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Cognitive, physical, and mental health outcomes between long-term cannabis and tobacco users

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HIGHLIGHTS

- We examined health outcomes of long-term cannabis users and long-term tobacco users.
- Cannabis users had poorer learning and memory than tobacco users.
- Cannabis users had slower reaction time on some tasks than tobacco users.
- Tobacco users reported poorer physical and mental health than cannabis users.
- Tobacco should be controlled in research investigating cannabis health outcomes.

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ABSTRACT

Introduction: Cannabis intoxication adversely affects health, yet persistent effects following short-term abstinence in long-term cannabis users are unclear. This matched-subjects, cross-sectional study compared health outcomes of long-term cannabis and long-term tobacco-only users, relative to population norms.

Methods: Nineteen long-term (mean 32.3 years of use, mean age 55.7 years), abstinent (mean 15 h) cannabis users and 16 long-term tobacco users (mean 37.1 years of use, mean age 52.9 years), matched for age, educational attainment, and lifetime tobacco consumption, were compared on measures of learning and memory, response inhibition, information-processing, sustained attention, executive control, and mental and physical health.

Results: Cannabis users exhibited poorer overall learning and delayed recall and greater interference and forgetting than tobacco users, and exhibited poorer recall than norms. Inhibition and executive control were similar between groups, but cannabis users had slower reaction times during information processing and sustained attention tasks. Cannabis users had superior health satisfaction and psychological, somatic, and general health than tobacco users and had similar mental and physical health to norms whilst tobacco users had greater stress, role limitations from emotional problems, and poorer health satisfaction.

Conclusions: Long-term cannabis users may exhibit deficits in some cognitive domains despite short-term abstinence and may therefore benefit from interventions to improve cognitive performance. Tobacco alone may contribute to adverse mental and physical health outcomes, which requires appropriate control in future studies.

1. Introduction

Whilst it is established that acute cannabis intoxication can contribute to adverse effects on cognitive functioning and mental and physical health, less is known about the health outcomes of long-term cannabis use following short-term abstinence (see Battisti et al., 2010; Hall, 2009; Hall & Solowij, 1998). Cannabis use has more than doubled in the last 10 years in the United States, with one in 10 users subsequently developing cannabis use disorder (Hasin et al., 2015). Given its increased use, it is important to gain greater understanding of the effects of long-term cannabis use on health (Choo & Emery, 2016). Research into the effects of long-term cannabis use on cognition provides conflicting

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evidence. Solowij et al. (2002b) found in their cross-sectional study that long-term (mean 23.9 years of use) cannabis users with a median abstinence of 17 h exhibited poorer performance on tests of learning and memory and attention than short-term users and controls, with moderate to large effect sizes (Cohen's *d* 0.47 to 1.29). Conversely, meta-analyses have demonstrated that long-term cannabis users do not exhibit substantial cognitive deficits (Grant, Gonzalez, Carey, Natarajan, & Wolfson, 2003; Schreiner & Dunn, 2012). Abstinence and dose effects may explain conflicting evidence to date. An abstinence effect may occur in which long-term users exhibit cognitive deficits following short periods of abstinence (i.e., several hours or days) that reverse following several weeks of abstinence (Pope, Gruber, & Yurgelun-Todd, 2001). Recent electroencephalography data show a similar process of recovery, moderated by age of first cannabis use, in two-week abstinent cannabis users (Allsop & Copeland, 2015). A dose-dependent relationship can occur whereby cognitive deficits may reverse following abstinence from light (2–14 joints per week) and moderate (18–70 joints per week) but not heavy use (78–117 joints per week; Bolla, Brown, Eldreth, Tate, & Cadet, 2002). Abstinence and dose therefore need to be controlled in cannabis research.

Researchers must also control for substances other than cannabis. It is common practice, in Australia, to mix cannabis with tobacco but tobacco may be a confound as it is associated with adverse cognitive outcomes, such as memory deficits (see Hill, Nilsson, Nyberg, & Bäckman, 2003; Nooyens, van Gelder, & Verschuren, 2008; Ott et al., 2004). However, it has both been reported that tobacco is not associated with cognitive deficits among cannabis users and that tobacco may mask detrimental effects of cannabis on cognition, such as episodic memory (Meier et al., 2012; Schuster, Crane, Mermelstein, & Gonzalez, 2015). Consistent with the former, cross-sectional evidence indicated that abstinent cannabis users, but not tobacco-only users or controls, had deficits in visual recognition, verbal fluency, and delayed visual recall (McHale & Hunt, 2008). Researchers must investigate and account for such potential confounding variables to gain an accurate understanding of the impact that long-term cannabis use has on health, particularly during short-term abstinence.

Cannabis use is also associated with poor mental and physical health. Cannabis is related to increased risk of psychological distress, depression, and anxiety relative to non-users, however, the nature of the association remains unclear due to lack of control of major confounds (Australian Institute of Health and Welfare, 2011; Danielsson, Lundin, Allebeck, & Agardh, 2016; Hoch et al., 2015; Lev-Ran et al., 2014). Long-term cannabis use is also associated with increased respiratory symptoms, myocardial infarction, and greater pulmonary problems than tobacco use alone (Mittleman, Lewis, Maclure, Sherwood, & Muller, 2001; Tashkin, 2010; Tashkin, Baldwin, Sarafian, Dubinett, & Roth, 2002; Tetrault et al., 2007; Tzu-Chin, Tashkin, Djahed, & Rose, 1988). Cannabis may produce more harmful health effects than tobacco because cannabis tar contains carcinogenic agents (e.g., benzanthracenes) in higher concentrations than tobacco smoke (Ashton, 2001). It therefore appears that both substances are harmful, but cannabis may be more deleterious than tobacco. As tobacco alone is also associated with poor physical and mental health, it needs to be controlled in studies investigating health outcomes of cannabis use.

The aim of the current study was to compare cognitive functioning and mental and physical health between long-term cannabis users, following short-term abstinence, to long-term tobacco users and population norms. It was hypothesised that long-term cannabis users would have significantly poorer learning and memory, sustained attention, information-processing speed, executive control, and response inhibition as well as significantly poorer mental and physical health compared to chronic tobacco users and, where available, population norms.

2. Method

2.1. Participants and procedure

Ethical approval was provided by Universities of Sydney and Tasmania (#EC00113 and #H0014300). Participants were recruited via social medial and adverts in New South Wales and Hobart. Participants were screened by telephone (New South Wales) or internet survey (Hobart) prior to a two-hour face-to-face interview. Twenty-three non-treatment seeking cannabis users and 20 tobacco-only users were recruited. All cannabis users and three tobacco users were tested in New South Wales. Data from three tobacco users testing positive for THC, acetaminophen (APEP), and opiates, respectively, was excluded; along with four cannabis users reporting abstinence under eight hours. One further tobacco smoker was removed due to misunderstanding task instructions. The final sample included 19 cannabis users (M = 55.7 years, SD = 8.5) and 16 tobacco users (M = 52.9 years, SD = 7.5; Table 1). Inclusion criteria was current daily/near daily (4 + days a week) cannabis and tobacco use for 10 years or greater for cannabis and tobacco users, respectively. Exclusion criteria was active or unstable mental/physical health condition, current use of drugs

Table 1
Demographic and substance use details of cannabis and tobacco users.

	Group			
	Cannabis n = 19	Tobacco n = 16	g	p
Demographics				
Age (years)	55.7 (8.5)	52.8 (7.7)	0.35	0.303
Male sex, % (n)	68.4 (13.0)	31.3 (5.0)	0.37[b]	0.028*
Education years, M (SD)	14.2 (3.6)	13.7 (3.4)	0.14	0.665
Married, including de facto, % (n)	42.1 (8.0)	68.8 (11.0)	0.35[b]	0.236
Non-Indigenous status, % (n)	100 (19.0)	100 (16.0)		
WTAR std. score, M (SD)	111.6 (11.5)	106.2 (10.23)	0.42	0.216
Substance use history				
Alcohol use per occasion past month, standard drinks	4.4 (4.3) range 1.8–18.0	5.1 (4.0) range 1.0–18.0	0.16	0.635
Alcohol use, days per month (n)	14.1 (13.1)	9.6 (11.0)	0.36	0.326
Tobacco pack years[c]	20.7 (24.8)	22.8 (7.8)	0.11	0.725
Age first used tobacco, years	14.9 (3.9)	15.8 (3.2)	0.22	0.521
Nicotine dependence, Fagerstrom score	0.5 (1.3)	4.6 (2.5)	2.08[a]	< 0.001*
Age first used cannabis, years	18.1 (4.5)	17.5 (2.0)	0.15	0.621
Past month cannabis use, days	27.6 (3.9)			
Cannabis severity of dependence score	2.1 (2.5)			
Cannabis abstinence	15.0 h (7.9) range 8–36	23.6 years (9.8)	4.42[a]	< 0.001*
Lifetime illicit drug use				
Hallucinogens, % (n)	94.7 (18.0)	6.3 (1.0)	0.89[b]	< 0.001*
Amphetamines, % (n)	78.9 (15.0)	25.0 (4.0)	0.54[b]	0.002*
Cocaine, % (n)	73.7 (14.0)	18.8 (3.0)	0.55[b]	0.001*
Ecstasy, % (n)	68.4 (13.0)	6.3 (1.0)	0.63[b]	< 0.001*
Opiates, % (n)	57.9 (11.0)	20.0 (3.0)	0.38[b]	0.038*
Benzodiazepines, % (n)	21.1 (4.0)	37.5 (6.0)	0.28[b]	0.454
Synthetic cannabinoids, % (n)	16.7 (3.0)	0.0 (0.0)	0.29[b]	0.230

SDS ≥ 3 indicates cannabis dependence (Swift, Copeland, & Hall, 1998). Two cannabis users had used benzodiazepines and synthetic cannabinoids in the past month; however, their drug results were negative.

