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J Psychopharmacol 2006; 20; 14 originally published online Oct 4, 2005;
DOI: 10.1177/0269881105056644

Original Papers

Psychopharm

Journal of Psychopharmacology
20(1) (2006) 14–23

ISSN 0269-8811
SAGE Publications Ltd,
London, Thousand Oaks,
CA and New Delhi
10.1177/0269881105056644

Cannabis use, cognitive performance and mood in a sample of workers

E. J. K. Wadsworth *Centre for Occupational and Health Psychology, Cardiff University, 63 Park Place, Cardiff, CF10 3AS, UK.*

S. C. Moss *Centre for Occupational and Health Psychology, Cardiff University, 63 Park Place, Cardiff, CF10 3AS, UK.*

S. A. Simpson *Centre for Occupational and Health Psychology, Cardiff University, 63 Park Place, Cardiff, CF10 3AS, UK.*

A. P. Smith *Centre for Occupational and Health Psychology, Cardiff University, 63 Park Place, Cardiff, CF10 3AS, UK.*

Abstract

There are well documented acute and chronic effects of cannabis use on mental functioning. However, less is known about any effects on cognition within the context of work and everyday life.

The aim of the study was to examine any association between cannabis use and cognitive performance, mood and human error at work.

Cannabis users and controls completed a battery of laboratory based computer tasks measuring mood and cognitive function pre- and post-work at the start and end of a working week. They also completed daily diaries reporting their work performance.

Cannabis use was associated with impairment in both cognitive function and mood, though cannabis users reported no more workplace errors than controls. Cannabis use was associated with lower alertness and slower response organization. In addition, users experienced working memory problems at the start, and psychomotor slowing and poorer episodic recall at the end of the working week.

This pattern of results suggests two possible effects. First a 'hangover'-type effect which may increase with frequency of use. Second a subtle effect on cognitive function, perhaps more apparent under cognitive load and/or fatigue, which may increase with more prolonged use. The results also highlight the importance of the timing of testing within the context and routine of everyday life.

Keywords
cannabis, cognitive performance, mood, error

Introduction

Latest British Crime Survey figures show that 12% of those aged 16–59 had taken an illicit drug in the previous year (Aust *et al.*, 2002). Cannabis is, and has consistently been, the most commonly used drug: 11% reported using it in 2001/02 (Aust and Condon, 2003). Longitudinal work also suggests that drug use is increasingly limited to cannabis use as people move into adulthood (Williams and Parker, 2001).

The sedative effects of cannabis use are well established, with users typically reporting mental slowness, tiredness, anxiety and paranoia as well as relaxation and euphoria (Parrott *et al.*, 2004). Acute effects on cognition and performance, limited to periods of intoxication, have been well-documented. Detrimental effects have been demonstrated in a range of areas, including recall (Golding, 1992; Heishman *et al.*, 1997; Solowij, 1998), reaction time (Golding, 1992) and driving (Parrott, 1987). These acute effects may continue for several hours, even up to 24 h, after cannabis use (Robbe and O'Hanlon, 1993).

Somewhat less research has focused on the long-term effects of chronic cannabis use on cognitive function. However, heavy use has been associated with impaired verbal expression, mathematical skills (Block *et al.*, 1990), memory (Block and Ghoneim, 1993; Pope and Yurgelun-Todd, 1996; Dafters *et al.*, 2004), attention (Pope and Yurgelun-Todd, 1996) and perhaps a detrimental effect on the ability to learn and retain new information (Grant *et al.*, 2003).

There has also been recent focus on the possibility of a link between cannabis use and mental health problems, in particular schizophrenia. There is an association between cannabis dependence or misuse and co-morbidity for other psychiatric diagnoses (Regier *et al.*, 1990). However, recent work suggests that there is no evidence that cannabis use is a causal factor in the development of schizophrenia (Johns, 2001). Rather, chronic cannabis use may precipitate schizophrenia in vulnerable individuals (Andreasson *et al.*, 1987), and be linked to more psychotic symptoms among those with the illness (Linszman *et al.*, 1990).

Overall the evidence suggests that long-term cannabis use

Corresponding author: E. J. K. Wadsworth, Centre for Occupational and Health Psychology, Cardiff University, 63 Park Place, Cardiff, CF10 3AS, UK.
Email: wadsworthej@cardiff.ac.uk. Figures 1–2 appear in colour online: http://jop.sagepub.com

leads to subtle and selective impairments of specific higher cognitive functions (Solowij, 1998). The performance of ex-users may improve, relative to that of current users, but perhaps not to the level of non-users (Solowij, 1995). The degree of impairment may be related to duration of cannabis use (Block and Ghoneim, 1993; Solowij, 1995), and those whose cannabis careers started earlier may show greater performance deficits (Pope, 2002).

