individuals with higher scores on the expectancy and purposefulness subscales had a 10% higher rate of cannabis use for each point higher on the scale, while individuals with higher scores on the emotionality subscale had a 7% lower rate of cannabis use for each point higher on the scale. The compulsivity subscale of the MCQ-SF was not significant in the model (all *p*'s > .05).

Table 13

*Motive and Craving Subscales Predicting Frequency of Cannabis Use at Session 1**

	B(SE)	95% CI		Wald	Exp(B)	*p*
		Lower	Upper			
		Motive Subscales [a]				
Enjoyment	.07 (.03)	.02	.12	6.94	1.07	.01
Conformity	-.09 (.04)	-.17	-.02	5.55	.91	.02
Boredom	.08 (.03)	.03	.14	8.64	1.09	.001
Alcohol Use	-.07 (.03)	-.13	-.02	7.50	.93	.01
Sleep	.07 (.02)	.03	.12	11.21	1.08	.001
		Craving Subscales [b]				
Emotionality	-.08 (.03)	-.13	-.03	8.41	.93	.001
Expectancy	.09 (.03)	.04	.14	13.84	1.10	.001
Purposefulness	.10 (.02)	.06	.13	31.97	1.10	.001

Note. * table showing only significant results. CI = confidence interval; SE = standard error. [a] Model $\chi^2(12) = 155.46$, $p < .001$. [b] Model $\chi^2(4) = 109.00$, $p < .001$.

3.4.3 Session 6 Frequency of Cannabis Use Prediction

Variables specific to the Session 6 regression analyses are reported in Table 14. A Pearson Chi-Square goodness-of-fit test suggested that the data fit the negative binomial model, $\chi^2(192) = 218.09$, value/df = 1.14. The model containing the cognitive variables at Session 6 was significant, $\chi^2(3) = 45.51$, $p < .001$. In this model, the COEL score predicted frequency of cannabis use at Session 6, indicating that individuals with more positive explicit cannabis expectancies had a 54% higher rate of cannabis use for each point higher on the scale. EC scores also significantly predicted cannabis use at Session 6, suggesting that individuals with higher EC scores had a 3% higher rate of cannabis use for each point higher on the scale. Scores on the AAT did not predict frequency of cannabis use at Session 6.

The model containing the demographic variables at Session 6 was significant, $\chi^2(3) = 9.71$, $p = .02$. A Pearson Chi-Square goodness-of-fit test suggested that the data fit the negative binomial model, $\chi^2(201) = 249.15$, value/df = 1.24. In this model, gender predicted frequency of cannabis use at Session 6, indicating that males had a 44% higher rate of cannabis use. Similarly, presence of mental health disorder diagnosis also predicted frequency of cannabis use at Session 6, suggesting that those who reported a mental health diagnosis had a 54% higher rate of cannabis use. Age did not contribute significantly to the model.

The model containing the cravings and motives scale variables at Session 7 was significant, $\chi^2(2) = 72.85$, $p < .001$. A Pearson Chi-Square goodness-of-fit test suggested that the data fit the negative binomial model, $\chi^2(205) = 219.22$, value/df = 1.07. In this model, motives for using cannabis (as measured by the full scale CMMQ score) significantly predicted frequency of cannabis use at Session 6, indicating that those reporting more motives for cannabis use had a 1% higher rate of cannabis use for each point higher on the scale. Similarly, craving for cannabis (as measured by the full scale MCQ-SF score) significantly predicted cannabis use at Session 6, suggesting that those reporting greater craving for cannabis use had a 3% higher rate of cannabis use for each point higher on the scale.

Table 14

Frequency of Cannabis Use Prediction at Session 6

	B(SE)	95% CI		Wald	Exp(B)	*p*
		Lower	Upper			
			Cognitive Variables [a]			
AAT Score	.001 (.001)	.001	.73	.73	1.00	.39
EC Score	.70 (.34)	.03	1.38	4.19	1.03	.04
COEL Score	.61 (.09)	.43	.80	43.38	1.54	.001
			Demographic Variables [b]			
Gender	.36 (.17)	.02	.70	4.33	1.44	.01
Age	-.01 (.02)	-.06	.03	.39	.99	.53
Mental Health Diagnosis	.43 (.17)	.09	.78	6.25	1.54	.01
			Scale Variables [c]			
CMMQ Score	.01 (.004)	.005	.02	8.97	1.01	.003
MCQ-SF Score	.03 (.006)	.02	.04	26.88	1.03	.001

Note. CI = confidence interval; SE = standard error. [a] Model $\chi^2(3) = 45.51$, $p < .001$. [b] Model $\chi^2(3) = 9.71$, $p = .02$. [c] Model $\chi^2(2) = 72.85$, $p < .001$.

3.4.3.1 Motives and Cravings. To further examine which motive and craving factors were important in predicting the rate of cannabis use at Session 6, a negative binomial regression was conducted with the subscales from the CMMQ and MCQ-SF independently. Significant variables specific to these regression analyses are reported in Table 15. The full table including all variables is reported in Appendix H.

In the regression examining motives, a Pearson Chi-Square goodness-of-fit test suggested that the data fit the negative binomial model, χ^2 (195) = 168.84, value/df = .87. The model

containing the CMMQ subscales was significant, $\chi^2(12) = 105.98$, $p < .001$. In this model, enjoyment, experimentation, and sleep motives predicted frequency of cannabis use at Session 6. Individuals with higher scores on the enjoyment and sleep subscales had a 13% and 8% higher rate of cannabis use for each point higher on the scale, respectively. In contrast, individuals with higher scores on the experimentation subscale had an 8% lower rate of cannabis use for each point higher on the scale. No other subscales of the CMMQ were significant in the model (all *p*'s > .05).

In the regression examining cravings, a Pearson Chi-Square goodness-of-fit test suggested that the data fit the negative binomial model, χ^2 (203) = 214.03, value/df = 1.05. The model containing the MCQ-SF subscales was significant, $\chi^2(4) = 81.43$, $p < .001$. In this model, emotionality, expectancy, and purposefulness craving subscales predicted frequency of cannabis use at Session 6. Individuals with higher scores on the expectancy and purposefulness subscales had a 14% and 8% higher rate of cannabis use for each point higher on the scale, respectively. Individuals with higher scores on the emotionality subscale had a 9% lower rate of cannabis use for each point higher on the scale. The compulsivity subscale of the MCQ-SF was not significant in the model (all *p*'s > .05).

Table 15

*Motive and Craving Subscales Predicting Frequency of Cannabis Use at Session 6**

	B(SE)	95% CI		Wald	Exp(B)	*p*
		Lower	Upper			
			Motive Subscales [a]			
Enjoyment	.12 (.03)	.06	.18	14.48	1.13	.001
Experimentation	-.08 (.03)	-.15	-.02	6.33	.92	.01

Sleep	.07 (.03)	.02	.13	7.52	1.08	.01
			Craving Subscales [b]			
Emotionality	-.10 (.03)	-.16	-.03	8.24	.91	.001
Expectancy	.13 (.30)	.07	.19	19.51	1.14	.001
Purposefulness	.07 (.02)	.03	.11	13.01	1.08	.001

Note. * table showing only significant results. CI = confidence interval; SE = standard error. [a] Model $\chi^2(12) = 105.98$, $p < .001$. [b] Model $\chi^2(4) = 81.43$, $p < .001$.

3.4.4 Session 7 Frequency of Cannabis Use Prediction

Variables specific to the Session 7 regression analyses are reported in Table 16. The model containing the cognitive variables at Session 7 was not significant, $\chi^2(3) = 5.96$, $p = .11$. A Pearson Chi-Square goodness-of-fit test suggested that the data fit the negative binomial model, $\chi^2(70) = 64.25$, value/df = .92. In this model, COEL score, AAT score, and EC score did not predict frequency of cannabis use at Session 7.

The model containing the demographic variables at Session 7 was significant, $\chi^2(3) = 8.69$, $p = .03$. A Pearson Chi-Square goodness-of-fit test suggested that the data fit the negative binomial model, $\chi^2(75) = 67.14$, value/df = .90. In this model, gender predicted frequency of cannabis use at Session 7, indicating that males had a 204% higher rate of cannabis use. Presence of mental health disorder diagnosis and age did not predict frequency of cannabis use at Session 7.

The model containing the craving and motives scale variables at Session 7 was significant, $\chi^2(2) = 9.12$, $p = .01$. A Pearson Chi-Square goodness-of-fit test suggested that the data fit the negative binomial model, $\chi^2(77) = 63.91$, value/df = .83. In this model, craving for cannabis (as measured by the full scale MCQ-SF score) significantly predicted cannabis use at Session 7, suggesting that those reporting greater craving for cannabis use had a 2% higher rate of cannabis use for each point higher on the scale. Motives for using cannabis (as measured by the full scale CMMQ score) did not significantly predict frequency of cannabis use at Session 7.

Table 16

Frequency of Cannabis Use Prediction at Session 7

	B(SE)	95% CI		Wald	Exp(B)	*p*
		Lower	Upper			
		Cognitive Variables [a]				
AAT Score	-.01 (.01)	-.002	.001	1.84	1.00	.18
EC Score	1.10 (.57)	-.01	2.22	3.76	3.02	.052
COEL Score	.03 (.17)	-.30	.36	.04	1.03	.85
		Demographic Variables [b]				
Gender	.71 (.32)	.10	1.33	5.11	2.04	.02
Age	.04 (.04)	-.04	.012	.90	1.04	.34
Mental Health Diagnosis	.53 (.31)	-.08	1.14	2.88	1.70	.09
		Scale Variables [c]				
CMMQ Score	.004 (.008)	-.01	.02	.23	1.00	.63
MCQ-SF Score	.02 (.009)	.004	.04	5.77	1.02	.02

Note. CI = confidence interval; SE = standard error. [a] Model $\chi^2(3) = 5.96$, $p = .11$. [b] Model $\chi^2(3) = 8.69$, $p = .03$. [c] Model $\chi^2(2) = 9.12$, $p = .01$.