[a] Moderate effect size classified as > 0.5.

[b] Cramer's V effect size for categorical data.

[c] Tobacco pack years was calculated with respect to lifetime use, regardless of current tobacco status.

* $p < 0.05$.

(other than alcohol, tobacco, and cannabis) more than twice weekly, and drug injection more than once a week within the last month.

2.2. Measures

2.2.1. Demographics and substance use

Premorbid intelligence was measured with the Wechsler Test of Adult Reading (WTAR; Wechsler, 2001). Tobacco pack years was measured as the sum of the average quantity of tobacco used daily by number of years of use, divided by 20 (Ott et al., 2004). Past month cannabis use was assessed using the Timeline follow-back (TLFB; Sobell & Sobell, 1996). Cannabis dependence was assessed using past three month Severity of Dependence Scale (SDS), using a cut-off of three providing 64% sensitivity and 82% specificity for DSM cannabis dependence (Swift et al., 1998). The Discover Multi-Panel urine cup (at the Tasmanian site) and the Triage Drug Tox Screen (New South Wales site) assessed recent drug use.

2.2.2. Verbal learning and memory

The Rey Auditory Verbal Learning Test (RAVLT) measured verbal learning and memory. Participants were read a 15-word list (List A) followed by free recall. List A was repeated five times (Trial I – V) followed by one trial of List B. Participants were asked to recall as many words as they could remember from list A immediately after List B (Trial VI) and after a 20-minute delay (Trial VII). Outcomes included number of correctly recalled words from each trial; forgetting (Trial VII-Trial V); interference (Trial VI-Trial V); total learning acquisition (sum of words recalled Trials I-V). The original RAVLT form was used in Tasmania and NSW participants received three versions; original form (Rey, 1964), the Geffen, Butterworth, and Geffen (1994) version, and Form two by Majdan, Sziklas, and Jones-Gotman (1996). Forms were counterbalanced and provide comparable results to the original (Strauss, Sherman, & Spreen, 2006).

2.2.3. Mental and physical health

The Short Form-36 (SF-36 v2) is a 36-item survey forming eight subscales (physical functioning, role limitation due to physical problems, bodily pain, general health, vitality, social functioning, role limitations due to emotional problems, mental health) and a mental and physical component score (Bowling, Bond, Jenkinson, & Lamping, 1999). Scores were standardised to a mean of 50, where higher scores denote superior health (Gan et al., 2013).

The 21-item Depression, Anxiety, and Stress Scale (DASS 21; Lovibond & Lovibond, 1995) measured depression, anxiety, and stress. The World Health Organisation Quality of Life- Brief Survey (WHOQOL-BREF) is a 26-item survey measuring overall quality of life, health satisfaction, and four domains (physical health, psychological, social relationships, and environment; Min et al., 2002). Domain scores were transformed to a 0–100 scale. The Physical Health Questionnaire (PHQ) is a 14-item survey measuring somatic symptoms (Schat, Kelloway, & Desmarais, 2005).

2.2.4. Cognitive assessment

PenscreenSix software (version 1.6; Cameron, Sinclair, & Tiplady, 2001; Tiplady, Baird, Lütcke, Drummond, & Wright, 2005) on an Android 7″ tablet assessed four cognitive domains. Information processing speed was assessed with the Symbol Digit Substitution Task (Cameron et al., 2001; Mattila & Mattila-Evenden, 1997). Symbols were located at a central fixation point, along with a reference key displaying each symbol corresponding to a digit (0–9). Symbols were presented sequentially and participants responded by tapping the corresponding the digit associated with that symbol. Mean response time for correct responses and accuracy (out of 87 trials) were recorded. Response inhibition was assessed with the Stop Signal Task (Logan, Schachar, & Tannock, 1997). Following 500 ms presentation of a central fixation point, participants pressed a left or right square as fast as possible when 'X' or 'O' (go signal), respectively, was presented centrally. Stop-signal trials, requiring withholding of response consisted of a stimulus (X) that initially occurred 250 ms following letter onset (termed stop-signal delay). Stop signal delay increased 50 ms following failure to inhibit and decreased by 50 ms following correct inhibition. There were 48 trials (25% stop-signal). Mean reaction time for correct responses, number of incorrect responses, and stop signal response time was recorded. Stop signal response time was estimated by subtracting SSD from average go signal response time (Aron & Poldrack, 2006).

Sustained attention was assessed with Rapid Visual Information Processing (Bakan, 1959; Wesnes & Warburton, 1984). Single digits were located at a fixation point with a 600 ms inter-stimulus interval and participants responded when three even or odd digits appeared sequentially. This task consisted of 300 stimuli and 24 targets. Average RT for correct responses, number of correct responses, and false positive responses were recorded.

Executive control was assessed with Arrow Flankers (Eriksen & Eriksen, 1974). Stimuli consisted of five arrows with a central target arrow pointing left or right flanked on both side either by two squares (neutral), two arrows pointing in the same direction (congruent), or opposite direction (incongruent). Participants responded to the direction of the central arrow. Stimuli remained on screen until participants responded or 1000 ms had elapsed. Congruent, neutral, and incongruent trials each comprised 30% of 80 total trials. On 10% trials a No Go trial occurred, where suppressor flankers ('X') indicated to withhold a response. Outcome measures were the number of errors and the mean RT to congruent, neutral, and incongruent tasks and the number of false alarms on No Go trials.

2.2.5. Design and statistical analysis

Participants were matched for age, education years, and tobacco pack years. Outcomes were assessed using analysis of variance (ANOVA). Categorical data was analysed with Chi-square tests, with Pearson correlation used to assess associations (Appendix A). Mean RT and errors on arrow flankers were analysed with two separate 2 [Group: cannabis, tobacco] × 3 [Condition: congruent, neutral, incongruent] mixed ANOVAs. Greenhouse-Geisser and Welch corrections corrected for violated assumptions. Hedge's g and partial eta squared (η_p^2) are reported as measures of effect size, with $g = 0.5$ interpreted as medium and ≥ 0.80 as a large magnitude effect. Analyses of covariance (ANCOVA) was performed with premorbid IQ, sex, and tobacco pack years. Unadjusted descriptive statistics are reported because controlling for covariates were consistent with results of uncontrolled analyses. Four extreme outliers were removed from cognitive data where performance was lower than 70% accuracy, with no greater than 5.7% of data removed per outcome. We re-analysed data following listwise deletion of data from seven participants; three cannabis users and one tobacco user whose drug results were missing and three cannabis users who tested drug positive to identify if group differences were due to other substance use. The second analyses provided comparable results with similar interpretations (Appendix B). Nonparametric Mann-Whitney U tests were conducted to identify if violated assumptions biased results. These revealed similar results, except for WHOQOL-BREF psychological health and SF-36 physical functioning. Non-parametric results are reported for those two measures.

3. Results

3.1. Demographic variables

Groups were similar on measures of premorbid intelligence, education, age of tobacco initiation and tobacco pack years (Table 1). Cannabis users had used cannabis for 32.3 (SD = 9.1) years, had used 6.7 (SD = 6.5) cones/joints per day for 6.4 days a week (SD = 1.0), and had consumed a weekly cannabis weight of 9.0 g (SD = 7.5) and a weekly tobacco weight of 21.7 g (SD = 42.8). More cannabis users

Table 2
Comparisons on word recall between cannabis users, tobacco users, and population norms on RAVLT measures.