The increasing normalization of drug use as part of young adult life (Parker *et al.*, 2002) and continuation of cannabis use from teenage years into adulthood (Williams and Parker, 2001), together with suggestions of links between degree of impairment and both duration (Block and Ghoneim, 1993; Solowij, 1995) and earlier first use of cannabis (Pope, 2002), point to the increasing need to consider the effects of cannabis use within the context of everyday life.

Other factors may also affect cognitive performance and mood. These include specific, contextual factors, such as fatigue (Campbell, 1992), minor illness (Smith *et al.*, 1994), mental health status (Widlocher, 1983; Curran, 1992) or alcohol consumption (Finnigan and Hammersley, 1992; Smith *et al.*, 1995), as well as fixed factors, such as intelligence (Anderson, 1992) and age (Davies *et al.*, 1992). Some of these factors, for example age, alcohol use (Wadsworth *et al.*, 2004) and educational level (Hall and Solowij, 1998), are also associated with drug use.

The aim of this study, therefore, was to consider any impact of cannabis use on mood and cognitive performance among workers. In addition, the study was designed to allow this assessment within the context of work and everyday life and while controlling for potential confounders. The methodology allowed the consideration of both the potential for cannabis use to affect work performance, and the systems affected to manifest particular mood or performance changes.

Methods and materials

This study involved drug users and controls completing a battery of laboratory-based computer tasks measuring cognitive function during pre- and post-work sessions at the start and end of a working week. This method is based on the rationale that pre- and post-work measures (and the difference between them) may provide an indication of actual work performance (Broadbent, 1979). The computer tasks measured mood (alertness, anxiety and hedonic tone), psychomotor speed, momentary inefficiency, sustained and selective attention, organization of response and aspects of memory (episodic, semantic and working). The tasks have good psychometric properties and factor analysis confirms that they measure distinct functions. They have been shown to be sensitive to acute changes in state (e.g., noise, minor illness, night work) (see Smith *et al.*, 1995). They have also been used in a number of studies involving pharmacological challenges (e.g., Smith *et al.*, 2003), and the neurotransmitter systems underlying performance on each task are understood. In addition they measure performance in areas, such as psychomotor speed and memory, known to be affected by cannabis use (e.g., Pope and Yurgelun-Todd, 1996; Block and Ghoneim, 1993).

Both groups of participants also kept daily error diaries where they reported their frequency of human errors (such as mistakes, getting sidetracked) and level of performance (such as effort, efficiency) after work each day. This approach has been used previously to assess the effects of age on errors at work (Stollery and Rabbitt, 1994). In conjunction with the performance tasks, this allows the comparison of objectively measured mood and cognitive function deficits taken to give an indication of work performance, with self-awareness of workplace performance. This method has been described in more detail previously (Smith *et al.*, 2004).

Participants

Participants were recruited using several strategies:

- noticeboard outside the centre
- university intranet
- existing volunteer panel
- word of mouth.

They were all aged 18 or over and employed. Those taking prescribed psychotropic medication, who were pregnant (or attempting to become pregnant) or lactating were excluded. Participants received a £50 shopping voucher after completing the study.

Procedure

Following a familiarization session, participants attended four study sessions each. These were arranged to be before and after work on the first and last days of their working week. Pre-work sessions were arranged to take place immediately before work (i.e., participants went directly to work after these sessions) and post-work sessions immediately after work (i.e., participants came directly to these sesssions from work). Exact timings and days of the week varied according to participants work schedules. At each session participants completed a battery of computer tasks (see below) as well as a questionnaire which included details about their sleep and alcohol consumption. Participants also completed the questionnaire used in an earlier study (Wadsworth *et al.*, 2005) at home. This included measures of anxiety and depression (Hospital Anxiety and Depression Scale (Zigmond and Snaith, 1983)), neuroticism (Eysenck, 1988), occupation (from which major occupational groups were coded using CASOC (Elias *et al.*, 1993)), education and symptoms in the last 14 days. In addition they completed the National Adult Reading Test (NART), from which IQ scores were calculated (Nelson and O'Connell, 1978) and wore Actiwatch Activity Monitors (Cambridge Neurotechnology) throughout the study which measured length of sleep.