3.4.4.1 Motives and Cravings. To further examine which motive and craving factors were important in predicting the rate of cannabis use at Session 7, a negative binomial regression was conducted with the subscales from the CMMQ and MCQ-SF independently. Significant variables specific to these regression analyses are reported in Table 17. The full table including all variables is reported in Appendix I.

In the regression examining motives, a Pearson Chi-Square goodness-of-fit test suggested that the data fit the negative binomial model, χ^2 (67) = 42.81, value/df = .64. The model containing the CMMQ subscales was significant, $\chi^2(12) = 37.66$, $p < .001$. In this model, enjoyment and experimentation motives predicted frequency of cannabis use at Session 7. Individuals with higher scores on the enjoyment subscale had a 17% higher rate of cannabis use for each point higher on the scale. In contrast, individuals with higher scores on the experimentation subscale had an 13% lower rate of cannabis use for each point higher on the scale. No other subscales of the CMMQ were significant in the model (all *p*'s > .05).

In the regression examining cravings, a Pearson Chi-Square goodness-of-fit test suggested that the data fit the negative binomial model, χ^2 (75) =62.79, value/df = .83. The model containing the MCQ-SF subscales was significant, $\chi^2(4) = 12.00$, $p = .017$. However, none of the subscales of the MCQ-SF significantly predicted frequency of cannabis use at Session 7 (all *p*'s > .05).

Table 17

*Motive and Craving Subscales Predicting Frequency of Cannabis Use at Session 7**

	B(SE)	95% CI		Wald	Exp(B)	*p*
		Lower	Upper			
			Motive Subscales [a]			
Enjoyment	.16 (.07)	.02	.30	5.04	1.17	.03
Experimentation	-.14 (.05)	-.24	-.03	6.54	.87	.01

Note. * table showing only significant results. CI = confidence interval; SE = standard error. [a] Model $\chi^2(12) = 37.66$, $p < .001$. [b] Model $\chi^2(4) = 12.00$, $p = .017$.

3.5 Problematic Cannabis Use Prediction

3.5.1 Negative Binomial Regression

The assumptions of negative binomial regression were tested for before conducting the analysis (Hilbe, 2014). The distribution of the count outcome data fit the negative binomial distribution. The conditional mean was much smaller than the conditional variance, indicating that overdispersion was present and that a negative binomial model would be appropriate given its additional parameter to model the overdispersion. For the Session 1 analyses, negative binomial regressions were conducted with problematic cannabis use (e.g., CUDIT-R score) as the dependent variable and cognitive variables (e.g., AAT score, EC score, COEL score), demographic variables (e.g., gender, age, and presence of mental health disorder), and craving for cannabis and motives to use cannabis variables (e.g., craving and motive scores) as independent variables in each of the three regression models. For the Session 6 and 7 analyses, a negative binomial regression was conducted with problematic cannabis use (e.g., CUDIT-R score) as the dependent variable and cognitive variables (e.g., AAT score, EC score, COEL score) as the independent variables. Analyses were conducted with and without age and gender covaried in all models. The addition of age and gender were not significant in the models and did not change the outcome of any analyses of cognitive variables and as such, the models without age and gender are reported.

3.5.2 Session 1 Problematic Cannabis Use Prediction

Variables specific to the Session 1 regression analyses are reported in Table 18. The model containing the cognitive variables at Session 1 was not significant, $\chi^2(3) = 2.41$, $p = .49$. A Pearson Chi-Square goodness-of-fit test suggested that the data fit the negative binomial model,

$\chi^2(262) = 157.83$, value/df = .60. In this model, COEL score, AAT score, and EC score did not predict problematic cannabis use at Session 1.

The model containing the demographic variables at Session 1 was significant, $\chi^2(3) = 17.60$, $p = .001$. A Pearson Chi-Square goodness-of-fit test suggested that the data fit the negative binomial model, $\chi^2(277) = 150.93$, value/df = .55. In this model, gender predicted problematic cannabis use at Session 1, suggesting that males had a 47% higher rate of problematic cannabis use. Similarly, age and presence of mental health disorder diagnosis predicted problematic cannabis use at Session 1, indicating that for every year older a person was, they had a 4% lower rate of problematic cannabis use and that those who did not report a mental health diagnosis had a 38% lower rate of problematic cannabis use.

The model containing the motives and craving scale variables at Session 1 was significant, $\chi^2(2) = 47.48$, $p < .001$. A Pearson Chi-Square goodness-of-fit test suggested that the data fit the negative binomial model, $\chi^2(283) = 131.29$, value/df = .46. In this model, motives for using cannabis (as measured by the full scale CMMQ score) significantly predicted problematic cannabis use at Session 1, suggesting that individuals with more motives for cannabis use had a 1% higher rate of problematic cannabis use for each point higher on the scale. Similarly, craving for cannabis (as measured by the full scale MCQ-SF score) significantly predicted problematic cannabis use at Session 1, indicating that individuals with increased cravings had a 2% higher rate of problematic cannabis use for each point higher on the scale.

Table 18

Problematic Cannabis Use Prediction at Session 1

	B(SE)	95% CI		Wald	Exp(B)	*p*
		Lower	Upper			
			Cognitive Variables [a]			
AAT Score	.01 (.001)	.0001	.001	.97	1.00	.33
EC Score	.24 (.36)	-.47	.95	.44	1.27	.51
COEL Score	.06 (.08)	-.09	.21	.68	1.07	.41
			Demographic Variables [b]			
Gender	.38 (.15)	.09	.68	6.37	1.47	.01
Age	-.04 (.02)	-.09	.001	3.90	.96	.048
Mental Health Diagnosis	-.47 (.15)	-.76	-.19	10.59	.62	.001
			Scale Variables [c]			
CMMQ Score	.01 (.004)	.006	.02	13.64	1.01	.001
MCQ-SF Score	.01 (.005)	.005	.02	8.91	1.02	.003

Note. CI = confidence interval; SE = standard error. [a] Model $\chi^2(3) = 2.41$, $p = .49$. [b] Model $\chi^2(3) = 17.60$, $p = .001$. [c] Model $\chi^2(2) = 47.48$, $p < .001$.

3.5.2.1 Motives and Cravings. To further examine which motive and craving factors were important in predicting problematic cannabis use at Session 1, a negative binomial regression was conducted with the subscales from the CMMQ and MCQ-SF independently. Significant variables specific to these regression analyses are reported in Table 19. The full table including all variables is reported in Appendix J.

In the regression examining motives, a Pearson Chi-Square goodness-of-fit test suggested that the data fit the negative binomial model, χ^2 (273) = 112.44, value/df = .42. The model

containing the CMMQ subscales was significant, $\chi^2(12) = 67.00$, $p < .001$. In this model, the coping subscale predicted problematic cannabis use at Session 1. Individuals with higher scores on the coping subscale had a 9% higher rate of problematic cannabis use for each point higher on the scale. No other subscales of the CMMQ were significant in the model (all *p*'s > .05).

In the regression examining cravings, a Pearson Chi-Square goodness-of-fit test suggested that the data fit the negative binomial model, χ^2 (281) = 141.04, value/df = .50. The model containing the MCQ-SF subscales was significant, $\chi^2(4) = 38.35$, $p < .001$. In this model, the purposefulness craving subscale predicted problematic cannabis use at Session 1. Individuals with higher scores on the purposefulness subscale had a 4% higher rate of problematic cannabis use for each point higher on the scale. No other subscales of the MCQ-SF were significant in the model (all *p*'s > .05).

Table 19

*Motive and Craving Subscales Predicting Problematic Cannabis Use at Session 1**

	B(SE)	95% CI		Wald	Exp(B)	*p*
		Lower	Upper			
			Motive Subscales [a]			
Coping	.81 (.03)	.03	.14	8.31	1.09	.004
			Craving Subscales [b]			
Purposefulness	.04 (.02)	.008	.07	5.87	1.04	.02

Note. * table showing only significant results. CI = confidence interval; SE = standard error. [a] Model $\chi^2(12) = 67.00$, $p < .001$. [b] Model $\chi^2(4) = 38.35$, $p < .001$.

3.5.3 Session 6 Problematic Cannabis Use Prediction

Variables specific to the Session 6 regression analyses are reported in Table 20. A Pearson Chi-Square goodness-of-fit test suggested that the data fit the negative binomial model,

$\chi^2(196) = 112.08$, value/df = .57. The model containing the cognitive variables at Session 6 was not significant, $\chi^2(3) = 7.29$, $p = .06$. In this model, COEL score, AAT score, and EC score did not predict problematic cannabis use.

Table 20

Problematic Cannabis Use Prediction at Session 6

	B(SE)	95% CI		Wald	Exp(B)	*p*
		Lower	Upper			
			Cognitive Variables [a]			
AAT Score	.001 (.0003)	.0001	.001	.71	1.00	.40
EC Score	.40 (.35)	-.29	1.09	1.31	1.50	.25
COEL Score	.20 (.09)	.03	.37	5.40	1.22	.02

Note. CI = confidence interval; SE = standard error. [a] Model $\chi^2(3) = 7.29$, $p = .06$.

3.5.4 Session 7 Problematic Cannabis Use Prediction

Variables specific to the Session 7 regression analyses are reported in Table 21. A Pearson Chi-Square goodness-of-fit test suggested that the data fit the negative binomial model, $\chi^2(89) = 47.78$, value/df = .54. The model containing the cognitive variables at Session 7 was not significant, $\chi^2(3) =1.83$, $p = .61$. In this model, COEL score, AAT score, and EC score did not predict problematic cannabis use.

Table 21

Problematic Cannabis Use Prediction at Session 7

	B(SE)	95% CI		Wald	Exp(B)	*p*
		Lower	Upper			
			Cognitive Variables [a]			
AAT Score	-.001 (.001)	-.001	.001	1.34	1.00	.25
EC Score	.17 (.49)	-.80	1.14	.12	1.19	.73
COEL Score	-.10 (.14)	-.38	.17	.55	.90	.46

Note. CI = confidence interval; SE = standard error. [a] Model $\chi^2(3) = 1.83$, $p = .61$.

