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Review article

Identifying standardised neuropsychological test measures sensitive to cannabis consumption: A systematic review

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ABSTRACT

Background: While numerous studies have indicated acute neurocognitive changes following the administration of Δ9-tetrahydrocannabinol (THC; the psychoactive component of cannabis), the standardised neuropsychological tests most sensitive to THC are yet to be identified. As such, this systematic review analysed scientific evidence (since 2000) on the effects of THC on standardised neuropsychological test measures.

Methods: This review was conducted in line with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. Studies were eligible for inclusion if they utilised a between or within-subjects design in testing for differences in standardised neuropsychological test performance following the consumption of THC.

Results/discussion: Sufficient data were identified to examine 8 standardised neuropsychological test measures, with 12 studies being eligible for inclusion in the review. It was identified that the Cambridge Neuropsychological Test Automated Battery (CANTAB) subtest Spatial Working Memory, Hopkins Verbal Learning Test, Prose Recall and Rey Auditory Verbal Learning Test were sensitive to cannabis consumption.

Limitations: However, due to substantial variability observed across studies, the data could not be quantitatively analysed. It was noted that few studies employed standardised neuropsychological measures in assessing the effects of THC.

Conclusion: Overall, the findings highlight the need for further research examining the effects of cannabis on standardised and validated measures of neurocognitive function. Such an approach can be considered an important first step towards developing behavioural measures of impairment.

1. Introduction

With the medicinal and recreational use of cannabis increasing globally (United Nations Office on Drugs and Crime, 2022), there is a need to identify behavioural measures sensitive to cannabis impairment. Due to its psychoactive component, delta-9-tetrahydrocannabinol (THC), cannabis can induce varying levels of neurocognitive impairment through the modulation of neural activity/functional connectivity within fronto-subcortical circuitry and attentional networks (Ramaekers et al., 2021; Van Waes et al., 2012). As a result, THC may temporarily affect the execution of safety-related tasks such as driving, with studies observing increases in vehicle lane-weaving measures following THC consumption in occasional cannabis users (e.g., Arkell et al., 2020; Brooks-Russell et al., 2021; Hartman et al., 2015). Global epidemiological research indicates a low-to-moderate increase in crash risk in drivers testing positive to THC (Drummer et al., 2020; Li et al., 2013; Rogeberg, 2019).

The capacity to accurately assess cannabis impairment is limited, with THC concentrations (blood and saliva) having a weak relationship with neurocognitive performance and functional changes in driving ability (Arkell et al., 2021; McCartney et al., 2022; Ramaekers et al., 2006). Commonly utilised behavioural tests of impairment, such as the standardised field sobriety test, demonstrate limited sensitivity for detecting THC-induced driving impairment (Bosker et al., 2012; Marcotte et al., 2023; Spindle et al., 2021). As a further complication, THC binds to highly perfused tissue and remains detectable in saliva and blood samples days after abstinence, potentially leading individuals to test positive to THC in the absence of any cognitive or behavioural impairment (Karschner et al., 2009; Odell et al., 2015). Due to the poor association between blood and saliva THC markers with functional

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impairment, there is a need to identify cognitive and behavioural measures sensitive to the functional impact arising from cannabis consumption. The identification of such measures will aid in further elucidating the effects of cannabis consumption on neurocognitive function and help identify the window within which users should avoid safety-related tasks such as driving.

Since THC can affect cognition, standardised neuropsychological tests may be useful in this regard. Previous research demonstrates that acute THC administration can negatively impact performance on standardised measures of information processing speed, divided and sustained attention, and executive function (e.g., working memory, inhibition; McCartney et al., 2021; Ramaekers et al., 2021). However, characterising the overall effects of THC on cognitive function and driving-related skills is challenging, as the onset, duration, and extent of THC neurocognitive effects are moderated by factors such as dose, tolerance, and route of administration (for a full review of these moderating factors, see Ramaekers et al., 2021). As a result, delineating the effects of THC on specific cognitive functions has proven to be difficult. Further, despite the extensive research in the field, it remains unclear as to which cognitive performance measures are most sensitive to cannabis consumption. While the majority of research focuses on identifying cognitive domains most affected by THC, no review to date has aimed to identify specific cognitive tests that are adequately sensitive to THC consumption. In addition, close inspection of the extant literature indicates that standardised and validated neuropsychological test measures are infrequently used, limiting the ability to infer clinically and functionally meaningful performance impairments. The present study systematically reviews current evidence on the acute effects of THC on cognitive function, with the aim of identifying standardised neuropsychological test measures most sensitive to cannabis consumption.

