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Cannabis-related deficits in real world memory

Running Head: Cannabis and real world memory.

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Abstract

Background: Research shows that cannabis users exhibit deficits in prospective memory and executive function which persist beyond acute intoxication. However, many studies rely on self-reports of memory failures or use laboratory-based measures which may not mimic functional deficits in the real-world. The present study aimed to assess real-world memory functioning. *Method:* Twenty cannabis-only users and 20 non-illicit drug users were recruited. Participants completed a substance use inventory and a mood scale, followed by a non-immersive virtual reality task assessing prospective memory and executive functioning. The task involves the participant playing the role of an office worker for the day, and performing routine office duties. There are a number of subscales assessing facets of executive function (planning, adaptive thinking, creative thinking, selection, prioritisation) and prospective memory (time-based, event-based and action-based prospective memory). *Results:* MANOVA revealed cannabis users performed worse overall on the task, with poor performance on the planning, time-based prospective memory and event-based prospective memory subscales. In addition, indices of cannabis (length, dose, frequency, total use) were correlated with performance on these 3 subscales. *Conclusions:* The present study expands on previously established research, providing support for the cannabis-related deficits in prospective memory and executive functioning, and the role of different aspects of cannabis use in these deficits.

Keywords: cannabis; prospective memory; executive function; virtual reality.

CONFLICTS OF INTEREST

NONE

Introduction

Cannabis is the most commonly used recreational drug in Britain, with 1 in 6 young adults (aged 16-24), having used cannabis in the last year (Flatley et al. 2010). It is also the most consumed drug worldwide, with the number of users estimated between 20,850,000 and 20,990,000 in western central Europe in the last year, (UNDOC, 2010). Given the high levels of use of cannabis, any potential adverse effects should be cause for concern. The present paper assessed the effects of cannabis on memory using a laboratory-based non-immersive virtual reality paradigm.

The main active ingredient in cannabis, Δ^{9-}tetrahydrocannabinol (THC), exerts its effects on the endogenous cannabinoid system at specific cannabinoid receptors, labelled CB_1 and CB_2 receptors, which usually interact with the endogenous ligand anandamide, (Ashton 2001; Buttner. 2011; Lichtman et al. 2001). CB_1 receptors are particularly dense in the basal ganglia, substantia nigra, hippocampus and the cerebellum, (Ashton, 2001; Buttner, 2011; Lichtman, et al. 2001) within the brain and are located presynaptically in neuronal lipid membranes. Activation of these receptors by exogenous cannabinoids, such as THC inhibits synaptic transmission, (Ashton, 2001; Buttner, 2011; Lichtman et al. 2001). Due to this inhibition of synaptic transmission and the lipid membranes the receptors reside in, they act as neuromodulators; thus the endocannabinoid system can modulate neuronal activity of other transmitter systems, (Ashton, 2001; Pattij et al, 2008). This modulation produces concomitant changes in a number of neurochemical systems in the hippocampus, changes in glutamatergic, GABAergic and cholinergic systems (Pattij et al. 2008), that are responsible for the processes involved in memory, (Lichtman et al, 2001; Riedel & Davies, 2005), with cannabinoids having a detrimental effect on the prefrontal cortex mediated functions (Lafourcade et al. 2007). The discovery of this specific endogenous cannabinoid system and distribution of their receptors is consistent with the profile of effects of cannabinoids, on memory and executive functions, (Ashton, 2001; Buttner, 2011; Lichtman et al, 2001; Sim-Selley, 2003)

Using laboratory based measures of memory, there is extensive research suggesting that the use of cannabis has a detrimental effect on memory, attention and learning (Grant et al. 2003; Lundqvist, 2005; Montgomery & Fisk 2008; Pope et al. 2001; Pope, 2002; Pope et al. 2003; Solowij et al. 2002; Solowij & Battisti, 2008). Solowij & Battisti (2008) reviewed evidence of cannabis related impairments, specifically examining literature on memory function of cannabis users while unintoxicated. They found impairments in encoding, storage, manipulation, and the retrieval mechanism of memory in long term cannabis users, with dose, frequency of use and age of onset being associated with the impairments. Furthermore, it has been proposed that cannabis affects prospective memory, to a greater extent than it affects working memory (Bartholomew et al. 2010; Fisk & Montgomery, 2007; Montgomery et al. 2005; Montgomery et al. 2010; Rogers et al. 2001). Prospective memory refers to remembering to perform an action at a certain time point in the future i.e. formation of an intention followed by the execution of that intended action (Rendell et al. 2009). Recent research suggests that PM is supported by the medial temporal lobes (MTL), with MTL patients performing more poorly on PM tasks (Adda et al. 2008), and the hippocampal areas which are activated longer during both prospective and retrospective tasks (Martin et al. 2007). More broadly, PM also relies on prefrontal structures and is supported by working memory and executive processes (Marsh & Hicks 1998), which also rely on prefrontal areas (Okuda et al. 2007).