Group *M* (*SD*)				Cannabis vs tobacco		Cannabis vs tobacco[d]		Cannabis vs norms		Tobacco vs norms	
Trial	Cannabis $n = 19$	Tobacco $n = 16$	Norms[a] $n = 161$	*g*	*p*	*g*	*p*	*g*	*p*	*g*	*p*
I[b]	5.5 (2.7)	6.7 (2.0)	6.2 (1.6)	0.47	0.168	0.33	0.907	0.38	0.291	0.30	0.472
II	7.1 (2.2)	9.8 (2.0)	9.0 (1.9)	1.24[c]	0.001*	1.01[c]	0.006*	0.98[c]	0.001*	0.39	0.135
III	9.5 (1.8)	11.2 (1.5)	10.5 (1.9)	1.00[c]	0.005*	0.83[c]	0.011*	0.54[c]	0.026*	0.37	0.161
IV	10.6 (1.7)	12.4 (3.0)	11.4 (1.9)	0.96[c]	0.007*	0.98[c]	0.008*	0.41	0.094	0.51[c]	0.050*
V	11.2 (1.9)	12.2 (2.0)	12.1 (2.1)	0.48	0.159	0.48	0.174	0.42	0.081	0.04	0.870
Total learning, Σ I-V	44.0 (7.4)	52.7 (7.6)	47.6 (8.1)	1.08[c]	0.003*	0.99[c]	0.008*	0.45	0.063	0.62[c]	0.018*
Interference, trial VI minus V	− 2.4 (1.4)	− 1.8 (2.0)	–	0.36	0.301	0.17	0.621	–	–	–	–
Distractor list, B	4.5 (1.7)	6.4 (1.1)	5.7 (2.2)	1.34[c]	< 0.001*	1.13[c]	0.003*	0.57[c]	0.020*	0.35	0.186
Postdistractor trial, V1	8.8 (2.1)	10.4 (3.3)	9.9 (2.8)	0.58[c]	0.092	0.44	0.212	0.39	0.112	0.19	0.470
Delayed recall, VII	8.2 (2.9)	10.6 (3.4)	9.9 (3.2)	0.73[c]	0.034*	0.67[c]	0.062	0.53[c]	0.029*	0.20	0.435
Forgetting, trial VII minus V	− 3.0 (2.3)	− 1.6 (2.2)	–	0.60[c]	0.080	0.50[c]	0.160	–	–	–	–

Unadjusted means (*M*) and standard deviations (*SD*) are provided.
[a] Norms obtained from Schmidt (1996) as cited in Strauss et al. (2006), age range 50–59 years.
[b] Trials I to V, B, VI, and VII are measured as number of words recalled.
[c] Moderate effect size classified as > 0.5.
[d] Adjusted for premorbid IQ, gender, and tobacco pack years.
* $p < 0.05$.

reported using cannabis only ($n = 12$), than mixing cannabis with tobacco and tobacco separately ($n = 4$) and mixing cannabis with tobacco but not using tobacco separately ($n = 3$). Five cannabis users were current tobacco users and 12 were former tobacco users. The tobacco-only group had used tobacco for 37.1 years ($SD = 7.8$) and had smoked at their current level for 33.8 years ($SD = 9.4$). Of those who had ever used alcohol, 14 cannabis and tobacco users reported past month use. Of those reporting lifetime use of other illicit drugs, 40.0% (2 of 5) and 50% (2 of 4) of cannabis users reported past month use of benzodiazepines and synthetic cannabinoids, respectively. Participants reported no other past month illicit drug use.

3.2. Learning and memory

Cannabis users recalled significantly fewer words than tobacco users on Trials II-IV, B and VII, with a moderate magnitude effect on Trial VI in the same direction (Table 2). Cannabis users had significantly lower total learning acquisition ($g = 1.08$). While non-significant, there were moderate magnitude impairments on Trials I and V ($g = 0.47$ and 0.48), interference ($g = 0.36$), and forgetting ($g = 0.60$).

Trial I performance and daily standard cannabis units (SCU) were strongly inversely related ($r = -0.53$), indicating that poorer immediate recall is associated with greater cannabis use quantity. There were no other correlations between other RAVLT measures and indices of cannabis consumption.

Cannabis users systematically performed more poorly than published norms on RAVLT measures, but this only met statistical significance for Trials II-III, B, and delayed recall (VII; all $g > 0.50$). Tobacco users scored similarly to norms on all trials except for greater recall on Trial IV and total learning.

3.3. Symbol Digit Substitution Task

Cannabis users had poorer performance overall, with significantly slower RT ($g = 0.87$) and non-significant but moderate magnitude increased errors ($g = 0.48$). There were no significant correlations between task performance and cannabis use measures.

3.4. Stop Signal Task

Groups performed similarly for RT and errors (Table 3). While non-significant, there was a moderate magnitude effect for stop signal response time ($g = 0.61$) indicating that cannabis users were slower than tobacco users. There were significant strong correlations between years of cannabis use and RT ($r = 0.55$) and stop signal response time ($r = 0.58$), indicating that slower stop signal response time was associated with greater years of cannabis use.

3.5. Rapid Visual Information Processing

While there were no group differences in false positive rates, cannabis users had significantly slower RT ($g = 0.74$). There were no significant correlations between task performance and any measure of cannabis use.

3.6. Arrow flankers

There was a significant main effect of Condition on flanker RT ($\eta_p^2 = 0.35$) such that RT was slower for incongruent than congruent and neutral conditions. There were no group effects or interactions on RT and no correlations with cannabis measures. Cannabis users had slower RT on neutral stimuli ($g > 0.60$). No main effects or interactions were apparent for errors. The number of false positive responses to No Go trials were similar between groups. There was a strong and negative significant ($r = -0.52$) correlation between errors in the incongruent condition and abstinence, indicating increased length of abstinence is associated with a decrease in errors.

3.7. Depression, anxiety, and stress scale 21 (DASS 21)

Groups scored similarly on depression, anxiety, and stress (Table 4). There were significant, strong correlations between frequency of cannabis use and both depression ($r = 0.69$) and stress ($r = 0.61$). There were no other significant relationships between cannabis use measures and DASS 21 scales. Depression, anxiety, and stress were similar for cannabis users and norms whilst stress for tobacco users ($g = 0.57$) was significantly greater than norms.

3.8. Short Form 36

Cannabis users had moderately fewer role limitations due to emotional problems than tobacco users ($g = 0.53$; although this effect reduced following covariate control, $g = 0.37$; Table 4). Tobacco smokers had significantly poorer general health than cannabis users ($g = 0.72$).

Table 3
Computerised cognitive task performance of cannabis and tobacco users.

Measure	Cannabis *M* (*SD*)	Tobacco *M* (*SD*)	Cannabis vs tobacco		Cannabis vs tobacco[b]	
			g	*p*	*g*	*p*
Symbol Digit Substitution Test						
RT for correct responses (ms)	1825.0 (252.6)	1600.0 (250.3)	0.87[a]	0.014*	0.90[a]	0.016*
Number incorrect (*n*)	1.37 (1.9)	0.63 (0.89)	0.48	0.139	0.46	0.055
Stop Signal Task						
RT to correct responses (ms)	709.1 (125.7)	774.8 (145.8)	0.11	0.744	0.15	0.661
Mean stop signal response time, (ms)	375.6 (58.0)	336.6 (68.2)	0.61[a]	0.076	0.34	0.053
Number incorrect (*n*)	0.67 (0.97)	0.56 (1.03)	0.11	0.763	0.34	0.352
Rapid Visual Information Processing						
RT for correct responses (ms)	567.9 (56.9)	526.9 (51.8)	0.74[a]	0.038*	0.88[a]	0.021*
False positives (*n*)	4.94 (10.4)	4.81 (5.6)	0.02	0.965	0.14	0.694
Flankers No Go						
No Go false positives (*n*)	1.67 (1.1)	2.44 (2.3)	0.43	0.226	0.53[a]	0.146
Flankers Reaction Time (ms)						
Congruent	739.6 (120.9)	679.6 (107.5)	0.51[a]	0.134	0.42	0.235
Neutral	766.1 (128.3)	678.5 (143.2)	0.63[a]	0.065	0.71[a]	0.051
Incongruent	821.0 (117.5)	804.6 (199.2)	0.10	0.764	0.07	0.874
Flankers Errors (*n*)						
Congruent	0.94 (1.7)	0.27 (0.8)	0.48	0.108	0.51[a]	0.157
Neutral	0.89 (1.0)	0.53 (1.3)	0.30	0.256	0.30	0.391
Incongruent	1.28 (1.1)	1.00 (1.8)	0.19	0.583	0.04	0.905

Unadjusted means (*M*) and standard deviations (*SD*) are provided.
* $p < 0.05$.
[a] Moderate effect size > 0.50.
[b] Adjusted for premorbid IQ, gender, and tobacco pack years.

Non-parametric tests indicated that tobacco users had significantly poorer physical functioning ($p = 0.017$) than cannabis users. No additional significant or moderate magnitude differences were found between groups. Groups scored similarly to norms on all SF-36 measures, except tobacco users had significantly greater role limitations due to emotional problems ($g = 0.74$). There were no significant correlations between SF-36 measures and cannabis use variables.

