An Evidence-Based Review of Acute and Long-Term Effects of Cannabis Use on Executive Cognitive Functions

Rebecca D. Crean, PhD, Natania A. Crane, BA, and Barbara J. Mason, PhD

Abstract: Cannabis use may impair cognitive functions on a number of levels—from basic motor coordination to more complex executive function tasks, such as the ability to plan, organize, solve problems, make decisions, remember, and control emotions and behavior. These deficits differ in severity depending on the quantity, recency, age of onset, and duration of marijuana use. Understanding how cannabis use impairs executive function is important for clinicians. Individuals with cannabis-related impairment in executive functions have been found to have trouble learning and applying the skills required for successful recovery, putting them at increased risk for relapse to cannabis use. Here, we review the research on the acute, residual, and long-term effects of cannabis use on executive functions and discuss the implications for treatment.

Key Words: cannabis, marijuana, cognition, executive functions, treatment

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Consumption of cannabis for medical purposes is legal with a prescription in 15 states, and many states are in the process of decriminalizing nonmedical marijuana use. More than 97.5 million Americans older than 12 years have used illicit marijuana, and it is considered by many to be a benign recreational drug. However, evidence exists of significant harm for some individuals, with 1 in 10 users developing cannabis dependence (SAMHSA, 2007). Furthermore, 16% (~300,000) of all substance abuse treatment admissions in the United States were for cannabis-related disorders; this is second only to alcohol-related disorders (SAMHSA, 2006). It is estimated that more than 4 million Americans meet Diagnostic and Statistical Manual of Mental Disorders-IV (American Psychiatric Association, 1994) diagnostic criteria for cannabis dependence (SAMHSA, 2007). This figure has doubled from 2001 and will likely continue to grow. Thus, an understanding of the effects of cannabis on executive functions is likely to be of wide-spread clinical relevance.

Delta 9-tetrahydrocannabinol (THC) is the primary psychoactive constituent of the *Cannabis sativa* plant and is believed to be primarily responsible for the cognitive effects and the addictive potential of smoked cannabis. THC intoxication has been shown to impair cognitive function on a number of levels—from basic motor coordination to more complex tasks, such as the ability to plan, organize, solve problems, make decisions, remember, and control emotions and behavior. The higher level cognitive functions, termed executive functions (Table 1), are critically important, particularly when dealing with novel situations in which decisions must be made. This array of higher cognitive functions are vital for overriding and inhibiting responses that otherwise would be automatic or require little thought, such as continued substance abuse (Luria, 2002).

Some cannabis-related executive function deficits improve after cessation of cannabis use (Pope et al., 2002), but growing evidence suggests that other deficits persist after cannabis is discontinued (Bolla et al., 2005) and may hinder an individual's ability to make the best use of behavioral therapies, putting him or her at greater risk for relapse to cannabis use (Aharonovich et al., 2008; Blume and Marlatt, 2009). Adding to the complexity of this issue is the fact that many factors can impact cannabis-related impairment and recovery of executive functions, including age of onset of smoking cannabis, years of use, and amount of regular use (Grant et al., 2003). This clinical conundrum is compounded by the fact that treatment professionals may not be able to easily identify patients with cannabis-related impairment in executive functions without the benefit of neuropsychological assessment (Fals-Stewart, 1997).

Although there is convincing evidence that acute cannabis use generally affects cognitive and motor functions, it is less clear whether those deficits are short term and transient or whether they are more enduring. Previously published reports (Pope et al., 2001, 2002) using traditional neuropsychological assessment methods typically show a resolution of deficits by 28 days of abstinence. However, as neuroimaging technology has improved, more recent reports show subtle, long-term effects of cannabis on cognition and brain functioning (Bolla et al., 2005). In addition, newly published reports suggest that the deficits change depending on the amount of cannabis consumed and duration of use (Solowij et al., 1995, 2002; Grant et al., 2003). Adolescents who started smoking between the ages of 14 and 22 years and stopped by