Previous research has shown that some cannabis-related memory deficits appear to subside with increasing periods of abstinence, particularly after a wash-out period (Pope et al, 1995). However, many studies still show cannabis-related memory impairments after the acute intoxication, and residual intoxication periods implying a longer-term deficit. Regarding memory and executive functioning, Fisk & Montgomery (2007) looked at ecstasy poly-drug users' self reports of failures in prospective memory. Cannabis use was found to be a significant predictor of deficits in prospective memory. This was supported by Bartholomew et al. (2010) who also looked at ecstasy poly drug users using self report measures, finding cannabis use to be a significant predictor of performance on prospective memory. Harvey et al, (2007) found adolescents who regularly used cannabis (more than once a week), to be impaired on a number of cognitive measures. Using CANTAB, cannabis use was found to be an independent predictor of poor performance on working memory and strategy measures. However, cannabis users had only abstained from use for 12 hours prior to the study and thus could have still been acutely intoxicated (Pope et al, 1995). Looking specifically at cannabis users, assessing real world memory and executive processes Fisk & Montgomery (2008), found cannabis users to be impaired on a number of aspects of real world memory function, but not impaired in regards to the executive processes underlying real world memory.

Regarding the subcomponents of executive functioning, Skosnik et al. (2001) used a negative priming task to assess inhibition in current and previous cannabis users and controls. Accuracy was not significantly different between the groups although current cannabis users did get a more positive negative-priming score, indicating disinhibition or absence of negative priming, while previous users and controls showed normal negative priming. Solowij et al. (2002) found that short and long term cannabis users were impaired on a demanding version of the Stroop task where inhibitory control required is high, with duration of cannabis use being related to performance. However, all effects were reduced to below statistical significance following removal of those with THC metabolites in their urine.

Similarly, Pope et al. (1997) found no significant differences between cannabis users and nonusers on the Stroop. Cannabis users have also shown impairments in decision making in a gambling task, continually choosing from the less advantageous deck, where nonusers learnt to choose advantageously (Whitlow et al. 2004). When assessing memory updating using a paradigm similar to the n-back task, Ehrenreich et al. (1999) found no differences between early and late onset cannabis users, and performance was not related to levels of THC metabolites in the urine. However, using a memory updating task, Solowij et al. (2002) found that long-term users recalled significantly fewer items than short-term users, controls and published norms on auditory consonant trigrams. Attention switching has also been assessed in cannabis users. Ehrenreich et al. (1999) found no group differences between early onset users, late onset users and controls. In addition, performance was not correlated with the presence of urinary THC metabolites. Solowij et al. (2002) used the Wisconsin Card Sort Task and the alphabet task to assess switching in long-term cannabis users, short-term users and controls. On the WCST, no significant differences were observed on any of the dimensions, but there was a trend towards significance in maintaining mental set: with long-term users failing to maintain set more often than short-term users and controls. On the alphabet task, the time taken to complete the alternating condition of the task increased with increasing duration of use, as did the times taken on alternating and difference trials (which the authors state is an indication of interference and a lack of cognitive flexibility). This was however reduced to below statistical significance following removal of those with THC metabolites in their urine, suggesting that it may be more related to recent cannabis use. Whitlow et al. (2004) used the CANTAB intra- and extra-dimensional shift task and found a trend towards a cannabis effect with users giving more errors than nonusers. McHale & Hunt (2008) who used verbal recall as a measure of executive functioning found cannabis use impaired executive functioning and short and long-term internal prospective memory.