Outcome measures

The computer based tasks measured:

- psychomotor speed (using simple reaction time, and focused and sustained attention choice reaction time): mean reaction times (ms) for each task

- momentary inefficiency (using errors and long reaction times in the choice reaction time tasks): number of errors made for each task and number of trials in which reaction time was greater than 1000 ms for sustained attention and 800 ms for focused attention
- speed of focus of attention (the Eriksen effect): mean difference (ms) between effect of distractors in the periphery and those close to the central target focus attention
- speed of encoding of new information: mean time (ms) to encode new information
- organization of response (S-R compatibility): mean difference in reaction time and accuracy between compatible and incompatible target and response key positions
- mood (alertness, hedonic tone and anxiety): numeric scores representing pre- and post-test mood
- memory (immediate, delayed and recognition recall, verbal reasoning and semantic memory): number of words recalled correctly for immediate, delayed and recognition recall, percentage of verbal reasoning trials correct, number of semantic memory trials correct, and number of intrusion errors for immediate, delayed and recognition recall.

Psychomotor tasks

Simple Reaction Time Task (measuring psychomotor speed) A box was displayed on the screen and this was followed, after a variable fore-period (1–8 s) by a square (the target) being presented in the middle of the box. Participants had to press a key as soon as the square was detected. This task lasted for 3 min.

Focused Attention Task (measuring psychomotor speed, momentary inefficiency, speed of encoding of new information and organization of response) This choice reaction time task was developed by Broadbent *et al.* (1986, 1989). Target letters appeared as upper case As and Bs in the centre of the screen. Participants were required to respond as quickly and accurately as possible to the target letter presented in the centre of the screen, ignoring any distracters presented in the periphery. The correct response to A was to press a key with the forefinger of the left hand, while the correct response to B was to press a different key, with the forefinger of the right hand. Prior to each target presentation three warning crosses were presented on the screen, the outside crosses were separated from the middle one by either 1.02 or 2.60 degrees. The crosses were on the screen for 500 ms and were then replaced by the target letter. The central letter was either accompanied by 1) nothing, 2) asterisks, 3) letters that were the same as the target, or 4) letters which differed from the target. The two distracters presented were always identical and the targets and accompanying letters were always A or B. Participants were given ten practice trials followed by three blocks of 64 trials. In each block there were equal numbers of near/far conditions, A or B responses and equal numbers of the four distracter conditions. The nature of the previous trial was controlled. This test lasted approximately 6 min.

This task measured several aspects of performance. The global measures of choice reaction time were mean reaction time and accuracy of response (per cent correct) when the target was presented alone or when distracters were present. Long response times (>800 ms) were also recorded. In addition a measure of selective attention was recorded (the Eriksen effect). This provided a measure of focusing of attention, describing the effect of spatial interference caused by disagreeing stimuli placed near to or far from the target upon reaction time and accuracy of response to the target. A more specific aspect of choice response was measured recording choice reaction time and accuracy with which new information was encoded e.g., alternations and repetitions of responses to the target.

Categoric Search Task (measuring psychomotor speed, momentary inefficiency, speed of encoding new information and organization of response) This task was also developed by Broadbent *et al.* (1986, 1989) and was similar to the focused attention task. Each trial started with the appearance of two crosses either in the central positions occupied by the non-targets in the focused attention task, i.e., 2.04 or 5.20 degrees apart or further apart, located towards either left and right extremes of the screen. The target letter then appeared in place of one of these crosses. However, in this task participants did not know where the target would appear. On half the trials the target letter A or B was presented alone and on the other half it was accompanied by a distracter, in this task a digit (1–7). Again the number of near/far stimuli, A versus B responses and digit/blank conditions were controlled. Half of the trials led to compatible responses (i.e., the letter A on the left side of the screen, or letter B on the right) whereas the others were incompatible. The nature of the preceding trial was also controlled. In other respects (practice, number of trials, etc.) the task was identical to the focused attention task. This task also lasted approximately 6 min.

As in the focused attention task several aspects of choice responses to a target were measured. The global measures recorded were choice reaction time and accuracy of response when the target was presented alone in either near/far locations. Long response times (>1000 ms) were also recorded. A more specific aspect of choice response was measured, recording choice reaction time and accuracy with which new information was encoded. In addition a measure of response organization was recorded. This refers to the effect of compatibility of the target position and the response key upon reaction time and accuracy.

Mood

This was measured using 18 bi-polar visual analogue scales (e.g., Drowsy-Alert, Tense-Calm; after Herbert, Johns and Dore, 1976) presented on the screen. Mood was rated at the start and end of each session. Three scores were derived from the mood scales: alertness, hedonic tone and anxiety.