From the Committee on the Neurobiology of Addictive Disorders, The Scripps Research Institute, La Jolla, CA.
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Send correspondence and reprint requests to Barbara J. Mason, PhD, Committee on the Neurobiology of Addictive Disorders, The Scripps Research Institute, 10550 North Torrey Pines Road, TPC-5, La Jolla, CA 92037. E-mail: mason@scripps.edu
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TABLE 1. Definitions of Key Aspects of Executive Functioning

Aspect of Executive Functioning	Definition
Attention	Process of selectively attending to one aspect of the environment while ignoring other things, includes divided and sustained attention to target stimuli
Concentration	Intense mental application
Decision-making	Process of selecting a course of action among several alternatives
Impulsivity	Initiation of behavior without adequate forethought as to the consequences of actions
Inhibition	Imposing restraint on behavior or another mental process; resistance to prepotent responding
Reaction time	Lapse of time between the presentation of a stimulus and a response
Risk taking	Engaging in behaviors that have the potential to be harmful or dangerous
Verbal fluency	Generating multiple, verbal responses associated with a specified conceptual category
Working memory	Ability to hold and manipulate information and remember it after a short delay

age 22 had significantly more cognitive problems at age 27 than their nonusing peers (Brook et al., 2008). In addition, adult cannabis users who began smoking before age 17, but not users who began smoking after the age of 17, had significant impairments in measures of executive functioning, including abstract reasoning, verbal fluency, and verbal learning and memory compared with controls (noncannabis users) (Pope et al., 2003). Understanding how cannabis use impacts executive functions is important for clinicians. Patients who routinely use cannabis may have deficits that make it difficult for them to adhere to treatment, to follow medical advice, and to experience successful outcomes.

LITERATURE SEARCH CRITERIA

A literature search was conducted through Medline and PsychInfo with no publication date restrictions. The search terms used were "marijuana," "delta-9-tetrahydrocannabinol," "THC," and "cannabis" crossed with "neuro," "cognitive," "assessment," "neuropsychological," "brain functioning," "executive functions," "impairment," or "clinical." Articles containing these search terms were included in this evidence-based review if they reported results of cannabis-related studies conducted in an adult, human population and used neuropsychological assessments to assess executive functions. Review articles, commentaries, preclinical studies, and those involving human children and adolescents were excluded.

ACUTE EFFECTS OF CANNABIS ON EXECUTIVE FUNCTIONS (0 TO 6 HOURS AFTER USE)

Smoking cannabis produces levels of THC in blood plasma that can be detected almost immediately and which reach peak concentrations within minutes (Grotenhermen, 2003). THC is fat soluble and, therefore, easily stored and released into the bloodstream (Grotenhermen, 2003). Because it is fat soluble, THC has a long half-life and can be detected in urine anywhere from 1 day to more than a month after ingestion (Huestis et al., 1996). The psychoactive effects of cannabis are experienced immediately after smoking, with peak levels of intoxication occurring after approximately 30 minutes and lasting several hours (Grotenhermen, 2003).

Researchers first began studying the acute effects of cannabis on neuropsychological functioning in the 1970s and consistently found disruptions in learning and memory functions (Ferraro, 1980). The findings on executive functioning, however, have been less clear (Pope et al., 1995). For the purposes of this review, literature reviewed for the acute effects of cannabis on executive functions are studies in which assessment took place within 6 hours since last use. The findings are detailed below.

Attention and Concentration

Attentional processing is the ability to use both divided and sustained attention when targeting a stimulus, and it is mediated by the frontal lobes (Grady, 1999). Several investigators studied the acute effects of cannabis specifically on attentional processing. Hart et al. (2001) studied the effects of placebo, light (1.8%), and heavy (3.9%) THC cigarettes in chronic, daily cannabis users and found no significant differences in the accuracy of response to attentional tasks. However, performance on a tracking task which requires sustained attention was found to improve significantly after the high dose of THC, relative to the other conditions. Similarly, Haney et al. (1999) found that after acute intoxication, daily cannabis users significantly improved on a task of divided attention. Morrison et al. (2009) tested light cannabis users 30 minutes after administration of either placebo or moderate (2.5%) THC cigarettes and found significant impairment in attention and concentration in the THC group compared with the placebo group. These discrepant findings may be explained by the characteristics of the subjects studied; Haney et al. (1999) and Hart et al. (2001) studied chronic, daily cannabis smokers, whereas Morrison et al. (2009) studied infrequent cannabis users. Hence, the disparate findings may be a function of sample differences involving degree of cannabis exposure and the degree of tolerance and other neuroadaptations resulting from long-term cannabis use.