Lundqvist (2005) associated heavy use of cannabis with reduced function of the attentional/ executive system demonstrated by the impairments in mental flexibility and shifting of attention. In addition Verdejo- Garcia et al, (2005) also found heavy long term cannabis users to be impaired on cognitive flexibility measure. In summary, it appears that different aspects of cannabis use can contribute to performance levels. For example, length of use (Solowij et al. 2002), period of abstinence (Skosnik et al. 2001) and age of onset (Ehrenreich et al. 1999). These aspects of cannabis use will be examined through correlation with performance in the present study.

Advances in technology with the development of virtual reality have lead to further improvements in the methodologies used in cognitive psychology that attempt to address the limitations with self-reports and laboratory tasks, offering real-world function testing through the use of simulated settings (Rizzo et al. 2002). Laboratory-based virtual reality tasks (usually of a non-immersive nature) have documented deficits in executive functioning in clinical populations, with a wide range of conditions and functional deficits (Rizzo et al. 2004; Schultheis et al. 2002), and patients with frontal lobe damage (Jansari et al. 2004) that are found to perform normatively on traditional measures of executive functioning despite reporting daily problems with these functions. Previous research has proposed that this is due to the lack of ecological validity of the laboratory task (McGeorge at al. 2001). In drug users, non-immersive VR technology has been used to investigate some aspects of cognition previously. Rendell et al. (2007) found ecstasy users to be significantly impaired on time-based tasks in their completion of the virtual week task. Montgomery et al. (2010) investigated the functional significance of ecstasy-related memory deficits using the JAAM task to measure prospective memory and executive functioning. They found ecstasy poly-drug users to perform significantly worse on the JAAM task, with frequency of cannabis use significantly correlated with poor performance on the planning subscale of the JAAM task, specifically frequency of use and use in the last 30 days.

In summary, previous laboratory research investigating prospective memory and executive functioning in cannabis users has found selective deficits. Such tasks may not reflect problems that cannabis users would have in the real world. The present study sought to investigate this. Based on previous research it was predicted that cannabis users would be impaired on all of the prospective memory scales. Cannabis users have been found to have impairments on strategic measures tasks involving planning, (Harvey et al. 2007), with cannabis use in ecstasy-polydrug users also significantly correlated with poor performance on the planning subscale of the JAAM task, (Montgomery et al. 2010). Thus it seems reasonable to expect that cannabis users in the present study will perform worse on the planning subscale of the JAAM. In addition research has shown evidence of cannabis related impairment in shifting of attention, and mental flexibility (Lundqvist, 2005; Verdejo-Garcia et al. 2005).

Various indices of cannabis use have been implicated in cannabis-related deficits in previous research. In particular, long-term heavy user (Pesa & Solowij, 2010), average dose (Bolla et al, 2002), and THC concentration within the cannabis used (Shannon et al, 2010) appear to be particularly important. Consequently, indices of cannabis use will be calculated, and where relevant, will be incorporated in to the analyses as necessary.

Method

Design

A between groups design was used; the independent variable was user group status (non-users vs. Cannabis users). Dependent variables were the scores on the JAAM task. The JAAM scores were analysed using a MANOVA, with correlations between JAAM scores and drug use indices.

Participants

Forty participants were recruited from the Liverpool John Moores University undergraduate student population using the SONA Experiment Management Scheme and through snowball sampling. Twenty were cannabis users[1], (13male; mean age 21) and the other 20 were non-illicit drug users (7male, mean age 20)[2]. All participants were of white British origin and were right handed. Participants were eligible to participate if they were aged between 18 and 25. Participants in the cannabis user group should have used cannabis at least 4 times in the last month, and were requested to have not smoked cannabis in the 5 days prior to testing (Mean abstinence period 2.15 weeks, SD 2.25). Participants in the nonuser group reported no illicit drug use. Participants were not eligible to take part if they had ever been diagnosed with an alcohol or substance use disorder. In addition, participants were excluded if they had a neurological disorder (e.g. migraine, epilepsy, dyslexia), were currently taking medication that may affect Central Nervous System Functioning (e.g. antipsychotics, antidepressants) or had a history of illicit drug use other than cannabis use.

<<Insert Table 1 About Here>>

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[1] All cannabis users reported smoking resin, with the exception of 1 who also smoked skunk.

[2] Gender distribution between the groups was comparable χ^2 (df = 1; N = 40) = 3.60, p>.05.