Memory tasks

Immediate Free Recall Task (measuring episodic memory) A list of 20 words was presented on the screen at a rate of one every

2 s. At the end of the list, the participant had 2 min to write down (in any order) as many of the words as possible.

Delayed Free Recall Task (measuring episodic memory) Towards the end of the test session participants had unlimited time to write down (in any order) as many of the words from the list of 20 presented for the Immediate Free Recall Task as possible.

Delayed Recognition Memory Task (measuring episodic memory) At the end of the test session, participants were shown a list of 40 words, which consisted of the 20 words shown at the start of the session plus 20 distracters. Participants had to decide as quickly as possible whether each word was shown in the original list or not.

Verbal Reasoning Task (measuring working memory) Participants were shown statements about the order of the letters A and B followed by the letters AB or BA (e.g., A follows B: BA). The participants had to read the statement and decide whether the sentence was a true description of the order of the letters. If it was, the participant pressed the T key on the response box, and if not they pressed the F key. The sentences ranged in syntactic complexity from simple active to passive negative (e.g., A is not followed by B). The task lasted 3 min.

Semantic Processing Task (measuring retrieval from semantic memory) This test measured speed of retrieval of information from general knowledge. Participants were shown a sentence and had to decide whether it was true (e.g., canaries have wings) or false (e.g., dogs have wings). This task also lasted 3 min.

The daily diary required participants to rate four measures on a 5-point scale from not at all to extremely:

- how demanding was work
- did you put a lot of effort in
- how productive were you
- how efficient were you.

In addition they rated themselves on a further six measures using 5-point scales from often to never:

- did you feel you were making mistakes
- did you lose concentration
- did you forget what you intended to do
- did you have trouble making decisions
- did you forget where you put things
- did you intend to do one thing and get sidetracked into another.

Analyses

Analyses were carried out in two stages. First repeated measures analyses of covariance were used to compare controls with cannabis users. This allowed the assessment of any main effects and any interactions with day (start or end of the week) or time (before or after work) of testing. Second analyses of covariance were used to compare controls with cannabis users for each testing session separately. These analyses were used to explore interactions with day and/or time of testing in more detail. Each model also included age, IQ, sleep length, alcohol consumption (units consumed on the three days immediately prior to each test session), neuroticism and HADS anxiety and depression scores as covariates, and sex, occupation, education and 14-day symptom scores as fixed factors.

In order to clarify cannabis effects, further analyses were also carried out focusing on use of cannabis in the 24 h prior to testing, and use of drugs other than cannabis in the month prior to the study.

Partial correlations were used to consider the effects of duration and frequency of use. These were carried out where analyses of covariance had identified an association with cannabis use. Measures were adjusted for IQ, age, sleep length, alcohol consumption, anxiety, depression and neuroticism.

Ethical approval

The study was approved by the Cardiff University School of Psychology Ethics Committee.

Results

Participants

Comparisons were made between 34 participants who reported using cannabis and no other drug during the week of the study, and 85 controls who reported no drug use during the previous year and were in the same age range as the cannabis users (i.e., 18 to 37 years). Table 1 shows the characteristics of the groups. Cannabis users were younger than controls ($p = 0.001$), drank more alcohol during the study week ($p = 0.001$), more were male ($p = 0.002$) and more were smokers ($p < 0.0001$). Most of the participants had managerial or professional (42% of controls and 30% of cannabis users), associate professional (13% and 12% respectively) or clerical jobs (27% each). A further 18% of controls and 30% of cannabis users had manual occupations.

Performance tests not affected by cannabis use

Repeated measures analyses showed no detrimental effect of cannabis use on recognition memory, simple reaction time, focus of attention (Eriksen effect), intrusion errors (on the recognition, immediate and delayed recall tasks), semantic recall, immediate recall, speed of encoding of new information or ratings of anxiety.