Information processing is a fundamental aspect of attention and concentration and a basic building block of higher-order cognitive processing (Dosher and Sperling, 1998). Kelleher et al. (2004) evaluated information processing in heavy, chronic cannabis users compared with controls. Cannabis users completed a task when abstinent and then attempted the same task 30 minutes after smoking their "regular" amount of cannabis. They found that users in the abstinent state showed significantly slower information processing speed compared with controls; however, functioning normalized after smoking cannabis. According to the authors, this finding shows that abstinence after chronic cannabis use may result in a deficit in information processing, which normalizes after acute intoxication. They surmised that cannabis users who experience slowing of information process-

ing as a result of abstinence after chronic cannabis use may be at risk to resume smoking in an attempt to regain information processing abilities.

Decision-Making and Risk Taking

Decision-making and risk taking hinge on one's ability to anticipate and reflect on the consequences of one's decision; both are sensitive to frontal lobe disruption (Bechara et al., 2000) and have been a recent area of interest in cannabis research. Lane et al. (2005) found that subjects exposed to a high dose of THC (3.6%) demonstrated significantly greater risk taking than subjects receiving lower doses of THC. Conversely, similar studies by Ramaekers et al. (2006) and McDonald et al. (2003) found no significant differences in risk taking between groups.

Vadhan et al. (2007) tested chronic, daily cannabis users after administering placebo, light (1.8%), or heavy (3.9%) THC and found no differences in performance on decision-making tasks. The researchers did find, however, that both THC groups were significantly slower in decision-making than the placebo group. On another decision-making task Ramaekers et al. (2006) found that, compared with the placebo group, subjects receiving THC were significantly less likely to make correct decisions. In addition, those in the THC groups required longer planning times (latency to respond) than the placebo group. It seems then that the acute effects of cannabis on decision-making and risk taking are somewhat discrepant and may indicate a dissociable difference in functions. Overall, there is evidence that acute cannabis use may lead to observable deficits in aspects of planning and decision-making particularly with regard to response speed, accuracy, and latency.

Inhibition and Impulsivity

Drugs of abuse are often linked to an array of socially unacceptable, poorly controlled, and maladaptive behaviors, collectively referred to as impulsivity. Few controlled studies have investigated the effects of acute doses of cannabis on impulsive behavior. In one study of 37 adults with a history of light cannabis use, acute intoxication with a high dose of THC resulted in significant impairment on a measure of impulsivity (McDonald et al., 2003). Another study (Ramaekers et al., 2006) found similar impairment on a task of inhibition in intoxicated, chronic cannabis users. Given this evidence, it seems that acute cannabis use promotes more impulsive behavior and less inhibition of maladaptive responses.

Working Memory

Another measure of executive function is working memory. For more than 40 years, researchers have shown that cannabis consumption impairs working memory or the ability to hold and manipulate information and remember it after a short delay (Tinklenberg et al., 1970; Miller et al., 1977; Heishman et al., 1997). This finding has been replicated in present-day research. In a recent study of chronic cannabis users, Hart et al. (2001) found that acute intoxication resulted in significant impairment in working memory, and those subjects receiving a higher dose of THC (3.9%) took significantly longer to complete the task.

TABLE 2. A Summary of Research Findings on the Effects of Cannabis on Executive Functions

Executive Function Measured	Acute Effects	Residual Effects	Long-Term Effects
Attention/concentration	Impaired (light users) Normal (heavy users)	Mixed findings	Largely normal
Decision-making and risk taking	Mixed findings	Impaired	Impaired
Inhibition/impulsivity	Impaired	Mixed findings	Mixed findings
Working memory	Impaired	Normal	Normal
Verbal fluency	Normal	Mixed findings	Mixed findings

Acute effects denote 0–6 hours after last cannabis use; residual effects denote 7 hours to 20 days after last cannabis use; and long-term effects denote 3 weeks or longer after last cannabis use.