3.9. World Health Organisation Quality of Life – Brief Survey (WHOQOL-BREF)

Cannabis users had significantly greater health satisfaction and psychological health than tobacco users ($g > 0.50$; Table 4). Non-parametric results failed to identify a statistical significance between groups for psychological health. No other significant or moderate magnitude differences were found between groups on remaining measures. Cannabis frequency had a significant, strong negative correlation with physical and psychological health ($r = -0.51$ and $r = -0.59$, respectively). A significant, strong correlation was apparent between standard cannabis units consumed and satisfaction with health ($r = 0.57$). There were no additional significant correlations with cannabis measures.

Cannabis users performed similar to norms (all $g < 0.17$) on all measures except for having poorer social functioning ($g = 0.48$). Tobacco users had significantly poorer satisfaction with health ($g = 0.81$), psychological health ($g = 0.74$), and social functioning than norms ($g = 0.61$).

3.10. Physical Health Questionnaire

Tobacco users had significantly poorer somatic health than cannabis users ($g = 1.68$). The Physical Health Questionnaire had a significant and strong inverse relationship with cannabis use frequency ($r = -0.54$) but no other relationships with cannabis measures.

4. Discussion

4.1. Cognitive outcomes

Consistent with our hypothesis, cannabis users had poorer learning and memory than tobacco users, suggesting an effect of long-term cannabis use on memory despite short-term abstinence. Cannabis users were slower to learn and experienced poorer memory retention, as indicated by poorer performance on intermediate RAVLT trials. Cannabis may have contributed to memory deficits due to partial agonistic effects of Δ-9 tetrahydrocannbinol (THC; the primary psychoactive component of cannabis) on cannabinoid type I (CB_1) receptors, that are highly concentrated in the hippocampus, which can subsequently block mechanisms necessary for learning and memory, i.e. long term potentiation (Battisti et al., 2010; Hoffman, Oz, Yang, Lichtman, & Lupica, 2007; Kawamura et al., 2006). Other evidence suggests that THC has full agonistic effects on CB_1 receptors which impairs memory by inhibiting gamma-aminobutyric acid transmission in the hippocampus (Laaris, Good, & Lupica, 2010; Tsou, Mackie, Sanudo-Pena, & Walker, 1999). The results are similar to past findings which indicate long-term cannabis use may impair learning and memory, even following short-term abstinence, and is consistent with models that assert cognitive deficits are implicated in ongoing drug use (Broyd et al., 2013; Goldstein & Volkow, 2011; Solowij et al., 2002a). As cognitive deficits may contribute to poorer everyday functioning, ongoing drug use, and relapse following drug cessation (Goldstein & Volkow, 2011; Volkow, Fowler, Wang, & Goldstein, 2002), long-term cannabis users may benefit from memory interventions.

Contrary to our hypothesis, sustained attention, inhibition, and executive control were similar between groups. Cannabis users in our study used approximately six to seven cones per day nearly seven days per week, which is a “medium” dose size according to the criteria of Bolla et al. (2002) whom found users of that dose did not exhibit cognitive deficits. This suggests that short-term abstinence in long-term, moderate cannabis users may not result in impairments in executive

Table 4
Mental and physical health results for cannabis users, tobacco users, and population norms.

	Group			Cannabis vs tobacco		Cannabis vs tobacco††		Cannabis vs norms		Tobacco vs norms	
	Cannabis *M* (*SD*)	Tobacco *M* (*SD*)	Norms *M* (*SD*)	*g*	*p*	*g*	*p*	*g*	*p*	*g*	*p*
Depression, Anxiety, and Stress Scale 21											
Depression	2.8 (3.5)	3.8 (4.0)	2.6 (3.9)	0.29	0.427	0.17	0.623	0.06	0.807	0.32	0.207
Anxiety	2.3 (2.6)	2.6 (2.5)	1.7 (2.8)	0.12	0.732	0.11	0.761	0.19	0.423	0.30	0.245
Stress	4.4 (3.9)	6.2 (3.2)	4.0 (4.2)	0.48	0.155	0.48	0.180	0.10	0.664	0.57†	0.040*
Short Form 36											
Physical functioning	52.1 (7.2)	49.0 (7.0)	50.6 (9.2)	0.43	0.204	0.46	0.195	0.17	0.309	0.17	0.493
Role limitations due to physical problems	50.0 (10.3)	49.4 (7.0)	50.8 (9.9)	0.18	0.602	0.24	0.503	0.35	0.802	0.14	0.632
Bodily pain	49.8 (9.9)	50.3 (9.5)	52.2 (8.9)	0.05	0.881	0.20	0.575	0.27	0.245	0.06	0.399
General health	52.3 (10.0)	45.6 (8.0)	50.5 (10.4)	0.72†	0.038*	0.84†	0.021*	0.18	0.446	0.47	0.062
Vitality	53.3 (8.9)	49.0 (8.8)	51.4 (10.4)	0.47	0.162	0.26	0.454	0.18	0.439	0.24	0.349
Social functioning	51.1 (7.4)	49.1 (9.8)	50.8 (9.7)	0.23	0.497	0.29	0.410	0.03	0.908	0.18	0.479
Role limitations due to emotional problems	50.4 (8.1)	45.9 (8.4)	52.0 (8.2)	0.53†	0.121	0.37	0.297	0.20	0.397	0.74†	0.003*
Mental health	53.5 (6.0)	49.8 (10.8)	53.2 (9.6)	0.42	0.211	0.34	0.333	0.04	0.876	0.35	0.170
Physical component score	51.0 (9.1)	49.0 (8.6)	50.3 (9.7)	0.23	0.506	0.22	0.534	0.08	0.774	0.13	0.593
Mental component score	52.3 (5.7)	48.5 (12.9)	52.9 (10.2)	0.38	0.291	0.27	0.445	0.06	0.794	0.43	0.086
Brief Version of the World Health Organisation Quality of Life											
Overall quality of life	4.4 (0.7)	4.3 (0.6)	4.3 (0.8)	0.17	0.627	0.18	0.611	0.15	0.522	0.01	0.961
Satisfaction with Health	3.7 (1.2)	2.9 (1.0)	3.6 (0.9)	0.79†	0.023*	0.75†	0.041*	0.15	0.515	0.80†	0.002*
Physical health	77.3 (17.4)	75.2 (12.3)	80.0 (17.1)	0.13	0.696	0.19	0.622	0.16	0.495	0.28	0.269
Psychological health	71.8 (8.9)	62.0 (17.0)	72.6 (14.2)	0.73†	0.049*	0.54†	0.133	0.06	0.813	0.74†	0.004*
Social relationships	63.2 (27.3)	60.9 (20.6)	72.2 (18.5)	0.09	0.790	0.19	0.594	0.48	0.044*	0.61†	0.018*
Environment	77.3 (12.4)	72.0 (19.5)	74.8 (13.7)	0.32	0.349	0.37	0.303	0.18	0.415	0.20	0.457
Physical Health Questionnaire											
	85.4 (8.5)	68.1 (11.6)	–	1.68†	< 0.001*	1.40†	< 0.001*	–	–	–	–

Unadjusted means (*M*) and standard deviations (*SD*) are provided.
Norms from Murphy, Herrman, Hawthorne, Pinzone, and Evert (2000), Crawford, Cayley, Lovibond, Wilson, and Hartley (2011) and Hawthorne (2006). DASS 21, $N = 497$, SF-36 $N = 3013$–15, WHOQOL-BREF, $N = 369$.
Higher scores on DASS 21 denote poorer mental health; higher scores on the SF-36, PHQ, and WHOQOL-BREF denote superior functioning.
* $p < 0.05$.
† Moderate effect size > 0.05.
†† Adjusted for premorbid IQ, gender, and tobacco pack years.

functioning. However, cannabis users had slower responses during processing speed, inhibitory, and sustained attention tasks. The finding of reduced RT but equivalent behavioural performance may reflect neuroadaptation/tolerance in response to long-term cannabis use (Kanayama, Rogowska, Pope, Gruber, & Yurgelun-Todd, 2004; Struve et al., 1999). That is, engaging in an ineffective neural processing strategy that maintains accuracy at the cost of speed. This finding is consistent with previous results indicating that behavioural performance is maintained at the cost of another process (Jager, Block, Luijten, & Ramsey, 2010; Kanayama et al., 2004; Nicholls, Bruno, & Matthews, 2015). This suggests that even during short-term abstinence, long-term cannabis use may affect tasks requiring speedy behavioural responses, such as driving, and necessitates the provision of education to long-term cannabis users regarding consequences of cannabis to enhance safety.