Cannabis users and controls – main effects

Cognitive performance However, there was a main effect of cannabis use on the categoric search task response organization measure, $F = 4.73$, $p = 0.03$ (controls vs. cannabis users mean (SE) time in milliseconds: 22.18 (2.00) and 29.89 (2.88)) (see Fig. 1). This is the difference between incompatible responses (e.g., a response made to a stimulus on the left hand side of the screen

Table 1 Characteristics of cannabis users and controls

	Controls $n = 85$	Cannabis users $n = 34$	p
Males: N (%)	28 (33)	22 (65)	0.002
Age: mean (SD)	26.79 (4.64)	24.03 (5.28)	0.001
Hours worked per week: mean (SD)	33.88 (9.42)	33.83 (11.25)	0.59
IQ: mean (SD)	113.22 (6.73)	113.28 (6.34)	0.97
Alcohol: mean (SD)	6.89 (8.36)	17.44 (16.77)	0.001
Smoker: N (%)	5 (6)	19 (58)	<0.0001
Other drug use last month: N (%)	–	15 (48)	
Frequency of use (days, max 6) mean (SD, range)	–	3.35 (1.70, 1–6)	
Duration of use (years) mean (SD, range)	–	7.63 (4.72, 1–21)	

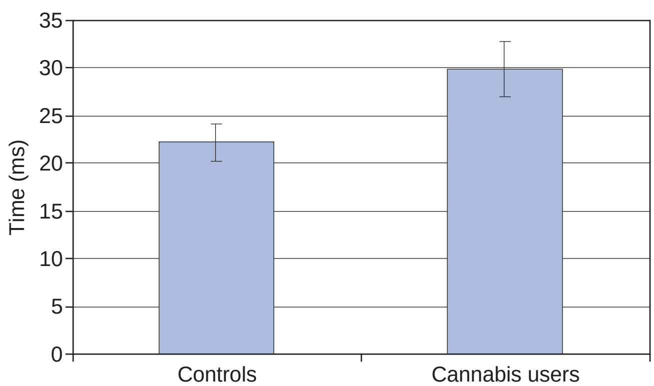

Figure 1 Speed of response organization (mean, SE) for cannabis users and controls (scores are the differences in ms between incompatible and compatible responses)

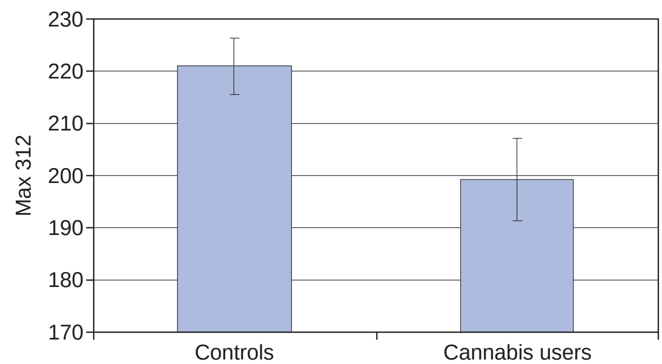

Figure 2 Alertness levels (mean, SE) for cannabis users and controls (higher score = greater alertness; maximum score = 312)

with the right hand) and compatible responses (e.g., right hand side stimulus and right hand response). The results show that cannabis users were slower at responding in the incompatible condition.

Mood Alertness also showed a main effect of cannabis use with cannabis users reporting that they felt less alert, F = 5.10, $p = 0.03$ (220.97 (5.43) among controls compared to 199.25 (7.81) among cannabis users) (see Fig. 2).

In addition, there was an interaction between cannabis use and day, time, and order of testing (i.e., mood tests carried out before or after the battery of performance tests), F = 3.92, $p = 0.05$. Cannabis users had lower alertness prior to doing the battery of tests before work on Monday, before work on Friday and after work on Friday (191.49 (12.27), 190.78 (10.33) and 199.24 (10.98), respectively compared to 223.44 (8.53), 212.32 (7.19) and 227.80 (7.64) among controls), as well as after doing the battery of tests following work on Monday and following work on Friday (213.68 (9.14) and 196.31 (10.18), respectively compared to 239.24 (6.36) and 217.42 (7.08) among controls).

Analyses of the remaining performance tests showed interactions between cannabis use and either day of testing, time of testing or both. These fell broadly into two groups: those showing effects at the start of the week and those showing effects at the end of the week. They were considered in more detail by analysing each testing session separately.

Effects apparent at the start of the week

Cognitive performance

Cannabis users performed the verbal reasoning task less accurately: this was significant at the first session (Monday morning) (see Table 2).

In order to consider whether this start of week effect reflected recent cannabis use, further analyses were carried out subdividing cannabis users according to their cannabis use in the previous 24 h. These suggested that the working memory deficit was significant only among those who had used cannabis in the last 24 h, though the trend was also apparent among those who had not used cannabis so recently (see Table 3).