Verbal Fluency

Morrison et al. (2009) studied verbal fluency, or the ability to generate letters or words in a set amount of time, in recreational cannabis users 30 minutes after administering placebo or moderate (2.5 mg) THC. Compared with controls, they found no impairing effects on verbal fluency abilities.

Summary of Acute Effects of Cannabis on Executive Functions

Research assessing the effects of acutely administered doses of cannabis on executive functioning has yielded mixed results (Table 2). Evidence of the impairing effects of cannabis intoxication on attention and concentration is stronger in less experienced cannabis users than those with established drug tolerance; attention and concentration in the latter group is disrupted more by acute abstinence than acute cannabis administration, probably as a function of neuroadaptation to chronic, heavy cannabis use. Comparable effects were observed on tasks involving information processing, a function that is a basic building block for attention and concentration. Acute cannabis use has generally been found to impair aspects of planning and decision-making, for example, response speed, accuracy, and latency. Some studies also found risk taking increased with higher doses of cannabis. Acute, impairing effects of cannabis on tasks assessing inhibition and impulsivity have also been documented. Verbal fluency seems intact after acute cannabis administration, but cannabis-related impairments in aspects of working memory are well established.

RESIDUAL EFFECTS OF CANNABIS ON EXECUTIVE FUNCTIONS (7 HOURS TO 20 DAYS AFTER LAST USE)

Cannabis use may impact executive functions for several weeks. The literature reviewed for the residual effects of cannabis use on executive functions covers the period of time from 7 hours to 20 days since last use.

Attention and Concentration

Pope et al. (2001, 2002) tested current, heavy cannabis users, former heavy cannabis users, and control subjects on days 0, 1, 7, and 28 of abstinence. On all 4 occasions, no significant differences were found on attentional abilities. This finding was replicated by Jager et al. (2006). Contrary to those findings, however, Solowij et al. (1995, 2002) assessed long- and short-term cannabis users who were abstinent for 24 hours and found that their attention was significantly impaired, and they showed longer reaction times to complete the tasks, compared with controls. Solowij et al. (2002) also reported impaired information processing abilities in cannabis users compared with controls. Another study (Hermann et al., 2007) of recreational cannabis users with an unknown duration of abstinence reported poorer performance on attentional tasks, compared with controls.

Wadsworth et al. (2006) examined attentional capacities in "real world" situations; that is, right before work and immediately after work, at both the beginning and end of the work week. They found that, compared with controls, cannabis subjects had significantly impaired attention both at the beginning of the work week and at the end, which was significantly correlated with duration of cannabis use. This finding has implications for everyday activities, suggesting that even with abstinence, some attentional deficits remain.

Decision-Making and Risk Taking

In the single study assessing this domain, Whitlow et al. (2004) evaluated the performance of chronic, heavy cannabis users with at least 12 hours of abstinence on a task that simulates decision-making and risk taking. Compared with controls, the cannabis users had significantly impaired decision-making capacities and greater risk taking tendencies. More research is needed to augment the finding of residual cannabis effects on decision-making and risk taking.

Inhibition and Impulsivity

One of the first groups (Pope and Yurgelun-Todd, 1996) to study inhibition and cognitive flexibility in cannabis users examined heavy and light users after a minimum of 19 hours of abstinence. Heavy cannabis users demonstrated significantly more errors of inhibition and perseveration compared with light users. Solowij et al. (2002) replicated these findings in cannabis users after at least 12 hours of abstinence. The severity of these deficits was correlated with years of use. Several other researchers have found a similar pattern of impairment (Aharonovich et al., 2008; Cunha et al., 2010). In contrast, a number of researchers found no residual effects of cannabis use on inhibition or impulsivity (Whitlow et al., 2004; Gruber and Yurgelun-Todd, 2005; Hermann et al., 2007); however, these studies had small sample sizes (eg, $N = 10$), and the length of abstinence was unspecified or was highly variable, ranging from 12 hours to 18 years. Thus, although clear indication exists of impairment after acute cannabis intoxication, the residual effects seem less consistent. One possible explanation may be the samples sizes used in these studies lacked statistical power to detect differences. Studies that found significant differences had much larger sample sizes than those detecting no differences.