Materials

Substance Use (Montgomery et al, 2005)

Previous and current drug and alcohol use was assessed using a substance use inventory developed by Montgomery et al. (2005). The questionnaire assesses various the frequency and intensity of the use of various drugs. The questionnaire also measures background variables including self-rated health, education, qualifications, employment status, and living arrangements.

UWIST Mood Adjective Checklist UMACL (Matthews et al, 2004)

Mood was measured using the UWIST Mood Adjective Checklist (UMACL- Matthews et al. 2004). This is an 18 item checklist, and participants have to indicate how they are feeling at the time of testing on a 5–point Likert scale ranging from "not at all" to "extremely". The test yields scores for State Anxiety (items include: tense, calm), Arousal (items include: fatigued, alert) and Depressed Mood (items include: sad, cheerful). A total score for each scale is calculated by summing the component responses, taking account of reverse scored items, thus a high score (above the midpoint of 18) is indicative of higher levels of anxiety, arousal and depression.

JAAM (Jansari et al, 2004)

Prospective memory and executive functioning were assessed using the JAAM task (Jansari et al. 2004). The JAAM task is a laboratory-based non-immersive virtual reality assessment set in an office where the participant has to play the role of an assistant for the day. It was originally designed for assessing various abilities that individuals with dysexecutive syndrome have difficulties with, and has been used to look at ecstasy-related deficits in executive functioning, and the effects of acute alcohol intoxication on executive functioning (Montgomery et al. 2010; Montgomery et al. 2011).

Participants are given a scenario to read, describing their role and the virtual environment of the office, followed by a list of tasks that their manager has left for them to complete. The tasks include, noting down times of fire alarms, completing and updating the post diary at different times, organising chairs and tables for a meeting. Throughout the task participants are given memos (virtual and hard copy), which require either the performance of an additional task or amendment of another.

The JAAM assessment consists of eight constructs: Planning, Prioritisation, Selection, Creative thinking, Adaptive thinking, Action-based prospective memory, Event based prospective memory, and Time based prospective memory.

The Planning subscale: requires the participant to write a plan of action of the tasks given to them by their manager, they then have to logically order the tasks in relation to the 3 main events: the meeting, post and event based.

Prioritisation subscale: the tasks for this require ordering of items, based on their importance, as an example, within the task the participant is given a list of agenda topics that they have to make a selection from, they have to choose which of the topics should be discussed first.

For the Selection subscale: participants must use knowledge to decide between 2 or more options, for example they are told a parcel needs to be sent by a certain time and they have to decide what company to use.

Creative thinking subscale: this involves problem solving, the participant has to find a solution to a problem that they have not been informed of, such as dealing with a leak in the roof of the meeting room.

Adaptive thinking : this requires participants to come up with solutions to arising problems, an example being, arranging for another company to pick up the post when the company postman does not arrive.

Action-based prospective memory (ABPM): this requires the participant to perform a task that is cued to them, whilst they are currently performing another task, such as receiving a memo about an item of post that needs sending urgently, which then needs to be updated on to the post diary.

Event-based prospective memory (EBPM): participants have to remember to perform a task that is cued by an event, such as turning on the coffee machine when the first person arrives for the meeting, as cued by a memo saying the first person has arrived for the meeting.

Time-based prospective memory (TBPM) : for this participants have to remember to 'do something' at a certain point in time, such as indicating whether the postman has arrived, after being informed what time he will arrive.

It takes 40 minutes to complete the JAAM task. Each construct has sub-tasks which participants receive a score of 0 (no attempt made), 1 (satisfactory performance), or 2 (perfect performance), a standardised JAAM score sheet is used when measuring each subscale (see appendix 3).The scores on each subset were worked out to percentages of each subscale, by dividing the participants actual score by the total score possible and multiplying by 100.

Procedure

The experiment took place in a quiet laboratory. Participants were informed of the general aim of the experiment, and gave written informed consent. First, participants completed the substance use inventory and UMACL. After this they completed the JAAM task. On completion of the JAAM task, participants completed Raven's progressive matrices (Raven et al. 1998) and were debriefed and given information regarding drug education websites. Ethical approval for the research was granted by Liverpool John Moores University Research Ethics Committee and all ethical guidelines of the British Psychological Society were followed.