3.6 Desire to Discontinue Cannabis Use Prediction

3.6.1 Negative Binomial Regression

The assumptions of negative binomial regression were tested for before conducting the procedure (Hilbe, 2014). The distribution of the count outcome data fit the negative binomial distribution. The conditional mean was much smaller than the conditional variance, indicating that overdispersion was present in the data and that a negative binomial model would be appropriate given its additional ancillary parameter to model the overdispersion. A negative binomial regression was conducted with desire to discontinue cannabis use as the dependent variable. Cognitive variables (e.g., AAT score, EC score, COEL score), demographic variables (e.g., gender, age, and presence of mental health disorder), and craving and motives variables (e.g., craving and motive scores) were input as independent variables. Analyses were run with and without age and gender covaried in all models. The addition of age and gender did not change the outcome of any analyses of cognitive variables and as such, the models without age and gender are reported.

3.6.2 Session 1 Desire to Discontinue Cannabis Use Prediction

Variables specific to the regression analyses are reported in Table 22. A Pearson Chi-Square goodness-of-fit test suggested that the data fit the negative binomial model, $\chi^2(267) = 119.52$, value/df = .45. The model containing the cognitive variables was not significant, $\chi^2(3) = 5.92$, $p = .12$. In this model, COEL score, AAT score, and EC score did not predict desire to discontinue cannabis use.

The model containing the demographic variables was not significant, $\chi^2(3) = 5.06$, $p = .17$. A Pearson Chi-Square goodness-of-fit test suggested that the data fit the negative binomial model, $\chi^2(282) = 127.93$, value/df = .45. In this model, gender, age, and presence of mental health disorder did not predict desire to discontinue cannabis use.

The model containing the cravings and motives scale variables was significant, $\chi^2(2) = 6.37$, $p = .04$. A Pearson Chi-Square goodness-of-fit test suggested that the data fit the negative binomial model, $\chi^2(288) = 118.39$, value/df = .41. However, neither of the full-scale motives or cravings scores significantly predicted desire to discontinue cannabis use.

Table 22

Desire to Discontinue Cannabis Use Prediction at Session 1

	B(SE)	95% CI		Wald	Exp(B)	*p*
		Lower	Upper			
		Cognitive Variables [a]				
AAT Score	.001 (.0003)	-.001	.001	.01	1.00	.93
EC Score	.03 (.38)	-.73	.78	.01	1.03	.95
COEL Score	-.18 (.08)	-.33	-.03	5.65	.83	.02
		Demographic Variables [b]				
Gender	.25 (.16)	-.06	.56	2.52	1.28	.11
Age	-.03 (.02)	-.08	.01	2.23	.97	.14
Mental Health Diagnosis	.09 (.15)	-.21	.38	.33	1.09	.57
		Scale Variables [c]				
CMMQ Score	-.002 (.003)	-.01	.004	.43	1.00	.51
MCQ-SF Score	-.01 (.01)	-.02	.001	2.98	.99	.08

Note. CI = confidence interval; SE = standard error. [a] Model $\chi^2(3) = 5.92$, $p = .12$. [b] Model $\chi^2(3) = 5.06$, $p = .17$. [c] Model $\chi^2(2) = 6.37$, $p = .04$.

3.6.2.1 Motives and Cravings. To further examine if any motive and craving subscales were important in predicting the desire to discontinue cannabis use, a negative binomial regression was conducted with the subscales from the CMMQ and MCQ-SF independently. Significant variables specific to these regression analyses are reported in Table 23. The full table including all variables is reported in Appendix K.

In the regression examining motives, a Pearson Chi-Square goodness-of-fit test suggested that the data fit the negative binomial model, χ^2 (278) = 105.08, value/df = .38. The model

containing the CMMQ subscales was significant, $\chi^2(12) = 25.59$, $p = .01$. In this model, coping motives predicted desire to discontinue cannabis use. Individuals with higher scores on the coping subscale had a 7% higher rate of desire to discontinue cannabis use for each point higher on the scale. No other subscales of the CMMQ were significant in the model (all *p*'s > .05).

In the regression examining cravings, a Pearson Chi-Square goodness-of-fit test suggested that the data fit the negative binomial model, χ^2 (286) = 107.14, value/df = .38. The model containing the MCQ-SF subscales was significant, $\chi^2(4) = 18.48$, $p < .001$. In this model, the purposefulness craving subscale predicted desire to discontinue cannabis use. Individuals with higher scores on the purposefulness subscale had a 5% lower rate of desire to discontinue cannabis use for each point higher on the scale.

Table 23

*Motive and Craving Subscales Predicting Desire to Discontinue Cannabis Use at Session 1**

	B(SE)	95% CI		Wald	Exp(B)	*p*
		Lower	Upper			
			Motive Subscales [a]			
Coping	.07 (.03)	.01	.13	5.23	1.07	.02
			Craving Subscales [b]			
Purposefulness	-.06 (.02)	-.09	-.02	9.31	.95	.002

Note. * table showing only significant results. CI = confidence interval; SE = standard error. [a] Model $\chi^2(12) = 25.59$, $p = .01$. [b] Model $\chi^2(4) = 18.48$, $p < .001$.

3.7 Change in Cannabis Use Frequency Over Time

Given the negative binomial distribution of the frequency of cannabis use data, the non-parametric Wilcoxon Signed Rank test was conducted to evaluate whether a difference existed in cannabis use frequency over time in each experimental group.

3.7.1 Change in Cannabis Use from Session 1 to Session 6

Wilcoxon Signed Rank test results found no significant difference in cannabis use frequency by group from Session 1 (*n* = 293*)* to Session 6 (*n* = 209*;* all *p*'s > .05). This suggests that participating in the EC, AAT, or combination training did not impact cannabis use behaviour over the training period.

3.7.2 Change in Cannabis Use from Session 6 to Session 7

Wilcoxon Signed Rank test results found no significant differences in cannabis use frequency by group from Session 6 (*n* = 209) to Session 7 (*n* = 80; all *p*'s > .05) except for those in the AAT training group such that their Session 7 (*Md* = 5) cannabis use frequency was significantly higher than their Session 6 (*Md* = 3) cannabis use frequency, *z* = -2.21, *p* = .03. This finding suggests that participating in the EC, AAT, or combination training did not reduce cannabis use behaviour at 1-month follow-up.

3.8 Change in Cognitive Scores Over Time

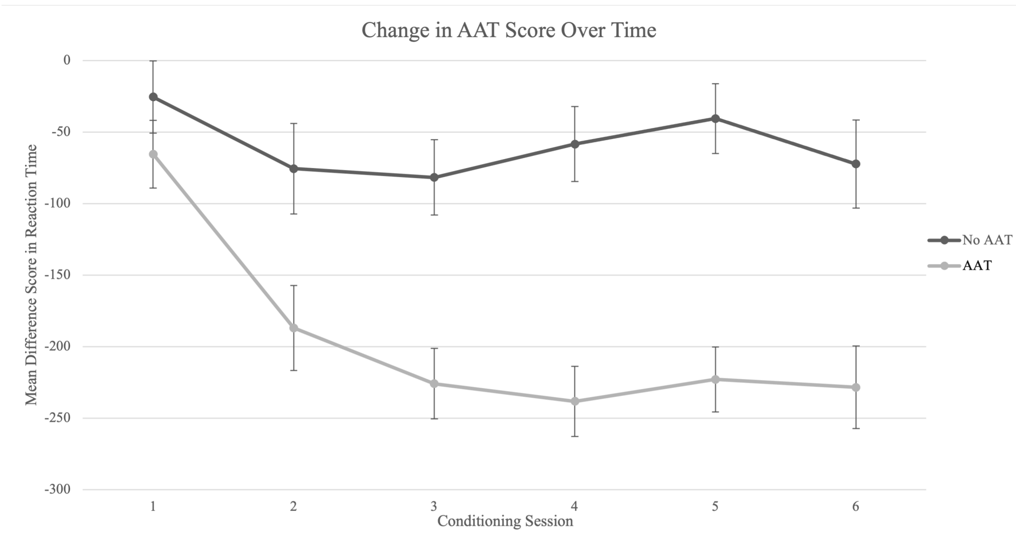
3.8.1 Change in AAT Score

Repeated measures ANOVAs were used to examine the difference between AAT cognitive scores over time. The assumptions of this analysis were checked prior to conducting the analysis. Normality of the AAT outcome data at each timepoint was assessed using the Shapiro-Wilk's test. At Session 1, the AAT assessment score was not normally distributed for the combination training group (*p* < .05). At Session 6, the AAT score was not normally distributed for sham training group (*p* < .05). At Session 7, the AAT score was not normally distributed for the sham group (*p* < .05). All other AAT data was normally distributed at all timepoints. We chose to proceed with the analyses as the repeated measures ANOVA is said to be fairly robust to deviations from normality. Further, AAT score residuals were normally distributed when assessed by Normal Q-Q Plot. There was homogeneity of variances in the AAT data, as assessed by Levene's test of homogeneity of variance ($p > .05$). There was not homogeneity of covariances in the AAT data, as assessed by Box's test of equality of covariance matrices ($p < .001$). One outlier was found at Session 6 in the AAT data which had a studentized residual of +3.59. No difference in results of the ANOVA was seen when analyses were conducted with and without the outlier and as such, the outlier was kept in the data set. Mauchly's test of sphericity indicated that the assumption of sphericity was violated for the two-way interaction, $\chi^2(2) = 25.14$, $p < .001$ and as such, the Greenhouse-Geisser correction was used to interpret the results.