Working Memory

Pope and Yurgelun-Todd (1996) found no differences in working memory abilities between recently abstinent (19 hours) heavy and light cannabis users compared with control subjects. In addition, no significant differences were found in working memory abilities of recently abstinent cannabis users across multiple studies (Kanayama et al., 2004; Jager et al., 2006; Solowij et al., 2002; Whitlow et al., 2004; Fisk and Montgomery, 2008).

Verbal Fluency

Pope and Yurgelun-Todd (1996) also studied verbal fluency in cannabis users, and although they did not have a control group for comparison, they found no differences between heavy users and light users after a minimum of 19 hours of abstinence. More recently, Fisk and Montgomery (2008) replicated this finding in light users relative to controls. In contrast, McHale and Hunt (2008) analyzed verbal fluency in regular cannabis users (past 6 months), recent cannabis users (past 7 days), and controls. Subjects were tested 24 hours after their last use, and significant differences in verbal fluency were found between the cannabis and control groups. It is unclear why these findings are discrepant; however, one possible explanation is the difference in samples used. Pope and Yurgelun-Todd (1996) did not use a control group, and Fisk and Montgomery (2008) used very light users, whereas McHale and Hunt (2008) used more regular, frequent users.

Summary of the Residual Effects of Cannabis on Executive Functions

Investigations on the residual effects of cannabis on executive functioning show that recently abstinent cannabis users (7 hours to 20 days) may experience impairment in certain aspects of executive functioning. Attention, concentration, inhibition, and impulsivity may or may not continue to be impaired during the interval associated with the elimination of THC and its metabolites from the brain. Decision-making and risk taking capabilities have not been thoroughly studied during this period, but a single study by Whitlow et al. (2004) suggests that these abilities are impaired. In contrast to the acute effects of cannabis on working memory, deficits resulting from residual cannabis effects have not been found. The findings for verbal fluency are somewhat mixed, but may be due in part to sample differences in the degree of cannabis exposure. Studies showing the greatest deficits in executive functioning used subjects who had been smoking heavy amounts of cannabis for long periods of time. It is likely that residual impairments are linked to the duration and quantity of cannabis use.

LONG-TERM EFFECTS OF CANNABIS ON EXECUTIVE FUNCTIONS (3 WEEKS OR LONGER SINCE LAST USE)

The long-term effects of cannabis use have received the greatest research attention in recent years. Nevertheless, this area of the literature has been fraught with inconsistent findings and is complicated by discrepant

definitions of what constitutes "long-term effects." For the purpose of this review, long-term effects refer to 21+ days since last using cannabis, which ensures that both the acute and residual effects of cannabis in the brain have been essentially eliminated. Only a handful of researchers have examined these long-term effects of cannabis use on executive functions, as reviewed below.

Attention and Concentration

In 5 of 7 studies, no attention or concentration impairments were found in subjects who had remained abstinent from 28 days to 1 year (Lyons et al., 2004; Pope et al., 2001, 2002, 2003; Verdejo-Garcia et al., 2005). Conversely, of the 2 remaining studies, Solowij (1995) examined cannabis users abstinent from 6 weeks to 2 years and found significant impairment in selective attention and concentration. Likewise, Bolla et al. (2002) found long-term deficits in attention and concentration in a sample of heavy, chronic cannabis users abstinent for approximately 28 days.

Decision-Making and Risk Taking

Another cognitive construct recently examined in abstinent cannabis users is decision-making and risk taking. One study compared cannabis users, cocaine users, and control subjects who were abstinent 25 days and found a trend toward significant impairment in decision-making and risk taking in the cannabis group compared with controls and no differences in performance when compared with the cocaine group (Verdejo-Garcia et al., 2006).