4.2. Mental and physical health of cannabis and tobacco users

Contrary to expectations, cannabis users exhibited superior mental and physical health on some measures than tobacco users and norms. It is likely that physical and mental health differences between groups are attributable to tobacco as only five of the 19 cannabis users self-reported being current tobacco users. Epidemiological research has confirmed that tobacco is more strongly associated with poorer mental health than cannabis (Degenhardt, Hall, & Lynskey, 2001). Cross-sectional studies also indicate that tobacco is substantially harmful to health (Castro, Matsuo, & Nunes, 2010; Laaksonen, Rahkonen, Martikainen, Karvonen, & Lahelma, 2006; Mano-Otagiri, Iwasaki-Sekino, Ohata, Arai, & Shibasaki, 2009; Moreira et al., 2013). Our results suggest that long-term tobacco use, *alone,* may be associated with poor mental and physical health.

4.3. Limitations

This study had a number of limitations. The small sample may have reduced the ability to detect differences in performance; however, measures of effect were interpreted in consideration of potential statistical power issues. In addition, we did not recruit a drug-naïve control group, which limits the ability to draw conclusions between cannabis users and non-drug users, however; norms were used to overcome this limitation. Whilst the use of self-report measures to assess substance use may be problematic as it relies on memory, evidence indicates that self-reporting is relatively reliable with little loss of accuracy over time (Del Boca & Darkes, 2003; Robinson, Sobell, Sobell, & Leo, 2014). We did not quantify cannabis withdrawal, however, the current results are unlikely due to withdrawal as cannabis users tested THC positive and had a short abstinence period. Onset of physical and psychological withdrawal symptoms range from one to ten days following cannabis cessation and typically peak at day three of abstinence (Allsop et al., 2014; Bonnet, Borda, Scherbaum, & Specka, 2015; Copersino et al., 2006). Altogether, it is likely that intoxication had passed but withdrawal had not begun when cannabis users underwent

testing. Additionally, some participants reported past use of other substances, however, this was minimal in the month prior to testing and exclusion criteria were used to screen out regular users of other drugs.

5. Conclusion

Overall, the results suggest that long-term cannabis use is associated with deficits in reaction time and learning and memory processes but not attention, inhibition, executive control, and information processing during short-term abstinence. Lack of differences between groups on some tasks suggests long-term cannabis use may not harm such domains, that tolerance may develop, or that impairments reverse following short-term abstinence, however, further research with larger sample sizes and control of confounds is needed to delineate stronger conclusions. That tobacco users exhibited poorer mental and physical health on some measures necessitates that researchers control for confounding factors in future studies. Our results suggest that individuals who have used cannabis long-term may benefit from mnemonic training to assist any learning and memory difficulties. Our results suggest that short-term abstinence in long-term cannabis use is associated with impairments in some areas of cognition that may affect everyday tasks, such as driving and remembering information, whilst long-term tobacco use may distinctly contribute to mental and physical health detriments.

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Contributors

Authors JJ, NL, DA, and IM designed the study. JJ and ML collected data. DA, JJ and ML cleaned and prepared data. ML ran statistical analyses with input from AM and RB. ML prepared the manuscript and all named authors reviewed and approved the document.

Conflict of interest

The authors declare no conflicts of interest.

Appendix A

Table A1
Correlations between cannabis parameters and outcome measures.

	Cannabis abstinence (hours)	Cannabis use (years)	Cannabis frequency (per day)	Daily standard cannabis units
Rey Auditory Verbal Learning Test				
I	0.37	− 0.06	− 0.24	− 0.53*
II	0.22	0.13	− 0.04	0.10
III	0.20	− 0.01	0.19	− 0.02
IV	0.21	− 0.27	− 0.14	0.06
V	0.33	− 0.10	− 0.11	− 0.09
I-V	0.39	− 0.08	− 0.12	− 0.17
B	0.19	− 0.09	− 0.22	− 0.28
VI	0.16	− 0.17	0.03	− 0.22
VII	0.17	− 0.01	− 0.03	− 0.38
Forgetting	− 0.07	0.07	0.06	− 0.41
Interference	− 0.22	− 0.12	0.20	− 0.23
Arrow flankers				
Congruent RT	− 0.06	0.37	− 0.002	0.33
Neutral RT	0.05	0.32	− 0.07	0.04
Incongruent RT	− 0.14	0.42	− 0.02	0.18
Congruent errors	− 0.24	− 0.11	− 0.09	− 0.24
Neutral errors	− 0.12	0.33	− 0.35	− 0.20
Incongruent errors	− 0.52*	0.23	0.08	0.20
No Go false positives	− 0.40	0.07	0.09	− 0.01
Symbol Digit Substitution Task				
RT correct	− 0.36	− 0.19	0.23	0.02
Number incorrect	0.02	− 0.34	0.18	− 0.15
Stop Signal Task				
RT correct	− 0.40	0.55	0.19	0.21
Stop signal response time	− 0.21	0.58	0.25	0.27
Number incorrect	− 0.28	− 0.29	− 0.21	− 0.17
Rapid Visual Information Processing Task				
RT correct	0.06	0.26	0.08	− 0.04
False positives	0.13	0.17	0.16	− 0.08

DASS 21				
Depression	− 0.06	0.12	0.69*	0.41
Anxiety	− 0.23	0.07	0.14	− 0.07
Stress	− 0.10	0.01	0.61*	0.36
Short Form 36				
Physical functioning	0.14	− 0.27	− 0.001	0.24
Role limitations due to physical problems	0.18	− 0.12	− 0.04	0.15
Bodily pain	0.26	− 0.32	− 0.23	− 0.23
General health	0.03	− 0.27	− 0.03	0.17
Vitality	0.22	− 0.19	− 0.41	0.01
Social functioning	0.22	0.18	− 0.07	0.26
Role limitations due to emotional problems	0.14	− 0.15	− 0.21	0.15
Mental health	0.16	0.20	− 0.18	0.01
Physical component score	0.17	− 0.33	− 0.07	0.08
Mental component score	0.20	0.19	− 0.33	0.12
World Health Questionnaire Quality of Life - Brief				
Overall Quality of life	0.07	− 0.16	− 0.01	− 0.13
Health satisfaction	0.20	− 0.16	0.09	0.57*
Physical health	0.17	− 0.10	− 0.51*	− 0.08
Psychological health	0.23	− 0.10	− 0.59*	− 0.09
Social relationships	− 0.21	0.08	− 0.27	− 0.25
Environment	0.38	− 0.37	− 0.13	0.19
Physical Health Questionnaire	0.24	− 0.40	− 0.54*	− 0.04

* $p < 0.05$.

Appendix B. Re-analysis of data excluding all participants that were drug positive/had unavailable drug urine results

Table B1
Demographic and substance use details of cannabis and tobacco users.

	Group			
	Cannabis $n = 14$	Tobacco $n = 15$	*g*	*p*
Demographics				
Age (years)	57.9 (8.3)	53.3 (7.5)	0.56†	0.135
Male sex, %, (*n*)	57.1 (8.0)	33.3 (5.0)	0.198††	0.198
Education years, *M* (*SD*)	14.6 (4.0)	13.3 (3.2)	0.35	0.337
Married, including de facto, % (*n.*)	42.9 (6.0)	66.7 (10.0)	0.265††	0.265
WTAR std. score, *M* (*SD*)	113.1 (12.1)	106.7 (10.6)	0.55†	0.136
Substance Use History				
Alcohol use per occasion past month, (standard drinks)	5.0 (4.7) range 1.8–18.0	5.1 (4.2) range 1.0–18.0	0.02	0.956
Alcohol use, days per month (*n*)	17.5 (12.9)	7.6 (8.9)	0.88†	0.039*,[a]
Tobacco pack years	23.0 (27.4)	22.9 (10.1)	0.01	0.987
Age first used tobacco, years	15.2 (4.4)	15.9 (3.2)	0.18	0.625
Nicotine dependence, Fagerstrom score	0.7 (1.5)	4.4 (0.6)	1.78†	< 0.001*
Age first used cannabis (years)	19.1 (4.5)	17.5 (2.0)	0.42	0.316

SDS scores of three or greater indicate cannabis dependence (Swift et al., 1998).

* Significant at the $p < 0.05$ level.

[a] Correlational analyses comparing past month alcohol use to outcome variables resulted in no statistically significant correlations, except for a strong, negative ($r = -0.48$, $p = 0.018$) association with WHOQOL-BREF social relationships. When past month alcohol use was included as a covariate with this variable, group differences were non-significant which is comparable to the original analysis and the re-analysis following removal of positive drug tests and unavailable urine results.

† Moderate effect size > 0.05.

†† Cramer's *V*.

Table B2
Mean word recall for cannabis users, tobacco users, and norms.