Table 2 Verbal reasoning accuracy scores (mean, SE) for controls and cannabis users at each testing session

	Time of testing	Controls	Cannabis	F	*p*
Verbal reasoning (% correct)	Pre work 1st day of week	81.38 (1.89)	73.89 (2.71)	5.07	0.03
	Post work 1st day of week	80.61 (2.02)	78.83 (2.89)	0.26	0.62
	Pre work last day of week	84.02 (1.82)	81.99 (2.58)	0.41	0.52
	Post work last day of week	83.67 (2.09)	79.15 (2.96)	1.54	0.22

Table 3 Verbal reasoning accuracy scores (mean, SE) before work at the start of the week for controls and cannabis users categorized according to their cannabis use in the previous 24 h

	Controls	Cannabis in last 24 h	No cannabis in last 24 h	Cannabis in 24 h vs. controls None in 24 h vs. controls *p*
Verbal reasoning (% correct)	81.43 (1.90)	71.99 (3.68)	75.90 (3.77)	0.03 0.19

Effects apparent at the end of the week

Cognitive performance

Cannabis users' and controls' speed of performance on the categoric search task was similar at the start of the week. However, controls improved more than cannabis users at subsequent sessions so that by the end of the week cannabis users were significantly slower (see Table 4). Repeated measures analyses showed interactions between cannabis use and both day of testing ($F = 5.01$, $p = 0.03$), reflecting cannabis users poorer performance at the end of the week, and time of testing ($F = 4.86$, $p = 0.03$), reflecting little or no improvement in cannabis users speed after work compared to before work. Similarly, repeated measures analyses showed a cannabis user by time interaction ($F = 4.05$, $p = 0.05$) on focused attention mean reaction time: controls were quicker following work (382.24 (6.28)) than cannabis users (389.56 (9.02)).

Further analyses showed that those who had not used cannabis in the last 24 h had significantly slower categoric search mean reaction times than controls at the final testing session ($p = 0.01$), whereas those who had were slower but not significantly so ($p = 0.19$) (478.53 (7.96) among controls, 500.49 (14.88) among those who had not recently used cannabis, and 526.65 (16.44) among those who had, $F = 3.61$, $p = 0.03$).

Repeated measures analyses also showed an interaction between cannabis use and time of testing for the delayed recall test. Cannabis users had poorer recall than controls pre-work (see Table 5).

Analysing just session 3 also shows this difference (6.96 (0.40) compared to 5.57 (0.58), $F = 3.92$, $p = 0.05$). Delayed recall at this session among both those who had used cannabis in the previous 24 h and those who had not approached significance when compared with controls ($p = 0.11$ and $p = 0.14$, respectively) (5.58 (0.77) among those who had not used cannabis in the last 24 h and 5.55 (0.84) among those who had, compared to 6.96 (0.40) among controls).

Table 4 Choice reaction time (mean, SE) for cannabis users and controls at each testing session

	Time of testing	Controls	Cannabis	F	*p*
Categoric search reaction time (ms)	Pre work 1st day of week	538.25 (8.08)	538.36 (11.59)	0.00	0.99
	Post work 1st day of week	512.49 (8.85)	518.57 (12.70)	0.15	0.70
	Pre work last day of week	493.98 (6.96)	504.79 (9.87)	0.79	0.38
	Post work last day of week	478.87 (7.98)	512.21 (11.31)	5.73	0.02

Table 5 Delayed recall (mean, SE) for cannabis users and controls

	Controls Mean (SE)		Cannabis users Mean (SE)		F, *p* Cannabis*time
	Pre work	Post work	Pre work	Post work	
Delayed recall (number correct; maximum 20)	6.30 (0.37)	6.23 (0.41)	5.80 (0.56)	6.93 (0.62)	6.72, 0.01

Use of other drugs

Further analyses showed no significant differences between those who had used only cannabis in the previous month and those who had also used other drugs on the tasks presented above.

Duration and frequency of use

Cognitive performance

Analyses were also carried out to assess the impact of duration and frequency of cannabis use on performance. Verbal reasoning accuracy was negatively correlated with frequency of use (−0.47, $p = 0.02$ at session 1). Correlations between frequency of use and both alertness and response organization also approached significance (−0.34, $p = 0.09$ at session 3 and 0.40, $p = 0.08$ at session 4, respectively). Both categoric search and focused attention mean reaction times were correlated with duration of use (0.45, $p = 0.03$ and 0.46, $p = 0.02$, respectively at session 3 and 0.59, $p = 0.007$ for categoric search at session 4). Finally there was a negative correlation between delayed recall and duration of use which was significant at session 1 (−0.42, $p = 0.04$) and approached significance at session 3 (−0.34, $p = 0.09$). This suggests that the start of week effects were correlated with frequency of use, and the end of week effects with duration of use.