Results indicated that there was no statistically significant interaction between training group and time on AAT assessment score, $F\ (4.77,135.06) = 1.84$, $p = .11$, partial $\eta^2 = .06$. The main effect of time showed a statistically significant difference in AAT score at the different timepoints, F (1.58, 135.06) = 6.97, $p = .003$, partial η2 = .08. AAT score at Session 1 was significantly different from Session 6 ($p = .01$) and Session 7 ($p = .01$) such that scores at Session 1 indicated more bias toward cannabis than scores at Session 6 or Session 7. This finding suggests that participation in the AAT training group lead to significant reductions in bias toward cannabis images over the six session AAT training period and at 1-month follow-up. Figure 2 shows the trend in AAT scores over the six conditioning sessions by group. AAT score at Session 6 was not significantly different from Session 7 ($p > .05$).

Figure 2

Change in AAT Score Over Conditioning Trials



To further examine the moderating impact of craving, motives, presence of mental health diagnosis, and motivation to stop using cannabis on AAT training effects over time, repeated measures ANOVAs were conducted. There was no statistically significant interaction between time, group, and any of the moderating variables on AAT score (all *p*'s > .05).

3.8.2 Change in EC Score

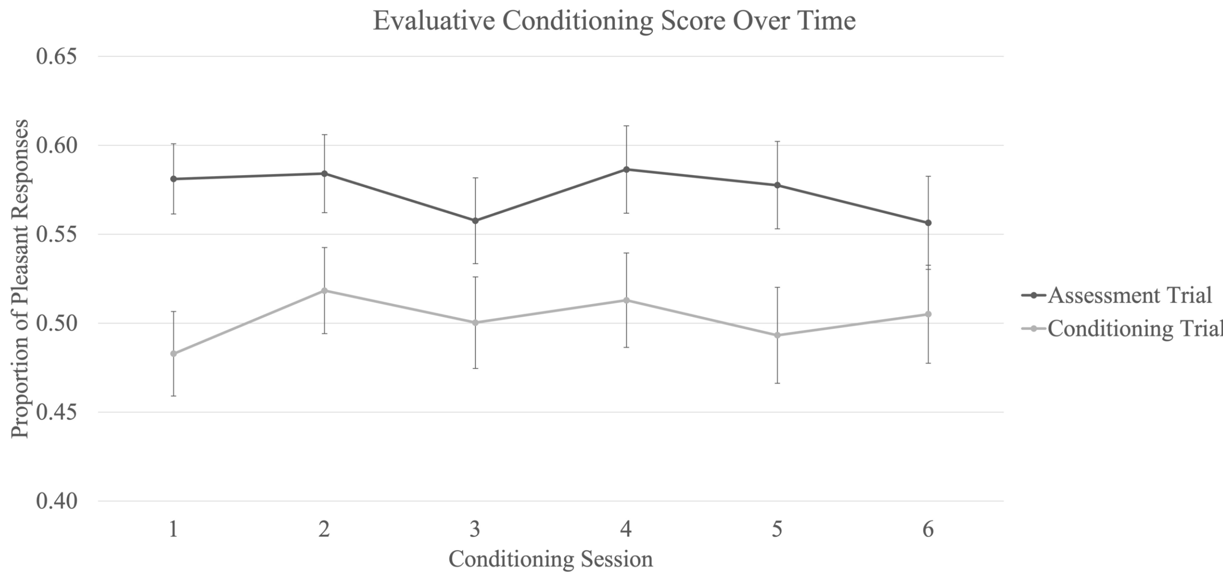
Repeated measures ANOVAs were used to examine the difference between EC cognitive scores over time. The assumptions of this analysis were checked prior to conducting the analysis. Normality of the EC outcome data at each timepoint was assessed using the Shapiro-Wilk's test. EC score data was normally distributed, as assessed by Shapiro-Wilk's test ($p > .05$). EC score residuals were normally distributed when assessed by Normal Q-Q Plot. There was homogeneity of variances in the EC data, as assessed by Levene's test of homogeneity of variance ($p > .05$). There was homogeneity of covariances, as assessed by Box's test of equality of covariance matrices ($p = .85$). There were no outliers, as assessed by examination of studentized residuals for values greater than ±3. Mauchly's test of sphericity indicated that the assumption of sphericity was violated for the two-way interaction, $\chi^2(2) = 12.03$, $p = .002$ and as such, the Greenhouse-Geisser correction was used to interpret the results.

Results indicated that there was no statistically significant interaction between training group and time on EC assessment score, F (5.3,151.95) = .33, $p = .90$, partial $\eta^2 = .01$. No main effect of time or group was observed ($p > .05$), indicating that EC assessment score did not change over time or based on training group. To examine the moderating impact of craving, motives, presence of mental health diagnosis, and motivation to stop using cannabis on EC training effects over time, repeated measures ANOVAs were conducted. There was no statistically significant interaction between time, group, and any of the moderating variables on EC score (all p's > .05).

To further examine whether the negative stimuli included in the EC conditioning trials were successful in reducing pleasant responses toward cannabis, we examined whether responses to trials with and without negative US differed. Results indicated that there was a statistically significant effect of trial type on EC score over time, F (1, 188.00) = 47.84, $p < .001$, partial η^2 = .20, such that scores on the negatively valenced US conditioning trials were significantly lower than scores on the trials without negatively valenced US. This finding suggests that the presence of negative US on conditioning trials significantly reduced the proportion of pleasant responses on these trials when compared to trials without negative US. Figure 3 shows the difference in EC score over the six conditioning sessions by trial type.

Figure 3

Evaluative Conditioning Score Over Time by Trial Type



3.9 Contingency Awareness

Open-ended responses were coded to determine if contingency awareness existed among participants and whether participants were able to report the study purpose. No participants reported being aware of the contingencies used in the picture tasks (e.g., 90% cannabis photos in push orientation and 10% in pull orientation). Regarding study purpose, 17.1% of participants reported the purpose of the study (i.e., to examine or change cannabis bias or behaviour). An independent-samples *t*-test was conducted to compare impulsive cognitive scores (e.g., AAT and EC) among those who did and did not report knowing the study purpose. Group-specific means and standard deviations are reported in Table 24.

At Session 6, analyses revealed that those who were able to report the study purpose did not differ from those who were not able to report the purpose on the AAT score. However, when examining EC score, those who were able to report the study purpose had lower EC scores at

Session 6 than those who were not able to report the study purpose. At Session 7, analyses revealed that those who were able to report the study purpose did not differ from those who were not able to report the purpose on both the AAT score and the EC score.

Table 24

Means and Standard Deviations by Group

	Reported Purpose		Did Not Report Purpose				
	M	*SD*	*M*	*SD*	*t*	*df*	*Sig.*
Session 6 AAT Score	-141.63	243.85	-119.18	312.52	-.23	43	.82
Session 6 EC Score	.45	.12	.64	.19	-3.26	44	.002
Session 7 AAT Score	-86.32	234.10	-117.37	264.11	.38	42	.71
Session 7 EC Score	.53	.17	.61	.19	.18	42	.18

Note. *M* = mean; *SD* = standard deviation. *t* = t-statistic. *Df* = degrees of freedom.

CHAPTER 4 Conclusion

4.1 Discussion

Among other substances, cannabis has the potential to produce negative psychological, emotional, social, and functional impacts for young people (Jacobus & Tapert, 2014; Rubino & Parolaro, 2008). Considering these findings, it is an important public health initiative to identify and treat problematic substance use with efficacious methods. Nevertheless, many of the prevention and intervention methods that are in use currently have limited effects (Cutler & Fishbain, 2005; Sherman & McRae-Clark, 2016). Most methods focus on the explicit cognitions that individuals can report and consider at a conscious level (e.g., CBT, D.A.R.E). However, current research suggests that substance use behaviour is impacted by both impulsive and reflective cognitive processes (Stacy & Wiers, 2010; Wiers, Stacy, et al., 2002). The widespread suggestion among those researching cognition and substance use is that substance use prevention and treatment should include an additional focus on impulsive cognitions given the considerable impact of these cognitive processes on developing and maintaining substance use behaviour (Heitmann et al., 2017; Krank & Robinson, 2017). Most of the studies that have explored the relationship between substance use and impulsive cognition have documented a predictive relationship characterized by stronger impulsive cognitions (e.g., approach bias, attentional bias) predicting increased levels of substance use (Everitt & Robbins, 2013; Peeters et al., 2012; Thush et al., 2008). However, the literature examining the influence of impulsive cognitions on substance use, especially cannabis use, is still in its infancy.

With cognitive biases in mind, novel cognitive techniques have been developed to alter biases associated with substance use. The goal of these techniques is often to increase cognitive control over problematic biases that may be underlying unhealthy substance use behaviours (C.

E. Wiers & Wiers, 2017). Two of these techniques include the AAT and EC, which have both been tested in the current study. The AAT has been tested in two studies (Jacobus et al., 2018; Sherman et al., 2018) for use with cannabis use while no studies have tested EC procedures to reduce cannabis use or cannabis biases to date. However, EC has been used to alter cognitions related to alcohol and smoking with good success (Məgurean et al., 2016; Tello et al., 2018). The extant literature that has explored CBM for cannabis use has produced variable outcomes and has been limited by methodological problems which potentially contribute to null findings (Cristea et al., 2016). Further investigation into the parameters and mechanisms related to cognitive change through this promising method of preventing and treating substance use is warranted and should be continued. The following discussion examines the findings from the current study, limitations, and suggestions for future research.

4.1.1 Prediction of Cannabis Use, Problematic Cannabis Use, and Desire to Discontinue Cannabis Use

We hypothesized that the cognitive measures in this study (e.g., COEL, AAT, and EC) would predict frequency of cannabis use such that those with increased scores on the cognitive measures would report greater frequency of cannabis use. Our study found that the explicit measure of cannabis cognition (e.g., COEL) predicted frequency of cannabis use at Session 1 and Session 6, but not at the 1-month follow-up. This finding is similar to previous research suggesting that outcome expectancies are particularly successful in predicting frequency of substance use (Fulton et al., 2012; Treloar et al., 2016). However, we did not find that outcome expectancies predicted cannabis use over a 1-month period, suggesting that the association between outcome expectancies and cannabis use did not remain when examined longitudinally. It is important to consider that the data at Session 7 was derived from a significantly smaller sample due to attrition. This smaller sample likely impacted the statistical power needed to detect meaningful results at Session 7. Nevertheless, the significant findings at Session 1 and Session 6 are important in that they provide confidence in using the COEL to predict current levels of cannabis use in young, undergraduate samples. Regarding the use of impulsive cannabis bias scores to predict frequency of cannabis use, we found that the AAT score did not predict frequency of use at any timepoint. Further, we found that EC score predicted cannabis use frequency at Session 6 but not at Session 1 or 7. These findings are unexpected given the substantial research literature that has found strong predictive ability of these measures (Cousijn et al., 2012; Hammerl & Grabitz, 2000; Loijen et al., 2020).