Inhibition and Impulsivity

The majority of research assessing the long-term effects of cannabis on inhibition and impulsivity have used 2 different tests: the Stroop test or the Wisconsin Card Sort test (WCST). Studies using the Stroop test have consistently found no significant differences between cannabis and control groups (Lyons et al., 2004; Pope et al., 2001, 2002, 2003; Verdejo-Garcia et al., 2005). In contrast, studies using the WCST have all found significant differences (Bolla et al., 2002; Pope et al., 2001, 2002, 2003), with the exception of Lyons et al. (2004). That study examined male monozygotic twins who used varying amounts of cannabis (>1 time/wk for a minimum of 1 year vs <5 times in their life time) and found no differences between the siblings. The Stroop test requires active selection and, as a result, may require inhibition of some aspects of attention to produce the appropriate response (Kosmidis et al., 2006), whereas the WCST requires additional functions such as conceptualizing, developing, testing hypotheses, and inhibition (Huguelet et al., 2000). Both tests require the ability to perform set shifting and maintenance. It is possible that the discrepant findings in the cannabis literature may represent intact set shifting and maintenance but impairment in concept formation, planning, and sequencing.

Working Memory

The only known study to analyze the long-term effects of cannabis on working memory is Vardejo-Garcia et al. (2005). This study did not find any significant differences between abstinent cannabis users and polysubstance abusers. Perhaps, studies using a control group may yield more definitive findings in this area.

Verbal Fluency

Pope et al. (2001, 2002, 2003) examined verbal fluency after 28 days of abstinence. Performance differences between groups reported in the earlier studies were nonsignificant; however, the most recent study showed significant differences between groups on verbal fluency. This later study divided the cannabis groups based on age of onset (early and late) and compared their performance with a control group. Early onset cannabis users (who began smoking before 17 years of age) demonstrated significant impairments in verbal fluency compared with controls. These findings suggest that age of onset, and possibly years of use, mediates the impact of the long-term effects of cannabis on verbal fluency.

Summary of the Long-Term Effects of Cannabis on Executive Functions

Cannabis seems to continue to exert impairing effects in executive functions even after 3 weeks of abstinence and beyond. Although basic attentional and working memory abilities are largely restored, the most enduring and detectable deficits are seen in decision-making, concept formation, and planning. Verbal fluency impairments are somewhat mixed at this stage. Similar to the residual effects of cannabis use, those studies with subjects having chronic, heavy cannabis use show the most enduring deficits following three weeks or more abstinence.

TREATMENT IMPLICATIONS

Few fully controlled treatment studies for cannabis dependence have been published and those focus primarily on motivation enhancement therapy, cognitive behavioral therapy, or a combination of the two (Nordstrom and Levin, 2007). High relapse rates were found, which were comparable with those for alcohol, tobacco, and other drugs of abuse, but were better than those for a delayed treatment control group (Stephens et al., 2000). A review of these studies by Nordstrom and Levin (2007) concluded that psychotherapy has been shown to reduce cannabis use, but that no form of psychotherapy performs significantly better than another in terms of reduced use, and longer psychotherapy studies do not provide any added benefit over shorter studies (ie, 3 months vs up to 15 months).

When a patient presents for treatment with a cannabis use problem, the treatment provider may wish to consider obtaining a neuropsychological assessment of executive functions, as deficits may have important implications for treatment outcome. Neuropsychological studies in adult cannabis users show deficits in multiple areas of executive functioning (eg, attention, decision-making, and inhibition). As discussed previously, deficits in executive functioning may be long lasting in some individuals and may impact everyday functioning. In addition, it is important to determine the age of onset of cannabis use, as cannabis use typically begins in adolescence, while the brain is still maturing. A number of

studies examining executive function across adolescence and early adulthood found abilities such as planning, inhibition, and decision-making continue to develop in early adulthood (Romine and Reynolds, 2005; Rubia et al., 2006; Eshel et al., 2007). Cannabis use throughout adolescence and young adulthood may impair achievement of such developmental milestones in executive functioning, such that deficits persist after establishing abstinence.