Group *M* (*SD*)				Cannabis vs Tobacco		Cannabis vs Norms		Tobacco vs Norms		Cannabis vs Tobacco††	
Trial	Norms $n = 161$[a]	Cannabis $n = 14$	Tobacco $n = 15$	*g*	*p*	*g*	*p*	*g*	*p*	*g*	*p*
I	6.2 (1.6)	6.0 (2.6)	6.7 (2.1)	0.29	0.411	0.12	0.673	0.30	0.262	0.27	0.460
II	9.0 (1.9)	7.1 (2.1)	9.8 (2.0)	1.28†	0.001*	0.99*	0.001*	0.42	0.122	0.98†	0.010*
III	10.5 (1.9)	9.4 (2.1)	11.2 (1.6)	0.94†	0.014*	0.57*	0.041*	0.37	0.169	0.89†	0.021*
IV	11.4 (1.9)	10.8 (1.5)	12.4 (2.0)	0.88†	0.023*	0.32	0.252	0.52*	0.054	0.91†	0.025*
V	12.1 (2.1)	11.4 (2.0)	12.0 (1.9)	0.30	0.443	0.33	0.232	0.05	0.859	0.39	0.340
Total learning acquisition, Σ I-V	47.6 (8.1)	44.7 (7.4)	52.1 (7.9)	0.94†	0.015*	0.36	0.198	0.55*	0.041*	0.90†	0.024*
Interference, trial VI minus V	–	− 2.3 (1.4)	− 1.7 (2.0)	0.34	0.343	–	–	–	–	0.20	0.599
Distractor list, B	5.7 (2.2)	4.6 (1.7)	6.5 (1.1)	1.30†	0.002*	0.51*	0.070	0.37	0.166	1.30†	0.004*
Postdistractor trial, V1	9.9 (2.8)	9.1 (2.0)	10.3 (3.4)	0.41	0.253	0.29	0.298	0.14	0.504	0.37	0.329
Delayed recall, VII[b]	9.9 (3.2)	8.6 (2.6)	10.5 (3.5)	0.60†	0.100	0.41	0.142	0.19	0.492	0.68†	0.074
Forgetting, trial VII minus V	–	− 2.9 (2.1)	− 1.5 (2.2)	0.63†	0.094	–	–	–	–	0.66†	0.092

Unadjusted means (*M*) and standard deviations (*SD*) are provided.
[a] Norms obtained from Schmidt (1996) as cited in Strauss et al. (2006), age range 50–59 years.
[b] Trials I to V, B, VI, and VII were measured as number of words recalled.
† Moderate effect size classified as > 0.5.
†† Adjusted for premorbid IQ, gender, and tobacco pack years.
* $p < 0.05$.

Table B3
Computerised cognitive task performance of cannabis and tobacco users.

Measure	Cannabis, *M* (*SD*)	Tobacco, *M* (*SD*)	Cannabis vs Tobacco			Cannabis vs Tobacco ††	
			F	*g*	*p*	*g*	*p*
Symbol Digit Substitution Test							
RT for correct responses (ms)	1825.0 (295.1)	1620.1 (245.3)	4.03	0.74†	0.055	0.82†	0.043*
Number Incorrect (*n*)	1.7 (2.1)	0.5 (0.8)	4.01	0.74†	0.062	0.59†	0.123
Stop Signal Task							
RT to Correct Responses (ms)	786.9 (127.7)	779.9 (149.4)	0.02	0.05	0.895	0.11	0.777
Stop Signal Response time (ms)	374.1 (58.1)	335.1 (70.4)	2.62	0.59†	0.117	0.71†	0.067
Number Incorrect (*n*)	0.8 (1.1)	0.6 (1.1)	0.17	0.15	0.681	0.26	0.496
Rapid Visual Information Processing							
RT for correct responses (ms)	575.3 (61.4)	529.7 (52.3)	4.35	0.78†	0.047*	0.84†	0.041*
False positives (*n*)	6.4 (12.2)	4.9 (5.8)	0.19	0.16	0.665	0.21	0.577
Flankers No Go							
No Go false positives (*n*)	1.6 (1.2)	2.5 (2.3)	2.07	0.47	0.165	0.60†	0.123
Flankers Reaction Time (ms)							
Congruent	758.6 (121.2)	683.9 (109.8)	3.03	0.63†	0.093	0.50†	0.197
Neutral	796.3 (126.4)	796.3 (126.4)	4.82	0.79†	0.037*	0.72†	0.065
Incongruent	837.4 (121.8)	813.3 (203.0)	0.15	0.14	0.705	0.04	0.914
Flankers Errors (*n*)							
Congruent	1.29 (1.9)	0.3 (0.8)	3.78	0.67†	0.063	0.59†	0.130
Neutral	1.21 (1.1)	0.5 (1.3)	3.28	0.49	0.135	0.38	0.320
Incongruent	1.38 (1.2)	1.1 (1.8)	0.28	0.18	0.604	0.08	0.839

Unadjusted means (*M*) and standard deviations (*SD*) are provided.
* $p < 0.05$.
† Moderate effect size > 0.50.
†† Adjusted for premorbid IQ, gender, and tobacco pack years.

Table B4
Mental and physical health results for cannabis users, tobacco users, and population norms.

	Group			Cannabis vs Tobacco		Cannabis vs Norms		Tobacco vs Norms		Cannabis vs Tobacco††	
	Norms *M* (*SD*)	Cannabis *M* (*SD*)	Tobacco *M* (*SD*)	*g*	*p*	*g*	*p*	*g*	*p*	*g*	*p*
Depression, Anxiety, and Stress Scale 21											
Depression	2.6 (3.9)	2.1 (2.3)	3.1 (2.8)	0.40	0.309	0.12	0.651	0.14	0.598	0.25	0.534
Anxiety	1.7 (2.8)	2.1 (3.0)	2.1 (1.8)	< 0.001	0.946	0.13	0.634	0.13	0.619	0.09	0.855
Stress	4.0 (4.2)	3.9 (3.4)	5.9 (3.0)	0.61†	0.112	0.02	0.937	0.45	0.084	0.58†	0.132
Short Form 36											
Physical functioning	50.6 (9.2)	52.1 (7.9)	48.9 (7.3)	0.41	0.270	0.17	0.534	0.18	0.483	0.59†	0.122
Role limitations due to physical problems	50.8 (9.9)	52.5 (10.1)	49.9 (6.9)	0.29	0.413	0.18	0.465	0.09	0.793	0.33	0.379
Bodily pain	52.2 (8.9)	52.1 (9.6)	51.7 (7.9)	0.04	0.898	0.16	0.980	0.05	0.842	0.12	0.761
General health	50.5 (10.4)	53.4 (11.1)	46.1 (8.0)	0.74†	0.052	0.28	0.300	0.42	0.103	0.30	0.026*
Vitality	51.4 (10.4)	54.3 (9.2)	50.2 (7.4)	0.48	0.195	0.28	0.297	0.12	0.655	0.26	0.478
Social functioning	50.8 (9.7)	51.4 (7.7)	49.3 (10.1)	0.23	0.543	0.06	0.824	0.16	0.547	0.29	0.56
Role limitations due to emotional problems	52.0 (8.2)	52.3 (6.7)	46.8 (7.9)	0.73†	0.055	0.04	0.876	0.63†	0.015*	0.61†	0.121
Mental health	53.2 (9.6)	54.6 (6.3)	51.5 (8.9)	0.39	0.292	0.15	0.579	0.18	0.498	0.30	0.448
Physical component score	50.3 (9.7)	51.9 (10.0)	49.1 (8.9)	0.29	0.434	0.17	0.531	0.12	0.641	0.32	0.406
Mental component score	52.9 (10.2)	53.6 (5.2)	49.9 (12.0)	0.38	0.307	0.07	0.803	0.30	0.252	0.37	0.488
Brief Version of the World Health Organisation Quality of Life											
Overall quality of life	4.3 (0.8)	4.4 (0.8)	4.3 (0.6)	0.14	0.929	0.13	0.646	0.00	0.100	0.13	0.949
Satisfaction with Health	3.6 (0.9)	3.7 (1.1)	2.9 (1.0)	0.74†	0.056	0.11	0.686	0.77†	0.004*	0.80†	0.053
Physical health	80.0 (17.1)	82.1 (15.5)	79.6 (10.6)	0.38	0.295	0.12	0.651	0.18	0.487	0.40	0.295
Psychological health	72.6 (14.2)	72.9 (8.3)	64.4 (14.3)	0.70†	0.061	0.02	0.938	0.58†	0.029*	0.55†	0.154
Social relationships	72.2 (18.5)	66.7 (24.7)	62.8 (19.9)	0.17	0.642	0.29	0.282	0.51†	0.055	0.24	0.529
Environment	74.8 (13.7)	77.9 (12.7)	74.6 (18.1)	0.20	0.570	0.23	0.405	0.01	0.956	0.31	0.424
Physical Health Questionnaire											
Total score	–	85.4 (8.5)	68.1 (11.6)	2.00†	< 0.001*	–	–	–	–	1.83†	< 0.001*

Unadjusted means (*M*) and standard deviations (*SD*) are provided.
Norms from Murphy et al. (2000), Crawford et al. (2011) and Hawthorne (2006). DASS 21, $N = 497$, SF-36 $N = 3013$–15, WHOQOL-BREF, $N = 369$.
Higher scores on DASS 21 denote poorer mental health; higher scores on the SF-36, PHQ, and WHOQOL-BREF denote superior functioning.
* $p < 0.05$.
† Moderate effect size > 0.05.
†† Adjusted for premorbid IQ, gender, and tobacco pack years.