We also hypothesized that the cognitive measures in our study would predict problematic cannabis use. In contrast to previous research that suggests implicit and explicit measures have strong predictive ability of problematic use (Barkby et al., 2012; Cousijn et al., 2011; Field et al., 2009; Fulton et al., 2012), we found that the impulsive cognitive measures we used (i.e., EC and AAT) did not predict problematic cannabis use. This finding was also surprising in that previous research has found that strong approach bias reliably predicts increases in use (Loijen et al., 2020). Previous studies have found that cognitive biases also predicted treatment dropout in alcohol-dependent patients (Cox et al., 2002) and relapse for cigarette use (Waters et al., 2003), cocaine use (Carpenter et al., 2006), and heroin use (Marissen et al., 2006). Given the substantial findings in many research studies, the null findings in the present study call into question the ability of the cognitive measures used in this study (e.g., AAT, EC, and COEL) to predict problematic levels of cannabis use with a non-treatment-seeking undergraduate sample. It is possible that we did not choose photo stimuli that were relevant to participants' cannabis use or that the number of training trials was insufficient to adequately assess cannabis bias and subsequently predict use. Future research may use personally relevant cannabis photos that are pre-selected by participants and may increase the numbers of trials to determine if this bolsters the predictive ability of impulsive measures.

We also predicted that motives for using cannabis would predict cannabis use behaviours. Consistent with previous literature (Fox et al., 2011; Simons et al., 1998), we found that motives significantly predicted the frequency of cannabis use in our sample at Session 1. More specifically, enjoyment, conformity, boredom, alcohol use, and sleep motives predicted frequency of use at Session 1. At Session 6, enjoyment and sleep motives significantly positively predicted frequency of use while experimentation motives negatively predicted use. Similarly, at Session 7, enjoyment motives positively predicted cannabis use frequency while experimentation motives continued to negatively predict frequency of use. Interestingly, at Session 1, the motives for use were different than at Session 6 and 7. At Session 6 and 7, our results suggest that those who are using for experimental reasons are in fact using less cannabis, while those who are using for enjoyment reasons are using more cannabis at each timepoint. Lastly, we found that only coping motives predicted problematic cannabis use at Session 1. This finding supports previous research that identifies coping motives as significantly associated with increased levels of problematic cannabis use (Fox et al., 2011; Simons et al., 1998). Intriguingly, coping motives were also predictive of more desire to discontinue cannabis use in this sample. It appears as though those who are using cannabis for coping with negative affect report more cannabis-related problems and have an increased desire to discontinue cannabis use.

From a substance use perspective, it makes sense that those who are experimenting with cannabis may be using less of the substance at once and be using less over time should they decide that the effects of the substance are undesirable. Conversely, it also makes sense that those using cannabis for enjoyment reasons continue to use cannabis at each timepoint. Unless cannabis use becomes problematic, undesirable, or detrimental over time, it is unlikely that individuals will change their cannabis behaviour (Wiers et al., 2015). These findings suggest that motives for cannabis use are important factors to consider when designing effective prevention and treatment programs for cannabis use. It is likely that individuals who are motivated to use cannabis for enjoyment reasons may benefit from tailored treatment that is different from treatment for those who are motivated to use cannabis for experimentation or coping reasons (Blevins et al., 2016; Glodosky & Cuttler, 2020). This suggestion has been borne out in literature examining personality correlates of substance use (Conrod, 2016; Edalati & Conrod, 2019).

Similarly, we hypothesized that cravings for cannabis use would predict cannabis use behaviours. Again, consistent with previous literature that suggests craving for cannabis is highly associated with cannabis use (e.g., Gray et al., 2011; Lundahl & Johanson, 2011), our findings replicate this relationship. Craving for cannabis use predicted frequency of cannabis use in our sample at Session 1 and Session 6. Specifically, emotionality, expectancy, and purposefulness cravings predict frequency of use at both Session 1 and 6. Interestingly, no subscales of the craving measure predicted use at Session 7. Moreover, the compulsivity craving subscale did not predict frequency of cannabis use or problematic cannabis at any timepoint. These findings suggest that cravings in this sample are related to the expected positive effects of using cannabis, the relief of negative mood, and the intention to use cannabis for positive outcomes rather than an inability to control cannabis use. Further, we found that purposefulness cravings were negatively related to desire to discontinue cannabis use, such that those who had higher scores on the purposefulness subscale had a lower rate of desire to discontinue their cannabis use. This finding may provide support for why we found no changes in cannabis behaviour throughout the cognitive training. The type of craving that influences participants' cannabis use may not interact significantly with motivation to change in this non-treatment-seeking sample. Moreover, cravings for cannabis use have been shown to predict withdrawal severity in heavy cannabis users (Cousijn & van Duijvenvoorde, 2018) as well as treatment outcome for adolescent treatment-seeking cannabis users (Cousijn et al., 2015). It may be the case that in treatment-seeking samples, higher compulsivity cravings are endorsed which may be targeted through cognitive training. Overall, the findings in our study add to the research that implicates craving as an important influence in maintaining cannabis use behaviour (Skinner & Aubin, 2010). As such, craving should be thoroughly assessed and incorporated into intervention protocols for those seeking cannabis use treatment given the predictive ability that craving has when it comes to withdrawal and treatment.

Finally, demographic variables including gender, age, and presence of mental health diagnosis predicted problematic cannabis use at Session 1. Male gender predicted higher rates of cannabis use frequency at Session 1. This finding replicates many studies of gender differences in cannabis use which have found that men use cannabis more frequently and in greater quantities than woman (Cuttler et al., 2016). Interestingly, however, age was not identified as a predictor of cannabis use frequency. The Canadian Cannabis Survey indicated that the highest rate of cannabis use was observed during the ages of 20 to 24 in 2020 (Health Canada, 2020) which mirrors the vast majority of the sample in our study. In addition, mental health predicted frequency of cannabis use at Session 1 and Session 6 such that those reporting a mental health diagnosis used more cannabis at each timepoint. However, we found that those who reported a mental health diagnosis were found to report less problematic cannabis use. It is not surprising that presence of mental health diagnosis predicted frequency of cannabis use given a large body of research that documents the strong relationship between cannabis use and mental health problems (Lev-Ran & Feingold, 2017; Schlossarek et al., 2016; van der Pol et al., 2013). Yet, it is interesting that those with a mental health disorder reported fewer problems associated with cannabis use. It may be that those who are using cannabis and have a mental disorder diagnosis use more frequently but are not using in such a way that is causing them problems in their life. Taken together, these findings are important given that these variables are easy to examine and query, making them accessible predictors of who may be at higher risk for problematic cannabis use.

4.1.2 Change in Cannabis Use Frequency Over Time

We hypothesized that participating in cognitive training would result in reductions in cannabis use after six sessions of training and at a 1-month follow-up. Despite successfully altering approach-avoidance bias toward cannabis with the AAT, results in our study found no effect of the cognitive training on reducing cannabis use frequency over time. Interestingly, we saw that those in the AAT group exhibited higher cannabis use at Session 6 relative to their initial use at Session 1. Upon further exploration, those in the AAT group used cannabis more times per day than other groups at Session 1; however, this difference was marginally significant (p = .052). It is likely that those who used more cannabis in the AAT group at Session 1 may have continued to use more at Session 6 or even increased their use over time, despite receiving cognitive bias training. This finding is in contrast with a body of literature that has shown decreased consumption rates in alcohol users and smokers immediately after completing training with the AAT and at a long-term follow-up (Wiers et al., 2011; Wittekind et al., 2015). Similar findings have been observed with EC procedures in that EC has been shown to reduce alcohol consumption and smoking (Houben, Havermans, et al., 2010; Məgurean et al., 2016).

Sherman et al., 2018 reported that, despite no changes occurring in approach-avoidance bias, a small but significant reduction in cannabis use was observed in moderate-to-severe male cannabis users after four sessions of AAT training for cannabis use. It should be noted that most effects of CBM for substance use have been found in those with clinical levels of substance use disorders (Eberl et al., 2013; Manning et al., 2016; Wiers et al., 2011), but some findings have appeared in college samples (Houben, Havermans, et al., 2010; Wolf et al., 2016). However, the null findings of this hypothesis are not surprising given the limitations of the study described below as well as the non-treatment-seeking sample used in the present research. Should the sample have reflected the levels of use of participants in the Sherman et al., 2018 study, our findings may have suggested similar reductions in cannabis use overtime.

4.1.3 Change in Impulsive Cannabis Bias Over Time

We hypothesized that those in the AAT, EC, and combined training groups would have significantly different scores from those in the control group immediately after training was completed and at 1-month follow-up. Results from our study found that scores on the AAT assessment trials were significantly more biased toward cannabis use at Session 1 than at Session 6 or Session 7, suggesting that the AAT training changed approach bias over six sessions. In contrast, we observed no change in the EC assessment scores over time, suggesting that the EC had no impact on biases toward cannabis use throughout the training. However, we did find that the conditioning in the EC procedure was effective in that trials with negative affective stimuli were rated lower during the conditioning phase than the trials without negative affective stimuli. However, this did not cause any change in EC assessment scores toward cannabis. Previous research suggests that cognitive biases toward cannabis use may differ based on level of use, with heavier cannabis users showing increased bias toward cannabis (Wolf et al., 2016). It may be that the effect of CBM depends on level of cannabis use, with greater effects being observed in heavier users. This may partially explain the null EC findings such that our sample may not have displayed significant enough levels of cannabis use that would fall in the range of use that is most impacted by EC.