Error diaries

Work performance

Repeated measures analyses showed no differences between cannabis users and controls on measures of effort, productivity, efficiency, making mistakes, concentration, forgetting intentions, decision making, forgetting where things were put or getting side-tracked. However, there was an interaction between cannabis use and day of testing for demand ($F = 2.95$, $p = 0.02$). Cannabis users found work less demanding, particularly at the start of the week. The main effect also approached significance ($F = 2.81$, $p = 0.10$) (see Table 6).

In addition there was a negative correlation between demand and duration of cannabis use (−0.41, $p = 0.04$, on day 3).

Discussion

The pattern of results broadly suggested three possible impacts of cannabis use on cognitive performance and mood.

First, cannabis users had slower response organization and were less alert than controls. Impaired response organization suggests a possible impact on information processing. This is consistent with work suggesting that cannabis use, particularly over many years, leads to subtle neurophysiological deficits (Solowij, 1998). Lower alertness is consistent with the drugs' well documented sedative effects (Parrott *et al.*, 2004).

Second, cannabis users had poorer working memory than controls at the start of the week (prior to work on the first day), suggesting a 'hangover' type effect. This was significant for those who had used cannabis in the previous 24 h but not for those who had not (though the trend was apparent for this group too). Their performance was not statistically different from that of controls during the rest of the week. Associations with working memory deficits have been reported previously, particularly among longer-term users (Block and Ghoneim, 1993; Fletcher *et al.*, 1996; Pope

Table 6 Work demand ratings (mean, SE) given by cannabis users and controls

	Day of rating (made post work)	Controls	Cannabis users	F, *p* Main effect Cannabis*day
Demand (higher scores = greater demand; maximum 4)	1st day of week	1.43 (0.15)	1.14 (0.23)	2.81, 0.10
	2nd day of week	1.58 (0.15)	1.12 (0.22)	2.95, 0.02
	3rd day of week	2.18 (0.17)	1.27 (0.25)	
	4th day of week	1.84 (0.16)	1.89 (0.24)	
	5th day of week	1.47 (0.18)	1.45 (0.27)	

and Yurgelun-Todd, 1996; Pope *et al.*, 2001; Bolla *et al.*, 2002; Solowij *et al.*, 2002). In this study cannabis users' generally lower alertness levels were also most evident prior to work at the start of the week, and tended to worsen with increased frequency of use. Impairments among heavy cannabis users have been detected hours or even days after smoking (Pope *et al.*, 1995; Pope and Yurgelun-Todd, 1996; Struve *et al.*, 1999). There is also some evidence of significant impairment even at lower levels of consumption up to 24 h after smoking (Robbe and O'Hanlon, 1993). This may be the result of withdrawal or a residue of cannabinoids in the brain (Parrott *et al.*, 2004).

Third, cannabis users had slower psychomotor speed than controls but only at the end of the working week. The pattern of results across the test sessions suggested not that cannabis users became slower as the week went on, but rather that their speed did not improve as much as that of controls. In this case those who had not used cannabis in the previous 24 h differed significantly from controls and those who had did not (though the trend was apparent). They also had poorer episodic recall later in the week. Previous work has also suggested links with both memory impairment (Block and Ghoneim, 1993; Pope and Yurgelun-Todd, 1996; Dafters *et al.*, 2004), and slower information processing particularly among longer-term users (Pope and Yurgelun-Todd, 1996; Kelleher *et al.*, 2004). In this study, performance on these tasks was negatively associated with duration of cannabis use. This suggests that they may result from subtle cognitive deficits arising following long-term cannabis use. These differences became apparent only later in the week, particularly after work, and this raises the possibility that they may become apparent only under certain circumstances, such as when users are tired. This is also consistent with the idea that deficits, perhaps because of subtle cognitive impairment following prolonged cannabis use, are more apparent under heavier cognitive load (Leavitt *et al.*, 1992, 1993). Alternatively, they may result from poorer learning among long-term cannabis users. This would be consistent with a detrimental effect of heavy cannabis use on the ability to learn and retain new information (Grant *et al.*, 2003).

Cannabis use has been associated with lower educational attainment previously (Hall and Solowij, 1998; Macleod *et al.*, 2004). However, cross-sectional studies, such as this one, cannot determine whether this is because of poorer cognitive function prior to first use of cannabis, the effect of the social context of the cannabis use (Fergusson *et al.*, 2003) or a direct effect of cannabis use on ability or motivation. In this study a measure of pre-morbid IQ was used (Nelson and O'Connell, 1978). Cannabis users and controls had very similar IQ levels. However, there was a negative correlation between IQ and frequency of cannabis use (−0.35, $p = 0.04$).