Behavioral therapies for the treatment of cannabis dependence rely on intact cognitive functions, yet the implications of cannabis-related cognitive impairments on treatment outcome have received little attention. On a related note, studies in alcohol-dependent subjects suggest that executive function impairments have a negative impact on treatment success (Gottschalk et al., 2001; Bates et al., 2006). Cognitive impairment has also been generally associated with poorer drug abuse treatment outcomes (Crawford, 1978; O'Leary et al., 1979; Abbott and Gregson, 1981; Aharonovich et al., 2008), and these deficits have been found to impede acquisition of new coping behaviors (McCrady and Smith, 1986), learning and retention of new material (Alterman and Hall, 1989), and to increase the likelihood of treatment dropout (Teichner et al., 2002).

The long-term executive functioning deficits associated with cannabis dependence and the associated risks for poor treatment outcome suggest that cognitively impaired cannabis users may not respond optimally to standard cognitively oriented treatment, such as cognitive behavioral therapy (Aharonovich et al., 2008). In fact, concern has been expressed that cognitive therapy approaches may not be effective with patients who have cognitive deficits (Verdejo-Garcia et al., 2004). A first-line approach may be to expose these patients to cognitive rehabilitative strategies—such as encouraging them to check and double check their work, to give themselves ample time to complete a task, to build in delays before responding, the use of repetition and cues to remember important tasks and information and to write things down, so that they can weigh the costs and benefits of their actions instead of reflexively responding. More research is needed in this area, both to better understand the complex effects of executive functioning and treatment outcome and to identify the methods for optimizing treatment outcome in patients with cannabis-related impairments in executive function (Blume and Marlatt, 2009).

CONCLUSIONS

Prevalence rates for cannabis use have increased in recent years (SAMHSA, 2007), and as such, chronic, heavy cannabis use is a growing health concern. Research on the effects of cannabis on cognition has generally lagged behind studies on the cognitive effects of alcohol, cocaine, methamphetamine, and heroin, and only recently seems to be gaining momentum. Even less attention has been given to the effects of cannabis on executive functions. There are some important methodological differences to take into consideration when interpreting the sometimes disparate results of studies of cannabis effects on executive functions, such as the recency, amount, duration, and age of onset of cannabis use.

The trajectory of effects of cannabis on executive functions follows an interesting pattern of recovery of some functions and persisting deficits in others (Table 2). The acute effects of cannabis use are evident in attentional and information processing abilities with recovery of these functions likely after a month or more of abstinence. Decision-making and risk taking problems are not necessarily evident immediately after smoking; however, if cannabis use is heavy and chronic, impairments may emerge that do not remit with abstinence, particularly if heavy use was initiated in adolescence, such that maturation of executive functions was not achieved. Acute cannabis use impairs inhibition and promotes impulsivity, and over a period of abstinence, these deficits are most evident in tasks that require concept formation, planning, and sequencing abilities. Working memory is significantly impaired after acute exposure to cannabis; however, these deficits resolve with sustained abstinence. Evidence is less clear in regards to verbal fluency abilities; however, research suggests that chronic, heavy use may impact verbal fluency abilities even after long-term abstinence. The long-term effects of cannabis on executive function is most clearly demonstrated when studies use chronic, heavy cannabis users, as opposed to light, occasional users. Yet even occasional cannabis use can acutely impair attention, concentration, decision-making, inhibition, impulsivity, and working memory.

An understanding of the effects of cannabis use on executive functions has considerable practical utility in the clinical setting. The consolidation of findings in this review can provide clinicians with an overview of the documented effects of cannabis use on executive functions as they relate to age of onset, duration, quantity, and recency of use with consequent treatment implications. With this information, clinicians can inform their patients who are regular, heavy, cannabis users of the cognitive liabilities associated with continued use and better understand the impairments their cannabis-abusing patients experience in comprehending, processing, and following-through on important health and treatment advice relevant to sustaining their recovery.

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