Nevertheless, the AAT findings in this study support the efficacy of AAT training paradigms to reduce bias toward cannabis and extend the results of Sherman et al., 2018 who found no change in approach bias over four sessions. Our study suggests that at least six sessions of training are needed to change bias in light-to-moderate cannabis users and that more sessions may be needed to change bias in those who have moderate-to-severe levels of cannabis use. Our findings also suggest that light-to-moderate users may not be motivated or invested in changing their cannabis use and no explicit changes in cannabis use behaviours may be found after AAT training despite reducing implicit bias toward cannabis. It may also be the case that Sherman et al., 2018 found significant reductions in male cannabis users because their level of use fell within the moderate to severe range. Although it was not measured in Sherman et al., 2018, motivation to reduce cannabis use in those who are heavy users may be much different than in those who are occasional users.

Motivation has been found to mediate the effectiveness of CBM training (Wiers et al., 2013, 2015) such that substance consumption levels may not change if the participant has little to no motivation to change their behaviour. One study of cigarette smokers found that although attentional bias was successfully changed in heavy smokers compared to a control group, this resulted in no changes in behaviour because those in the study were not motived to change their smoking behaviour (Kerst & Waters, 2014). The current study provides support for this finding. Results from our study suggested that motivation did not have a moderating effect on the results of the AAT or EC training in our sample. It is likely that CBM techniques will be most effective if those undertaking the training are interested in changing their substance use but have difficulty doing so given their strong cognitive biases toward the substance. In summary, CBM may be best paired as an adjunctive technique with another type of intervention that may bolster motivation and healthy decision-making (Wiers et al., 2013). Future research should measure levels of motivation to change use in a heavy using sample to determine if an interaction between motivation, level of cannabis use, and CBM outcomes exists.

4.1.4 Contingency Awareness

We hypothesized that participants would not be aware of the training contingencies present in the study and that participants' training outcomes would not be impacted by knowing the study purpose. As hypothesized, no participants were able to accurately report the contingencies used in the study. Further, as expected, among those who were aware of the study purpose, we did not find that this awareness impacted the participants' training outcomes relative to those who did not report the purpose. These findings fall in line with research that suggests that explicit knowledge of training factors is unlikely to impact implicit training outcomes (Baeyens et al., 1988, 1992; Houben, Havermans, et al., 2010). Taking a dual-process theory perspective, the training that takes place in CBM is said to occur at an indirect, associative level which often operates in a quick manner without significant deliberation. Therefore, it is unlikely that awareness of the study at the explicit level would be deeply impactful on the automatic cognitive processes being targeted in CBM training.

4.2 Limitations

Data collection was limited to an undergraduate sample which consisted mainly of heterogenous ethnic, young, female participants. The sample used in this study was a non-treatment-seeking sample. As such, the findings of this study may not generalize beyond this undergraduate population, although we believe this research is still meaningful given that ~20% of participants reported cannabis use that fell within the range of problematic cannabis use potentially requiring intervention. Further, despite the full sample reporting low desire to change their cannabis use, a subset of the sample (24.2%) rated themselves as a 6 or higher on the scale of motivation to quit using cannabis with 10 being 100% motivation to quit.

The data was further limited by self-report measures of substance use. Self-report measures may be subject to social desirability bias or other demand characteristics, but efforts were made to ensure participants understood confidentiality. Further, due to time constraints, the experimental training was limited to six sessions with a 1-month follow-up occurring after completion of the training phase. Data were collected during the university school semesters to make best use of the undergraduate research pool, limiting the period in which participants were able to complete the study.

Additionally, the COVID-19 pandemic began during the middle of the semester (i.e., March 2020) and as such, many participants in this study were likely experiencing significant upheaval and turmoil as they returned home and/or adjusted to online classes. COVID-19 shutdowns began for most students between the 6th conditioning session and the 1-month follow-up session. To continue research endeavors during the pandemic, the University of British Columbia Okanagan mandated that all data collection be shifted from in-person to online means. Retention across the study was moderate and likely impacted by students' varying priorities (e.g., safety, mental health, balancing online courses) at the time of data collection. Further, drop out between the final training session and the 1-month follow-up may be impacted by the lengthy time commitment required of participants and by the large proportion of participants who only required two research credits for their undergraduate psychology courses. The third and final credit that was obtained by completing the 1-month follow-up was likely not important or applicable to many participants. As such, high rates of drop out were postulated to be due to the time commitment required of participants, the large number of participants who required only one of two credits for their psychology courses, and the unfortunate timing of a global pandemic occurring sequentially with data collection.

Further, the first session of training was conducted in-person for approximately one-half of the sample. After the COVID-19 social-distancing mandate, the instructions for the first training session were delivered via pre-recorded video that the participant watched on their own. All efforts were made to clarify the procedure and the participants were given the option to consult with the primary investigator should they have had any questions. As such, it may be that some participants experienced a small degree of confusion about the cognitive tasks which may have impacted the outcomes of this study. Further, we attempted to examine stability of the EC and AAT tasks over time; however, the 1-month follow-up occurred during the first several months of the COVID-19 pandemic for many participants. As such, the findings suggested at the 1-month follow-up should be interpreted with caution considering the significant distress that occurred during this time. Future studies should re-evaluate durability of these tasks to better understand long-term stability of findings. Lastly, because the EC procedure employed in this study is novel and exploratory, the effective parameters of this procedure are unknown. However, the current research provides an important contribution to better understand the parameters that lead to effective EC when embedded within the AMP.

In contrast, our study had several strengths that should be noted. We used a statistically powerful 2 x 2 factorial design to examine interactions in the data. Further, we collected longitudinal data at seven timepoints in the study, allowing us to determine if any changes occurred over the training sessions and at a 1-month follow-up. As several previous studies with small sample sizes had noted limitations in statistical power, we collected data from a large sample to increase our power to detect meaningful results. Unfortunately, due to the constraints discussed above, the sample size at the 1-month follow-up did not have the same level of statistical power.

This study contributes to the larger body of research that examines the use of novel cognitive tasks to modify and change maladaptive cognitive biases that occur alongside substance use. This study was the first to use a novel EC task that was embedded within the AMP. Despite our modest findings, it will be important for future research to continue examining this procedure given the current theoretical foundations of EC as well as the ease with which the AMP is modified for use in EC. Despite our null findings, we believe this research contributes to the emerging body of literature examining appropriate parameters for AAT and EC procedures for cannabis use.

4.3 Future Directions

Future studies using CBM to alter cannabis biases would be strengthened by several methodological adjustments. Larger sample sizes may be needed to adequately detect effects within experimental groups. Research exploring the impact of CBM training as an add-on to treatment-as-usual is needed to determine if CBM training alone is substantial enough to produce clinically relevant outcomes or whether CBM outcomes are more pronounced when included as an adjunct to treatment-as-usual (Loijen et al., 2020). Further, future studies should examine a treatment-seeking sample that endorses levels of cannabis use that are considered problematic (Van Deursen et al., 2013). A treatment-seeking sample may be more motivated to change their cannabis use than a non-treatment-seeking sample, and as such, the effects of CBM may be more pronounced. Further, motivation to change should be further explored as a mediator of CBM (Wiers, 2018). The sample in the current study included approximately 20% of participants reporting significant cannabis-related problems and problematic use; however, motivation to immediately change their use may have been low across the entire sample. Consequently, without motivation to change, it is unlikely that levels of cannabis use will change despite undergoing several sessions of CBM (Boffo et al., 2015).

Additionally, modified CBM parameters should be examined in future studies. Given the infancy of the CBM for cannabis use literature, further investigation into the conditions for adequate bias modification in this population will need to occur. Protocols on number of training sessions and number of trials per session are parameters that are still being explored and further research is needed to determine an adequate dose-response relationship. Similarly, future studies may benefit from including personally relevant cannabis cues. Given that cannabis is being consumed in a variety of different ways with many different tools (e.g., vaping, joints, bongs), the photo stimuli used in CBM procedures may prove to be more or less relevant to the participant depending on their preferred methods of use (Aguinaldo et al., 2019). Stimuli that are matched to an individual's method and type of use may be an important area of exploration in future research. In a similar vein, standardized protocols for computing approach-avoidance scores among AAT studies should be developed to further facilitate comparisons between studies. It is likely that different methods for computing reaction times and bias calculations may impact the interpretation of outcomes within and across studies.

Finally, the mode of delivery of CBM programs is an interesting area of emerging research. While most studies have examined the effects of CBM when delivered in-person, research has begun to examine online delivery of CBM programs (Wiers et al., 2015; Wittekind et al., 2019). While the online adaptation of the two training protocols used in this study proved feasible in this sample, it is uncertain whether this is generalizable to other populations such as those with significant substance use problems or those who are less familiar with computers. Given that online or at-home delivery of CBM could potentially reach many more participants, future research should examine whether the effectiveness of CBM is reduced when completed online or at-home relative to typical delivery in a clinical or university setting. Development of gamified CBM tasks (e.g., "serious games") is underway and it will likely be necessary to adapt these tasks for tablets, smart phones, and laptops in the near future (Boendermaker et al., 2015; Flaudias et al., 2020).