Results

Background variables for cannabis users and non-users are displayed in Table 2. The mean age of participants was comparable $t(38) = -.67$, $p > .05$. There were no significant differences between the groups in terms of weekly alcohol consumption $t(37) = -.85$, $p > .05$, or Fluid Intelligence $t(38) = -0.74$, $p>.05$. Differences in state mood were also non-significant between the groups; For arousal, $t(28.90) = 1.41$, $p>.05$; for anxiety $t(25.34) = .63$, $p>.05$; and for depression, $t(27.66) = .54$, $p>.05$[3].

<<Insert Table 2 about here>>

The exclusion criteria excluded any other drug use other than cannabis. Indices for the use of cannabis in the cannabis user group are displayed in Table 1. Cannabis use in the user group was moderately high; cannabis users reported frequent use of cannabis, with an average of 4 times a week, with average life time dose of 6,042 joints.

Cannabis users scored lower than non users on all of the JAAM subscales, with the exception of the selection and action based prospective memory subscales (see Table 3 and Figure 1). The JAAM subscale scores were analysed using MANOVA. There was a significant main effect of cannabis use on the JAAM task, showing that overall cannabis users were impaired $F(8,31) = 3.23$, $p<.01$; wilks $\lambda =.55$, (Partial Eta squared of 0.454).Univariate analyses revealed that this was due to cannabis user's significantly worse performance on the planning subscale $F(1,38)= 6.21$, $p<.05$, (Partial Eta squared of 0.140) time based prospective memory subscale $F(1,38) = 4.87$, $p< .01$, (Partial Eta squared of 0.114) and event based prospective memory subscale $F(1,38)= 19.45$, $p< .001$, (Partial Eta squared of 0.338).

[3] For the mood t-tests, Levene's test was significant so degrees of freedom have been adjusted accordingly.

<< Insert Table 3 and Figure 1 about here>>

Relationship between indices of cannabis use and performance

To investigate the relationship between indices of cannabis use and performance, non-parametric (Spearman's) correlations were performed between the indices of cannabis use and JAAM subscales. A full Bonferroni correction is not appropriate in this case, as the performance measures are intercorrelated (Sankoh et al. 1997). However multiple comparisons remain potentially problematic, therefore an intermediate level of correction has been used, with correlations being evaluated at $p<.01$. The coefficients are displayed in Table 4. There were a number of significant correlations between indices of cannabis use and performance. All indices were significantly correlated with planning, EBPM and TBPM. For planning, amount of cannabis used in the last 10 days had the highest correlation coefficient, for EBPM and TBPM, average nightly dose had the highest correlation coefficient.

<<Insert Table 4 About Here>>

Discussion

The present study found cannabis users to be impaired on a laboratory-based non-immersive virtual reality task measuring executive functioning and prospective memory, with worse overall performance than non-users. Cannabis users were found to perform significantly worse than non-users on the Planning, time-based and event-based prospective memory subscales of the JAAM task, thus supporting the cannabis related deficits in prospective memory and executive functioning.

These findings are generally supportive of previous research in cannabis users. In previous studies looking at cannabis use and tasks which may require planning (e.g. the TOL and TOH), acute cannabis intoxication seems to be an indicator of impaired performance (Raemakers et al.2010). Cannabis users were found to be significantly worse on the Planning subscale of the JAAM task. This required logical organisation of tasks into 3 subsets of task, based on what they were about; meeting, post and events. In terms of functional significance, this proposes that cannabis users have difficulty in being able to order tasks logically and may struggle with logical planning in real-world settings.

Cannabis users were also found to be significantly impaired on the time-based prospective memory subscale of the task. This suggests that cannabis users will find it difficult to remember to perform an action at a certain time and is generally supportive of previous research showing cannabis to affect time-based prospective memory in animal and human studies (Pattij et al. 2008). In addition, this is consistent with cannabis users' self-reports of their memory failures in questionnaire-based studies (Heffernan et al. 2001; Montgomery & Fisk 2007; Rodgers et al. 2001). The present study also found cannabis users to be significantly impaired on event-based prospective memory. This required the performance of a task cued by an event, thus in terms of functional significance, cannabis users may find it difficult to perform an action that is cued by another event, for example remembering to make a dentist appointment when cued by driving past the dental surgery, remembering to return a library book when cued by walking past the library. Research shows that these two types of prospective memory (event based cued by an external event, and time based cued by the time elapsed) utilise distinct neural processes/areas in addition to the shared medial temporal regions mentioned previously. Burgess et al. (2003) and Gilbert et al. (2005) found that event-based PM activates frontopolar areas, and frontal patients perform particularly poorly in this aspect of PM tasks (Fleming et al. 2008). While time-based tasks do utilise frontopolar structures, the areas activated are more diverse (Okuda et al. 2007). Consequently, any cannabis-related neuronal changes could be localised in these areas and future research should seek to confirm this.