The patterns of ages of first cannabis use among respondents meant it was not possible to consider whether this was associated with mood or cognitive performance. However, correlations between duration of cannabis use and both poorer episodic memory and slower psychomotor speed are consistent with suggestion that early onset users (before age 17) perform worse, particularly on verbal cognitive measures (Pope, 2002). The mean age of first cannabis use of participants in this study was 16.09 years (SD = 1.92, range 11–21). This is close to recent figures for the UK giving a mean age of 15.5 years (Aust *et al.*, 2002). It may be, therefore, that future cohorts will show more performance deficits, and/or that they will become more apparent as participants get older.

Self-reported lower alertness levels imply that cannabis users may be aware of some cognitive problems. However, the error diary data seem to suggest that this is not the case, at least for workplace performance. They did imply that cannabis users may find work less demanding, and that this was correlated with duration of use. This may simply reflect a generally more relaxed approach to work. Other studies' findings, however, suggest that cannabis users subjectively report negative effects on cognition, career (Gruber *et al.*, 2003) and memory (Rodgers *et al.*, 2001; Gruber *et al.*, 2003). Cannabis use has been associated with both poorer reported short-term and internally cued prospective memory, and with the use of fewer strategic memory aids (Rodgers *et al.*, 2001).

All the results of this study could be explained by other differences between the cannabis users and controls. They may, for example, represent the prior use of other drugs. The differences between the drug user and control groups, particularly in terms of gender, alcohol use and smoking, (which reflect factors often associated with drug use (Wadsworth *et al.*, 2004)) may also have been influential. There was a significant effect of alcohol use on sustained attention reaction time, and of gender on delayed recall, though not on any of the other outcomes which were significantly associated with drug use. The analyses allowed the assessment of the impact of cannabis use independent of these influences. However, it was not possible to disentangle any effects of tobacco on cognition (which are well documented (e.g., Wesnes and Parrott, 1992)) because so few of the control group were smokers (n = 5). The results should also be interpreted cautiously because of the small numbers in some groups, and because of the cross-sectional design of the study. However, they are consistent with previous work.

The study does, nevertheless, represent an examination of the effect of cannabis use on mood and cognitive performance specifically among workers. Cannabis use is not a behaviour that occurs in isolation, and the study was designed specifically to incorporate this context, and to consider the effects of cannabis use within it, controlling, where possible, for the influence of potential confounding factors. It suggests a two-fold impact of cannabis use: first a possible 'hangover' type effect at the start of the working week, which seems to increase with more frequent cannabis use. Second an effect on psychomotor speed apparent at the end of the working week, which seems to increase with longer duration of cannabis use, perhaps resulting from subtle neurophysiologic deficits following prolonged use. The latter may become apparent particularly under specific circumstances, such as heavy cognitive load or fatigue, or may be the result of impaired learning. Furthermore, the study shows that the timing of testing may be fundamental. Certain functional changes may not be apparent unless testing is carried out at particular times within an individual's day to day routine. This is of particular importance when considering how cannabis (or other drug) use may affect performance and safety in the workplace or elsewhere.

Cannabis is the most widely used, and earliest first used, illicit drug in the UK (Aust *et al.*, 2002). It is also the one most likely to be continued into adulthood. It is the third most common drug of choice in Europe behind alcohol and tobacco (Calafat *et al.*, 1999), and is frequently used in combination with other illicit drugs and with alcohol. In a climate in which recreational drug use is increasingly part of young adult life (Parker *et al.*, 2002) among otherwise conforming individuals (Williams and Parker, 2001), the implications of a detrimental impact of cannabis use on mood and cognitive performance are potentially wide reaching. It is, therefore, even more important that research is carried out within the context of peoples work, routine and everyday lives, and that it is designed to control for the influence of potential confounders. Furthermore, it must allow and search for the possibility that any impact is only apparent at particular times and under particular circumstances: cannabis use may alter cognition subtly over time and with frequent use; it may also exacerbate or interact with other factors to produce specific effects. This is consistent with recent safety research suggesting that cannabis use may amplify risk factors associated with accidents and injuries (Hall *et al.*, 1994; Wadsworth *et al.*, 2005).

Acknowledgement

Funded by the Health and Safety Executive

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