4.4 Summary

Contemporary cognitive literature provides a strong argument that thoughts, behaviours, and emotions are influenced by both reflective and impulsive cognitive systems. The dual-process models of cognition have advanced our understanding of substance use behaviours (Stacy & Wiers, 2010). These models also provide insight into why traditional reflective-based prevention and intervention methods have limited effectiveness when preventing and treating substance use (Sheeran et al., 2013). Despite a growing body of research that suggests positive impacts of CBM training on substance use, the present study found mixed results. First, we found that EC had no impact on implicit cognitive cannabis bias, nor did EC have any impact on changing cannabis use behaviour. Although limited to the current parameters, using an aversive conditioning procedure to change cannabis cognitions or to gain control over actions and biases was ineffective and may not be a useful approach to substance use prevention. Other training parameters (e.g., stimulus timing and number of trials) may be effective, but it should be noted that in the Canadian setting, using an aversive training procedure encounters considerable resistance and raises ethical concerns. It may be argued that aversive conditioning counteracts overly positive biases and would enhance control over automatic responses. Nevertheless, the ethical and practical difficulties of using aversive methods strongly argues in favor of exploring alternative approaches (i.e., cognitive bias reduction procedures, Kahneman, 2011) to gain control over and mitigate the cognitive biases.

Second, we found that AAT training did reduce cognitive bias toward cannabis over six sessions. However, this reduction did not translate into reduction of cannabis use behaviour. Third, we found that demographic variables (i.e., age, gender, mental health diagnosis), cravings, and motives were better predictors of problematic cannabis use and frequency of cannabis use than were the cognitive measures used in this study (i.e., impulsive and reflective cannabis bias). In contrast to several studies (e.g., (Cousijn et al., 2012; Fulton et al., 2012; Robinson & Krank, 2018), this finding came as a surprise as we found little predictive value of implicit biases in our truncated sample of college student cannabis-users. In conclusion, the present research contributes to the CBM literature that uses cognitive methods to predict and treat substance use by examining the utility of CBM in a cannabis-using non-treatment-seeking undergraduate sample. Despite our mixed findings, we believe this study has succeeded in examining and testing important parameters of CBM training for cannabis use such that further studies in this area may meaningfully build upon our findings.

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Appendices

Appendix A: Picture Stimuli from the International Affective Picture System (IAPS)

Picture Number	Picture Number	Picture Number	Picture Number
1050	2722	6020	7400
1275	2791	6190	7492
1280	2800	6240	7499
1301	2811	6940	7501
1441	5000	7001	7502
1460	5001	7002	7508
1463	5010	7003	7521
1500	5020	7006	7570
1600	5030	7009	7660
1604	5040	7010	8030
1610	5130	7011	8162
1645	5199	7012	8330
1675	5200	7013	8350
1710	5201	7014	8461
1930	5202	7016	8485
1999	5210	7017	8490
2010	5300	7018	9001
2030	5301	7019	9008
2034	5470	7020	9031
2035	5471	7021	9050
2045	5480	7025	9090
2095	5535	7026	9280
2100	5700	7030	9290
2102	5725	7031	9291
2115	5726	7032	9295
2156	5740	7035	9300
2224	5750	7036	9301
2301	5760	7039	9325
2306	5779	7078	9341
2445	5780	7079	9395
2457	5800	7136	9404
2530	5811	7200	9417
2575	5829	7240	9421
2682	5831	7250	9470
2683	5833	7260	9495
2692	5849	7281	9600
2703	5973	7330	
2718	6010	7380	

<u>Positive Valence Stimuli Example</u>

Picture Number: 1710
Valence Rating: 8.34

Picture Number: 5700
Valence Rating: 7.61

<u>Negative Valence Stimuli Example</u>

Picture Number: 1275
Valence Rating: 3.30

Picture Number: 5973
Valence Rating: 3.51

Appendix B: Alcohol Use Disorders Identification Test

1. How often do you have a drink containing alcohol?
   - Never
   - Monthly or less
   - 2-4 times a month
   - 2-3 times a week
   - 4 or more times a week

2. How many standard drinks containing alcohol do you have on a typical day when drinking?
   - 1 or 2
   - 3 or 4
   - 5 or 6
   - 7 to 9
   - 10 or more

3. How often do you have six or more drinks on one occasion?
   - Never
   - Less than monthly
   - Monthly
   - Weekly
   - Daily or almost daily

4. During the past year, how often have you found that you were not able to stop drinking once you had started?
   - Never
   - Less than monthly
   - Monthly
   - Weekly
   - Daily or almost daily

5. During the past year, how often have you failed to do what was normally expected of you because of drinking?
   - Never
   - Less than monthly
   - Monthly
   - Weekly
   - Daily or almost daily

6. During the past year, how often have you needed a drink in the morning to get yourself going after a heavy drinking session?
   - Never
   - Less than monthly
   - Monthly
   - Weekly

- Daily or almost daily

7. During the past year, how often have you had a feeling of guilt or remorse after drinking?
- Never
- Less than monthly
- Monthly
- Weekly
- Daily or almost daily

8. During the past year, have you been unable to remember what happened the night before because you had been drinking?
- Never
- Less than monthly
- Monthly
- Weekly
- Daily or almost daily

9. Have you or someone else been injured as a result of your drinking?
- No
- Yes, but not in the past year
- Yes, during the past year

10. Has a relative or friend, doctor or other health worker been concerned about your drinking or suggested you cut down?
- No
- Yes, but not in the past year
- Yes, during the past year

Appendix C: Cannabis Outcome Expectancy Liking

This question asks you to tell us about what you think the effects of using cannabis would be. We do not assume that you have used cannabis. Please answer the question even if you do not use cannabis. We are interested in what you anticipate would happen.

Directions: Please enter the four most important things that you would expect or anticipate happening if you used cannabis. Then indicate how much you would like or not like this outcome if it happened.

What do you expect or anticipate happening? Type your response here.	How much would you like this outcome?				
	Like a lot	Like	Neither	Not like	Not like a lot
1.					
2.					
3.					
4.					

Appendix D: Cannabis Use Disorder Identification Test - Revised

Have you used any cannabis over the past 6 months? Yes No

If YES, please answer the following questions about your cannabis use. Please circle the response that is most correct for you in relation to your cannabis use over the past 6 months.

1. How often do you use cannabis?
   - Never
   - Monthly or less
   - 2-4 times a month
   - 2-3 times a week
   - 4 or more times a week

2. How many hours were you "stoned" on a typical day when you were using cannabis?
   - Less than 1
   - 1 or 2
   - 3 or 4
   - 5 or 6
   - 7 or more

3. How often during the last 6 months did you find that you were not able to stop using cannabis once you had started?
   - Never
   - Less than monthly
   - Monthly
   - Weekly
   - Daily or almost daily

4. How often during the last 6 months did you fail to do what was normally expected from you because of using cannabis?
   - Never
   - Less than monthly
   - Monthly
   - Weekly
   - Daily or almost daily

5. How often in the past 6 months have you devoted a great deal of your time to getting, using or recovering from cannabis?
   - Never
   - Less than monthly
   - Monthly
   - Weekly
   - Daily or almost daily

6. How often during the last 6 months have you had a problem with your memory or concentration after using cannabis?
- Never
- Less than monthly
- Monthly
- Weekly
- Daily or almost daily

7. How often do you use cannabis in situations that could be physically hazardous, such as driving, operating machinery, or caring for children?
- Never
- Less than monthly
- Monthly
- Weekly
- Daily or almost daily

8. Have you ever thought about cutting down, or stopping, your use of cannabis?
- Never
- Yes, but not in the past 6 months
- Yes, during the past 6 months

Appendix E: Comprehensive Marijuana Motives Questionnaire

This is a list of reasons people sometimes give for using marijuana. **Thinking of all the times you have used marijuana, how often would you say that you use for each of the following reasons?**	**Almost Never/ Never**	**Some of the time**	**Half of the time**	**Most of the time**	**Almost Always/ Always**
Because you were under the influence of alcohol					
Because it is readily available					
To relieve boredom					
Because it was a special day					
Because you felt peer pressure from others who do it					
Because you were depressed					
Because it is fun					
To be cool					
Because there are low health risks					
To allow you to think differently					
Because it is there					
Because you had nothing better to do					
To celebrate					
To forget your problems					
To enjoy the effects of it					
Because you were curious about marijuana					
Because you want to alter your perspective					
Because you can get it for free					
Because you wanted something to do					
Because you didn't want to be the only one not doing it					
To escape from your life					
To see what it felt like					
Because it is not a dangerous drug					
To help you sleep					
Because it was a special occasion					
Because you were experimenting					
Because it makes you more comfortable in an unfamiliar situation					
Because you had gotten drunk and weren’t thinking about what you were doing					
Because it is safer than drinking alcohol					
Because you are having problems sleeping					

Because it relaxes you when you are in an insecure situation					
Because you were drunk					
So you can look at the world differently					
To feel good					
Because it helps make napping easier and enjoyable					
To make you feel more confident					

Appendix F: Marijuana Craving Questionnaire-Short Form

Instructions*:* Indicate how strongly you agree or disagree with each of the following statements by placing a check mark in one of the spaces between STRONGLY DISAGREE and STRONGLY AGREE. The closer you place your check mark to one end or the other indicates the strength of your agreement or disagreement. If you don't agree or disagree with a statement, place your check mark in the middle space. Please complete every item. We are interested in how you are thinking or feeling **right now** as you are filling out the questionnaire.