Contrary to expectations cannabis users were not found to be significantly impaired on the action-based prospective memory subscale of the JAAM task. In addition cannabis users were also not found to be significantly impaired on the four other subscales of the JAAM task. Previous research using laboratory-based measures of executive functioning in cannabis users had found selective deficits. Cannabis users were generally impaired on tasks that required inhibition of prepotent responses, especially where inhibitory demands were high (Solowij et al. 2002), and in addition, many of the tasks used to assess mental flexibility or attention shifting (e.g. Solowij et al. 2002; Whitlow et al. 2004) had shown a trend towards a cannabis effect. In addition, previous research using laboratory tasks has shown that cannabis users may make disadvantageous decisions on gambling task (e.g. Whitlow et al. 2004). The lack of a significant cannabis-related effect on flexible thinking and adaptive thinking in the present study suggests that in real-world settings, cannabis users may not be impaired in their ability to think flexibly and shift their attention in relation to task demands. Neuroimaging has furthered our understanding of cannabis related deficits in terms of the underlying structural and functional differences associated with cannabis use. Indeed, areas supporting executive functions are comparable with areas found to have structural and functional anomalies in cannabis users (Ashton, 2001; Buttner, 2011; Lichtman et al, 2001; Sim-Selley, 2003). Animal studies suggest an increased turnover in neurotransmitters in the prefrontal cortex following cannabis use (Jentsch et al. 1998; Vericco et al. 2003), a reduction in the turnover of dopamine in the medial prefrontal cortex (Vericco et al, 2003), and alterations in the hippocampus and hippocampal regions (Nava et al, 2001; Scallet et al, 2003). However, some research has found evidence showing no damage to the hippocampus, (De Lisi et al. 2006; Tzilos et al. 2005). Studies in human cannabis users have found decreased activity in the hippocampus, (Ashtari 2011; Yucel et al. 2008). Yucel et al (2008) suggest that the localised hippocampal volume in cannabis users is associated with increasing cumulative cannabis exposure. Nestor et al, (2008) found higher bold activity in the right parahippocampal gyrus during task performance and propose that long term cannabis users exhibit increased cognitive effort which may compensate for any latent differences in task performance. Such findings could explain the negative findings in the present study and previous cognitive studies (e.g. Montgomery et al. 2008).

All indices of cannabis use were correlated with performance on the planning and event and time-based PM subscales of the JAAM task. These were the three subscales with between groups differences. In all cases the direction of the correlations shows that heavier use of cannabis was associated with worse performance. There was however a differentiation between the subscales in terms of the strength of the coefficients, with average nightly dose of cannabis being most strongly correlated with event-based PM and amount of cannabis smoked in the last 10 days being most strongly correlated with time-based PM and planning. Thus it remains a possibility that impairments in the time-based PM and planning subscales are related to residual intoxication. However, no participants reported use in the 5 days prior to testing and thus any intoxication effect would be minimal. Nonetheless, future research should seek to control for this.

It is worthy of note that one of the participants, despite heavy use of cannabis scored 100% on all of the JAAM subscales. The participant did however play video games such as transport tycoon and risk for many hours each day. Boot et al. (2008) found the playing of video games improves prospective memory and executive functioning, with expert gamers found to have significantly better executive functions than non-gamers. Consequently, there could be a cross-practise effect with laboratory-based non-immersive virtual reality tasks such as the JAAM and virtual week if participants are regular users of video games. Future research should seek to control for this.