References

Allsop, D. J., & Copeland, J. (2015). Age at first cannabis use moderates EEG markers of recovery from cannabis. *Journal of Substance Use, 21*(4), 400–406.

Allsop, D. J., Copeland, J., Lintzeris, N., Dunlop, A. J., Montebello, M., Sadler, C., ... McGregor, I. S. (2014). Nabiximols as an agonist replacement therapy during cannabis withdrawal: A randomized clinical trial. *JAMA Psychiatry, 71*(3), 281–291.

Aron, A. R., & Poldrack, R. A. (2006). Cortical and subcortical contributions to stop signal response inhibition: Role of the subthalamic nucleus. *The Journal of Neuroscience, 26*(9), 2424–2433. http://dx.doi.org/10.1523/JNEUROSCI.4682-05.2006.

Ashton, C. H. (2001). Pharmacology and effects of cannabis: A brief review. *The British Journal of Psychiatry, 178*(2), 101–106.

Australian Institute of Health and Welfare (2011). In D. s. s. n. C. N. P. 145 (Ed.). *2010 National drug strategy household survey report.* Canberra: AIHW.

Bakan, P. (1959). Extraversion-introversion and improvement in an auditory vigilance task. *British Journal of Psychology, 50*(4), 325–332.

Battisti, R. A., Roodenrys, S., Johnstone, S. J., Respondek, C., Hermens, D. F., & Solowij, N. (2010). Chronic use of cannabis and poor neural efficiency in verbal memory ability. *Psychopharmacology, 209*(4), 319–330.

Bolla, K. I., Brown, K., Eldreth, D., Tate, K., & Cadet, J. L. (2002). Dose-related neurocognitive effects of marijuana use. *Neurology, 59*(9), 1337–1343.

Bonnet, U., Borda, T., Scherbaum, N., & Specka, M. (2015). Abstinence phenomena of chronic cannabis-addicts prospectively monitored during controlled inpatient detoxification (part II): Psychiatric complaints and their relation to delta-9-tetrahydrocannabinol and its metabolites in serum. *Drug and Alcohol Dependence, 155*, 302–306.

Bowling, A., Bond, M., Jenkinson, C., & Lamping, D. L. (1999). Short Form 36 (SF-36) Health Survey questionnaire: Which normative data should be used? Comparisons between the norms provided by the omnibus survey in Britain, the health survey for England and the Oxford healthy life survey. *Journal of Public Health Medicine, 21*(3), 255–270.