1. Smoking marijuana would be pleasant right now.
STRONGLY DISAGREE ____ : ____ : ____ : ____ : ____ : ____ : ____ STRONGLY AGREE

2. I could not easily limit how much marijuana I smoked right now.
STRONGLY DISAGREE ____ : ____ : ____ : ____ : ____ : ____ : ____ STRONGLY AGREE

3. Right now, I am making plans to use marijuana.
STRONGLY DISAGREE ____ : ____ : ____ : ____ : ____ : ____ : ____ STRONGLY AGREE

4. I would feel more in control of things right now if I could smoke marijuana. STRONGLY DISAGREE ____ : ____ : ____ : ____ : ____ : ____ : ____ STRONGLY AGREE

5. Smoking marijuana would help me sleep better at night.
STRONGLY DISAGREE ____ : ____ : ____ : ____ : ____ : ____ : ____ STRONGLY AGREE

6. If I smoked marijuana right now, I would feel less tense.
STRONGLY DISAGREE ____ : ____ : ____ : ____ : ____ : ____ : ____ STRONGLY AGREE

7. I would not be able to control how much marijuana I smoked if I had some here. STRONGLY DISAGREE ____ : ____ : ____ : ____ : ____ : ____ : ____ STRONGLY AGREE

8. It would be great to smoke marijuana right now.
STRONGLY DISAGREE ____ : ____ : ____ : ____ : ____ : ____ : ____ STRONGLY AGREE

9. I would feel less anxious if I smoked marijuana right now.
STRONGLY DISAGREE ____ : ____ : ____ : ____ : ____ : ____ : ____ STRONGLY AGREE

10. I need to smoke marijuana now.
STRONGLY DISAGREE ____ : ____ : ____ : ____ : ____ : ____ : ____ STRONGLY AGREE

11. If I were smoking marijuana right now, I would feel less nervous.
STRONGLY DISAGREE ____ : ____ : ____ : ____ : ____ : ____ : ____ STRONGLY AGREE

12. Smoking marijuana would make me content.
STRONGLY DISAGREE ____ : ____ : ____ : ____ : ____ : ____ : ____ STRONGLY AGREE

Appendix G: Full Table - Motive and Craving Subscales Predicting Frequency of Cannabis Use at Session 1

Motive and Craving Subscales Predicting Frequency of Cannabis Use at Session 1

	B(SE)	95% CI		Wald	Exp(B)	*p*
		Lower	Upper			
			Motive Subscales [a]			
Enjoyment	.07 (.03)	.02	.12	6.94	1.07	.01
Conformity	-.09 (.04)	-.17	-.02	5.55	.91	.02
Boredom	.08 (.03)	.03	.14	8.64	1.09	.001
Alcohol Use	-.07 (.03)	-.13	-.02	7.50	.93	.01
Sleep	.07 (.02)	.03	.12	11.21	1.08	.001
Coping	.03 (.03)	-.03	.08	.81	1.03	.37
Experimentation	-.05 (.03)	-.10	.00	3.27	.95	.07
Celebration	-.01 (.03)	-.06	.05	.04	1.00	.85
Altered Perception	-.01 (.02)	-.05	.04	.07	.99	.79
Social Anxiety	.02 (.03)	-.05	.09	.40	1.02	.53
Relative Low Risk	.04 (.03)	-.01	.09	2.39	1.04	.12
Availability	-.03 (.03)	-.09	.03	1.16	.97	.28
			Craving Subscales [b]			
Emotionality	-.08 (.03)	-.13	-.03	8.41	.93	.001
Expectancy	.09 (.03)	.04	.14	13.84	1.10	.001
Purposefulness	.10 (.02)	.06	.13	31.97	1.10	.001
Compulsivity	.001 (.02)	-.04	.05	.001	1.00	.99

Note. CI = confidence interval; SE = standard error. [a] Model $\chi^2(12) = 155.46$, $p < .001$. [b] Model $\chi^2(4) = 109.00$, $p < .001$.

Appendix H: Full Table - Motive and Craving Subscales Predicting Frequency of Cannabis Use at Session 6

Motive and Craving Subscales Predicting Frequency of Cannabis Use at Session 6

	B(SE)	95% CI		Wald	Exp(B)	*p*
		Lower	Upper			
			Motive Subscales [a]			
Enjoyment	.12 (.03)	.06	.18	14.48	1.13	.001
Conformity	-.07 (.05)	-.17	.03	2.00	.93	.16
Boredom	.05 (.03)	-.02	.11	1.80	1.05	.18
Alcohol Use	-.01 (.03)	-.08	.05	.17	.99	.68
Sleep	.07 (.03)	.02	.13	7.52	1.08	.01
Coping	.02 (.04)	-.06	.09	.19	1.02	.66
Experimentation	-.08 (.03)	-.15	-.02	6.33	.92	.01
Celebration	.001 (.03)	-.06	.06	.002	1.00	.96
Altered Perception	-.01 (.03)	-.07	.05	.07	.99	.79
Social Anxiety	.05 (.04)	-.03	.14	1.62	1.06	.20
Relative Low Risk	.04 (.03)	-.02	.11	1.55	1.04	.21
Availability	-.05 (.04)	-.13	.03	1.75	.95	.19
			Craving Subscales [b]			
Emotionality	-.10 (.03)	-.16	-.03	8.24	.91	.001
Expectancy	.13 (.30)	.07	.19	19.51	1.14	.001
Purposefulness	.07 (.02)	.03	.11	13.01	1.08	.001
Compulsivity	.04 (.03)	-.02	.11	1.80	1.04	.18

Note. CI = confidence interval; SE = standard error. [a] Model $\chi^2(12) = 105.98$, $p < .001$. [b] Model $\chi^2(4) = 81.43$, $p < .001$.

Appendix I: Full Table - Motive and Craving Subscales Predicting Frequency of Cannabis Use at Session 7

Motive and Craving Subscales Predicting Frequency of Cannabis Use at Session 7

	B(SE)	95% CI		Wald	Exp(B)	*p*
		Lower	Upper			
			Motive Subscales [a]			
Enjoyment	.16 (.07)	.02	.30	5.04	1.17	.025
Conformity	.001 (.09)	-.17	.18	.001	1.00	.99
Boredom	.05 (.06)	-.06	.17	.80	1.06	.37
Alcohol Use	-.05 (.05)	-.16	.05	.96	.95	.33
Sleep	.08 (.05)	-.02	.18	2.57	1.09	.11
Coping	-.03 (.06)	-.14	.09	.19	.97	.66
Experimentation	-.14 (.05)	-.24	-.03	6.54	.87	.011
Celebration	-.09 (.05)	-.19	.01	3.16	.91	.08
Altered Perception	.07 (.05)	-.02	.16	2.61	1.08	.11
Social Anxiety	-.02 (.07)	-.16	.12	.07	.98	.79
Relative Low Risk	-.004 (.06)	-.12	.11	.004	1.00	.95
Availability	.03 (.07)	-.11	.17	.20	1.033	.65
			Craving Subscales [b]			
Emotionality	-.05 (.05)	-.15	.05	.89	.95	.35
Expectancy	.05 (.05)	-.05	.15	1.15	1.06	.28
Purposefulness	.05 (.03)	-.02	.12	2.28	1.05	.13
Compulsivity	.08 (.05)	-.02	.18	2.55	1.09	.11

Note. CI = confidence interval; SE = standard error. [a] Model $\chi^2(12) = 37.66$, $p < .001$. [b] Model $\chi^2(4) = 12.00$, $p = .017$.

Appendix J: Full Table - Motive and Craving Subscales Predicting Problematic Cannabis Use at Session 1

Motive and Craving Subscales Predicting Problematic Cannabis Use at Session 1

	B(SE)	95% CI		Wald	Exp(B)	*p*
		Lower	Upper			
			Motive Subscales [a]			
Enjoyment	.05 (.03)	-.002	.10	3.60	1.05	.06
Conformity	-.04 (.04)	-.11	.04	.94	.96	.33
Boredom	.03 (.03)	-.03	.08	1.00	1.03	.32
Alcohol Use	-.01 (.03)	-.07	.04	.30	.99	.58
Sleep	.01 (.02)	-.03	.05	.22	1.01	.64
Coping	.81 (.03)	.03	.14	8.31	1.09	.004
Experimentation	-.03 (.03)	-.08	.03	.92	.98	.34
Celebration	.02 (.03)	-.03	.07	.83	1.02	.36
Altered Perception	.001 (.02)	-.05	.05	.004	1.00	.95
Social Anxiety	.01 (.03)	-.05	.08	.18	1.01	.67
Relative Low Risk	-.01 (.03)	-.06	.05	.06	.99	.81
Availability	.02 (.03)	-.04	.07	.34	1.02	.56
			Craving Subscales [b]			
Emotionality	-.03 (.02)	-.08	.02	1.21	.97	.27
Expectancy	.05 (.02)	-.003	.09	3.37	1.05	.07
Purposefulness	.04 (.02)	.008	.07	5.87	1.04	.015
Compulsivity	.04 (.02)	-.002	.09	3.44	1.04	.06

Note. CI = confidence interval; SE = standard error. [a] Model $\chi^2(12) = 67.00$, $p < .001$. [b] Model $\chi^2(4) = 38.35$, $p < .001$.

Appendix K: Full Table - Motive and Craving Subscales Predicting Desire to Discontinue Cannabis Use at Session 1

Motive and Craving Subscales Predicting Desire to Discontinue Cannabis Use at Session 1

	B(SE)	95% CI		Wald	Exp(B)	*p*
		Lower	Upper			
			Motive Subscales [a]			
Enjoyment	-.05 (.03)	-.10	.01	2.99	.95	.08
Conformity	.02 (.04)	-.05	.10	.41	1.02	.52
Boredom	-.01 (.03)	-.06	.05	.04	.99	.84
Alcohol Use	-.02 (.03)	-.08	.03	.88	.98	.35
Sleep	-.02 (.02)	-.07	.02	.84	.98	.36
Coping	.07 (.03)	.01	.13	5.23	1.07	.02
Experimentation	.05 (.03)	-.01	.10	3.13	1.05	.08
Celebration	.01 (.03)	-.05	.06	.06	1.01	.82
Altered Perception	-.01 (.03)	-.06	.04	.26	.99	.61
Social Anxiety	-.002 (.03)	-.07	.06	.01	1.00	.94
Relative Low Risk	-.04 (.03)	-.10	.01	2.18	.96	.14
Availability	.01 (.03)	-.05	.07	.20	1.01	.65
			Craving Subscales [b]			
Emotionality	.04 (.03)	-.02	.09	1.80	1.04	.18
Expectancy	-.02 (.03)	-.08	.03	.74	.98	.39
Purposefulness	-.06 (.02)	-.09	-.02	9.31	.95	.002
Compulsivity	.05 (.03)	-.004	.09	3.21	1.05	.07

Note. CI = confidence interval; SE = standard error. [a] Model $\chi^2(12) = 25.59$, $p = .01$. [b] Model $\chi^2(4) = 18.48$, $p < .001$.