There were a number of limitations with the present study. We had to rely on self report measures of previous cannabis use, which may not be accurate as cannabis users are noted to have memory impairments. Nonetheless, this method is prevalent in drug use research. In addition, the acute intoxication period of cannabis is said to last 12- 24 hours after use (Pope, 1995) however residual intoxication may last for up to 30 days. While most participants had not used in the week preceding testing and were thus past the acute intoxication period, many may have been residually intoxicated as classified by Pope et al. (1995). While some studies do assess urinary metabolites and indeed exclude participants who have urinary THC metabolites present in their urine, this does not always negate cognitive deficits. For example while Solowij et al. (2002) found that group differences were reduced to below statistical significance after removing individuals with THC metabolites in their urine, Ehrenreich et al. (1999) found that controlling for recent use via levels of THC metabolites did not affect the significant groups differences. In the present study we have no reason to believe that cannabis users were untruthful about their last use of cannabis as they were not informed that there would be any penalties for recent use, so we can assume their mean abstinence period of 2 weeks to be correct and outside the acute intoxication phase. However, Future research should seek to include a cannabis wash-out period or collect and quantify levels of THC metabolites in the urine of cannabis users to account for residual intoxication effects. In addition, the present study does not further establish the various drug factors such as frequency of use (Harvey et al. 2007; Montgomery et al. 2010), age of onset (Pope et al. 2002; 2003) that have been said to affect cannabis-related deficits. In fact, indices of cannabis use were globally implicated in the deficits in planning, and TBPM and EBPM suggesting that it is general heavy use of cannabis that is detrimental to memory rather than specific aspects. Finally, in research investigating the chronic effects of illicit drug use on cognition, the legal status of drugs, ethical considerations, and time constraints prevent us from performing controlled studies mimicking long-term dosing regimens in human users. Thus to some extent, the samples in such research are self-selecting. While such samples are common in this type of research, it is nonetheless a methodological limitation.

In conclusion, the present study found evidence for selective cannabis-related impairments in prospective memory and executive function. The task used mimics functioning in the real world and thus it is proposed that cannabis users may exhibit problems with planning actions in a logical fashion and prospective memory.

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Table 1

Means for indices of cannabis use in the cannabis user group.

	Mean	SD
Length of cannabis use (weeks)	334.24	135.74
Average dose of cannabis (joints)	7.91	5.74
Frequency of use (times per week)	4.05	2.26
Joints smoked in last 10 days	12.30	10.19
Joints smoked in last month	77.15	85.65
Total lifetime dose (joints)	6042.10	6722.47

Table 2

Mean scores on background variables.

	Users		Nonusers	
	Mean	**SD**	**Mean**	**SD**
Age	21.05	1.79	20.30	4.65
Weekly Alcohol Use (UK units)	11.30	8.23	9.16	7.48
Raven's Progressive Matrices	48.25	5.99	46.95	5.07
UMACL Scales				
Arousal	23.4	1.93	22.10	3.64
Anxious	10.85	1.23	11.30	2.96
Depressed	11.60	1.27	11.25	2.59

Table 3

Means percentage accuracy of cannabis users and nonusers on the JAAM task.

JAAM Subscale	Nonuser		Cannabis User		F(1,38)
	Mean	SD	Mean	SD	
Planning	81.61	16.99	68.25	16.93	6.21*
Prioritisation	82.50	21.61	77.50	21.30	0.54
Selection	88.75	20.64	90.00	12.56	0.05
Creative Thinking	57.50	31.52	53.75	23.33	0.18
Adaptive Thinking	70.00	25.13	61.25	27.47	1.10
Action-based PM	41.25	36.52	43.75	27.95	0.06
Event-based PM	88.75	22.17	50.00	32.44	19.44**
Time-based PM	75.00	26.90	56.25	26.75	4.89*

* Significant at $p<.05$

** Significant at $p<.001$

Table 4

Correlations between performance and indices of cannabis use

	Planning	Prioritisation	Selection	Creative Thinking	Adaptive thinking	ABPM	EBPM	TBPM
Length of Use	-.404**	-0.074	0.020	0.024	-0.137	0.155	-0.503**	-0.320*
Average Dose	-0.497**	-0.049	-0.026	-0.064	-0.202	0.00	-0.599**	-0.428**
Use in last 10 days	-0.522**	-0.035	0.034	0.056	-0.059	-0.006	-0.540**	-.402**
Total lifetime dose	-.499**	-0.067	-0.021	-0.031	-0.186	0.016	-0.556**	-0.408**
Frequency of use	-0.487**	-0.152	-0.084	0.020	-0.154	-0.024	-0.521**	-0.394**
Use in last 30 days	-0.442**	-0.134	-0.074	0.012	-0.148	-0.009	-0.505**	-0.383**

** correlation significant at p<.001

Figure 1

Bar chart of % accuracy on JAAM scales