Broyd, S. J., Greenwood, L. M., Croft, R. J., Dalecki, A., Todd, J., Michie, P. T., ... Solowij, N. (2013). Chronic effects of cannabis on sensory gating. *International Journal of Psychophysiology, 89*(3), 381–389.
Cameron, E., Sinclair, W., & Tiplady, B. (2001). Validity and sensitivity of a pen computer battery of performance tests. *Journal of Psychopharmacology, 15*(2), 105–110.
Castro, M. R. P. D., Matsuo, T., & Nunes, S. O. V. (2010). Clinical characteristics and quality of life of smokers at a referral center for smoking cessation. *Jornal Brasileiro de Pneumologia, 36*(1), 67–74.
Choo, E. K., & Emery, S. L. (2016). *Clearing the haze: The complexities and challenges of research on state marijuana laws.* Annals of the New York Academy of Sciences.
Copersino, M. L., Boyd, S. J., Tashkin, D. P., Huestis, M. A., Heishman, S. J., Dermand, J. C., ... Gorelick, D. A. (2006). Cannabis withdrawal among non-treatment-seeking adult cannabis users. *American Journal on Addictions, 15*(1), 8–14.
Crawford, J., Cayley, C., Lovibond, P. F., Wilson, P. H., & Hartley, C. (2011). Percentile norms and accompanying interval estimates from an Australian general adult population sample for self-report mood scales (BAI, BDI, CRSD, CES-D, DASS, DASS-21, STAI-X, STAI-Y, SRDS, and SRAS). *Australian Psychologist, 46*(1), 3–14.
Danielsson, A.-K., Lundin, A., Allebeck, P., & Agardh, E. (2016). Cannabis use and psychological distress: An 8-year prospective population-based study among Swedish men and women. *Addictive Behaviors, 59*, 18–23.
Degenhardt, L., Hall, W., & Lynskey, M. (2001). Alcohol, cannabis and tobacco use among Australians: A comparison of their associations with other drug use and use disorders, affective and anxiety disorders, and psychosis. *Addiction, 96*(11), 1603–1614.
Del Boca, F. K., & Darkes, J. (2003). The validity of self-reports of alcohol consumption: State of the science and challenges for research. *Addiction, 98*(s2), 1–12.
Eriksen, B. A., & Eriksen, C. W. (1974). Effects of noise letters upon the identification of a target letter in a nonsearch task. *Perception & Psychophysics, 16*(1), 143–149.
Gan, H. P., Wee, H. L., Cheung, Y. B., Luo, N., Fong, K. Y., Feeny, D., & Thumboo, J. (2013). Impact of self-reported smoking status on health-related quality of life in Singapore. *Journal of Public Health, 21*(5), 389–401.
Geffen, G. M., Butterworth, P., & Geffen, L. B. (1994). Test-retest reliability of a new form of the auditory verbal learning test (AVLT). *Archives of Clinical Neuropsychology, 9*(4), 303–316.
Goldstein, R. Z., & Volkow, N. D. (2011). Dysfunction of the prefrontal cortex in addiction: Neuroimaging findings and clinical implications. *Nature Reviews Neuroscience, 12*(11), 652–669.
Grant, I., Gonzalez, R., Carey, C. L., Natarajan, L., & Wolfson, T. (2003). Non-acute (residual) neurocognitive effects of cannabis use: A meta-analytic study. *Journal of the International Neuropsychological Society, 9*(5), 679–689.
Hall, W. (2009). The adverse health effects of cannabis use: What are they, and what are their implications for policy? *The International Journal on Drug Policy, 20*(6), 458–466.
Hall, W., & Solowij, N. (1998). Adverse effects of cannabis. *The Lancet, 352*(9140), 1611–1616.
Hasin, D. S., Saha, T. D., Kerridge, B. T., Goldstein, R. B., Chou, S. P., Zhang, H., ... Grant, B. F. (2015). Prevalence of marijuana use disorders in the United States between 2001-2002 and 2012-2013. *JAMA Psychiatry, 72*(12), 1235–1242.
Hawthorne, G. (2006). *Measuring incontinence in Australia.* Victoria, Australia: The Department of Psychiatry, The University of Melbourne.
Hill, R. D., Nilsson, L. G., Nyberg, L., & Bäckman, L. (2003). Cigarette smoking and cognitive performance in healthy Swedish adults. *Age and Ageing, 32*(5), 548–550.
Hoch, E., Bonnet, U., Thomasius, R., Ganzer, F., Havemann-Reinecke, U., & Preuss, U. W. (2015). Risks associated with the non-medicinal use of cannabis. *Deutsches Ärzteblatt International, 112*(16), 271.
Hoffman, A. F., Oz, M., Yang, R., Lichtman, A. H., & Lupica, C. R. (2007). Opposing actions of chronic Δ9-tetrahydrocannabinol and cannabinoid antagonists on hippocampal long-term potentiation. *Learning & Memory, 14*(1–2), 63–74.
Jager, G., Block, R. I., Luijten, M., & Ramsey, N. F. (2010). Cannabis use and memory brain function in adolescent boys: A cross-sectional multicenter functional magnetic resonance imaging study. *Journal of the American Academy of Child and Adolescent Psychiatry, 49*(6), 561–572.
Kanayama, G., Rogowska, J., Pope, H. G., Gruber, S. A., & Yurgelun-Todd, D. A. (2004). Spatial working memory in heavy cannabis users: A functional magnetic resonance imaging study. *Psychopharmacology, 176*(3–4), 239–247.
Kawamura, Y., Fukaya, M., Maejima, T., Yoshida, T., Miura, E., Watanabe, M., ... Kano, M. (2006). The CB1 cannabinoid receptor is the major cannabinoid receptor at excitatory presynaptic sites in the hippocampus and cerebellum. *Journal of Neuroscience, 26*(11), 2991–3001.
Laaksonen, M., Rahkonen, O., Martikainen, P., Karvonen, S., & Lahelma, E. (2006). Smoking and SF-36 health functioning. *Preventive Medicine, 42*(3), 206–209.
Laaris, N., Good, C. H., & Lupica, C. R. (2010). Δ9-tetrahydrocannabinol is a full agonist at CB1 receptors on GABA neuron axon terminals in the hippocampus. *Neuropharmacology, 59*(1–2), 121–127.
Lev-Ran, S., Roerecke, M., Le Foll, B., George, T. P., McKenzie, K., & Rehm, J. (2014). The association between cannabis use and depression: A systematic review and meta-analysis of longitudinal studies. *Psychological Medicine, 44*(4), 797–810.
Logan, G. D., Schachar, R. J., & Tannock, R. (1997). Impulsivity and inhibitory control. *Psychological Science, 8*(1), 60–64.
Lovibond, P. F., & Lovibond, S. H. (1995). The structure of negative emotional states: Comparison of the depression anxiety stress scales (DASS) with the Beck depression and anxiety inventories. *Behavior Research and Therapy, 33*(3), 343–355.
Majdan, A., Sziklas, V., & Jones-Gotman, M. (1996). Performance of healthy subjects and patients with resection from the anterior temporal lobe on matched tests of verbal and visuoperceptual learning. *Journal of Clinical and Experimental Neuropsychology, 18*(3), 416–430.
Mano-Otagiri, A., Iwasaki-Sekino, A., Ohata, H., Arai, K., & Shibasaki, T. (2009). Nicotine suppresses energy storage through activation of sympathetic outflow to brown adipose tissue via corticotropin-releasing factor type 1 receptor. *Neuroscience Letters, 455*(1), 26–29.
Mattila, M., & Mattila-Evenden, M. (1997). Effects of alcohol and hypnosedative drugs on digit-symbol substitution: Comparison of two different computerized tests. *Journal of Psychopharmacology, 11*(4), 313–317.
McHale, S., & Hunt, N. (2008). Executive function deficits in short-term abstinent cannabis users. *Human Psychopharmacology, 23*(5), 409–415.
Meier, M. H., Caspi, A., Ambler, A., Harrington, H., Houts, R., Keefe, R. S., ... Moffitt, T. E. (2012). Persistent cannabis users show neuropsychological decline from childhood to midlife. *PNAS: Proceedings of the National Academy of Sciences of the United States of America, 109*(40), E2657–E2664.
Min, S. K., Kim, K. I., Lee, C. I., Jung, Y. C., Suh, S. Y., & Kim, D. K. (2002). Development of the Korean versions of WHO quality of life scale and WHOQOL-BREF. *Quality of Life Research, 11*(6), 593–600.
Mittleman, M. A., Lewis, R. A., Maclure, M., Sherwood, J. B., & Muller, J. E. (2001). Triggering myocardial infarction by marijuana. *Circulation, 103*(23), 2805–2809.
Moreira, T. D. C., Figueiró, L. R., Fernandes, S., Justo, F. M., Dias, I. R., Barros, H. M. T., & Ferigolo, M. (2013). Quality of life of users of psychoactive substances, relatives, and non-users assessed using the WHOQOL-BREF. *Ciec Saude Coletiva, 18*(7), 1953–1962.
Murphy, B., Herrman, H., Hawthorne, G., Pinzone, T., & Evert, G. (2000). *Australian WHOQOL instruments: User's manual and interpretation guide.* Melbourne, Australia: Australian WHOQOL Field Study Centre.
Nicholls, C., Bruno, R., & Matthews, A. (2015). Chronic cannabis use and ERP correlates of visual selective attention during the performance of a flanker go/nogo task. *Biological Psychology, 110*, 115–125.
Nooyens, A. C., van Gelder, B. M., & Verschuren, W. M. (2008). Smoking and cognitive decline among middle-aged men and women: The Doetinchem cohort study. *American Journal of Public Health, 98*(12), 2244–2250.
Ott, A., Andersen, K., Dewey, M. E., Letenneur, L., Brayne, C., Copeland, J. R. M., ... Launer, L. J. (2004). Effect of smoking on global cognitive function in nondemented elderly. *Neurology, 62*(6), 920–924.
Pope, H. G., Gruber, A. J., & Yurgelun-Todd, D. (2001). Residual neuropsychologic effects of cannabis. *Current Psychiatry Reports, 3*(6), 507–512.
Rey, A. A. (1964). *L 'examen clinique en psychologie [clinical tests in psychology].* Paris: Presses Universitaires de France.
Robinson, S. M., Sobell, L. C., Sobell, M. B., & Leo, G. I. (2014). Reliability of the timeline followback for cocaine, cannabis, and cigarette use. *Psychology of Addictive Behaviors, 28*(1), 154–162.
Schat, A. C., Kelloway, E. K., & Desmarais, S. (2005). The physical health questionnaire (PHQ): Construct validation of a self-report scale of somatic symptoms. *Journal of Occupational Health Psychology, 10*(4), 363–381.
Schreiner, A. M., & Dunn, M. E. (2012). Residual effects of cannabis use on neurocognitive performance after prolonged abstinence: A meta-analysis. *Experimental and Clinical Psychopharmacology, 20*(5), 420–429.
Schuster, R. M., Crane, N. A., Mermelstein, R., & Gonzalez, R. (2015). Tobacco may mask poorer episodic memory among young adult cannabis users. *Neuropsychology, 29*(5), 759–766.
Sobell, L. C., & Sobell, M. B. (1996). *Timeline follow back: A calendar method for assessing alcohol and drug use (users guide).* Toronto: Addiction Research Foundation.
Solowij, N., Stephens, R. S., Roffman, R. A., Babor, T., Kadden, R., Miller, M., ... Vendetti, J. (2002a). Cognitive functioning of long-term heavy cannabis users seeking treatment. *JAMA, 287*(9), 1123–1194.
Solowij, N., Stephens, R. S., Roffman, R. A., Babor, T., Kadden, R., Miller, M., & Vendetti, J. (2002b). Cognitive functioning of long-term heavy cannabis users seeking treatment. *JAMA, 287*(9), 1123–1131.
Strauss, E., Sherman, E. M. S., & Spreen, O. (2006). *A compendium of neuropsychological tests: Administration, norms, and commentary* (3 ed.). New York: Oxford University Press.
Struve, F. A., Straumanis, J. J., Patrick, G., Leavitt, J., Manno, J. E., & Manno, B. R. (1999). Topographic quantitative EEG sequelae of chronic marihuana use: A replication using medically and psychiatrically screened normal subjects. *Drug and Alcohol Dependence, 56*(3), 167–179.
Swift, W., Copeland, J., & Hall, W. (1998). Choosing a diagnostic cut-off for cannabis dependence. *Addiction, 93*(11), 1681–1692.
Tashkin, D. P. (2010). Does cannabis use predispose to chronic airflow obstruction? *European Respiratory Journal, 35*(1), 3–5.
Tashkin, D. P., Baldwin, G. C., Sarafian, T., Dubinett, S., & Roth, M. D. (2002). Respiratory and immunologic consequences of marijuana smoking. *The Journal of Clinical Pharmacology, 42*, S71–S81.
Tetrault, J. M., Crothers, K., Moore, B. A., Mehra, R., Concato, J., & Fiellin, D. A. (2007). Effects of marijuana smoking on pulmonary function and respiratory complications: A systematic review. *Archives of Internal Medicine, 167*(3), 221–228.
Tiplady, B., Baird, R., Lütcke, H., Drummond, G., & Wright, P. (2005). Effects of ethanol on kinaesthetic perception. *Journal of Psychopharmacology, 19*(6), 627–632.
Tsou, K., Mackie, K., Sanudo-Pena, M. C., & Walker, J. M. (1999). Cannabinoid CB1 receptors are localized primarily on cholecystokinin-containing GABAergic interneurons in the rat hippocampal formation. *Neuroscience, 93*(969–975).
Tzu-Chin, W., Tashkin, D. P., Djahed, B., & Rose, J. E. (1988). Pulmonary hazards of smoking marijuana as compared with tobacco. *New England Journal of Medicine, 318*(6), 347–351.
Volkow, N. D., Fowler, J. S., Wang, G.-J., & Goldstein, R. Z. (2002). Role of dopamine, the frontal cortex and memory circuits in drug addiction: Insight from imaging studies. *Neurobiology of Learning and Memory, 78*(3), 610–624.
Wechsler, D. (2001). *Wechsler Test of Adult Reading (WTAR).* Texas: The Psychological Corporation.
Wesnes, K., & Warburton, D. M. (1984). Effects of smoking on rapid information processing performance. *Neuropsychobiology, 9*(4), 223–229.