2. Method

This review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) guidelines. CS and TM completed citation screening at the title, abstract and full-text stages, with KS reviewing and resolving any disagreements at the abstract and full-text stages. MS was consulted as required. Supplementary file 1 further details the search strategy and study selection processes utilised, including eligibility requirements that were adhered to. As participant recruitment was not required for this research, approval from an ethics committee was not sought.

2.1. Search strategy & selection

Searches of PubMed, ProQuest, APA PsycINFO and Scopus were conducted to identify relevant citations. Pubmed and Scopus search terms were limited to titles and abstracts, with the Scopus search also limited to journal articles and the English language. The ProQuest and PsycINFO searches were restricted by abstract and to peer-reviewed full text journal articles and scholarly journals, respectively. No other restrictions were applied.

TM completed database searches on July 29, 2022 (which was updated again in February 2024), using the following keywords in each category:

1. *THC, tetrahydrocannabinol, cannabi*,* or *mari*uana*
2. *cognit*, neuropsycholog*, electroencephalogra*, EEG, event-related potential,* or *ERP*

Note that these search terms were also utilised for a secondary review focusing on neural markers of cannabis consumption (reported elsewhere). The outlined search strategy was the same for both review articles, with differences only at the full-text inclusion stage.

After finalising database searches, the identified citations were imported into Endnote for the removal of duplicates. Subsequently, 7861 citations remained for screening, which was completed using Rayyan (Ouzzani et al., 2016). All articles published after the year 2000 were screened by title according to their relevance to THC, cognition and EEG with the remaining citations reviewed according to abstract and additional irrelevant or ineligible articles were removed. During title/abstract screening, review papers were identified and the reference lists of these review papers were screened to identify any further citations missed in the initial database searches. Following this process, a total of 84 relevant articles remained for full-text review.

While screening at the final stage, the following eligibility criteria were applied to reduce heterogeneity in the identified literature:

1. *Study design.* The study examined changes/differences in performance following consumption of THC (non-synthetic) and focused on acute effects. As such, both within-subjects and between-subjects designs were eligible for inclusion.
2. *Participants.* The study included adults aged 18 years and over. Both clinical and healthy populations were included.
3. *Standardised neuropsychological assessment tasks.* The study investigated cognitive test performance on standardised neuropsychological tests. Where effect sizes were not reported, studies were included if they reported raw scores (mean and *SD*) as opposed to transformed, normed, scaled or composite scores. Adapted or computerised versions of tests were not included, such as the computerised Digit Symbol Substitution Task (DSST; McLeod et al., 1982) and Paced Auditory Serial Addition Task (Herrmann et al., 2015). For the DSST, only data from the WAIS subtest version (also termed 'coding') were eligible for inclusion (Wechsler, 1955). If it was unclear if a standardised version of the test was used (e.g., did not report reference or did not state the official test name), these tests were excluded from analysis. MS (registered Clinical Neuropsychologist) was consulted where required in conjunction with published compendia on validated and standardised neuropsychological tests (Lezak, 2004; Strauss et al., 2006). Non-standardised and computerised tests were excluded on the basis that they were not reported in published compendia and/or their psychometric properties (validity and reliability metrics) were not available. In the absence of published psychometric properties of specific cognitive tests, it was not possible to determine whether the test assessed the cognitive domains claimed. To minimise negative effect on bias estimates of the effects of THC on cognitive function, it is necessary to exclude data from studies using cognitive tests with unknown reliability and/or validity estimates. Note that tasks that primarily assessed motor control/dexterity (e.g., the Grooved Pegboard Test) were also ineligible for inclusion.

Of the articles that remained for full-text screening, CS and TM reviewed each study to determine that (a) THC had not been administered with any other substance (with the exception of tobacco, usual medication or placebo), (b) that data provided would allow for the calculation of effect sizes (Cohen's *d*) and (c) the standardised neuropsychological test utilised appeared (with available data) in at least one other study. KS was consulted where required and reviewed the data once consolidated. Where insufficient data were available from the study, the necessary values were requested from the corresponding author (where valid contact details were available; $n = 18$).

TM completed an updated database search in February 2024, to ensure all relevant articles published post 2022 were captured. PubMed, ProQuest, APA PsycINFO and Scopus were again searched using the previously defined keywords and strategy, with year published limited to 2022 and onwards. As a result of the updated search, a total of 2412 additional citations were identified. These were imported into Endnote for duplicate removal, leaving a total of 1695 for title and abstract screening. TM independently screened these citations for relevance, identifying 14 articles that required full text screening. Authors TM and

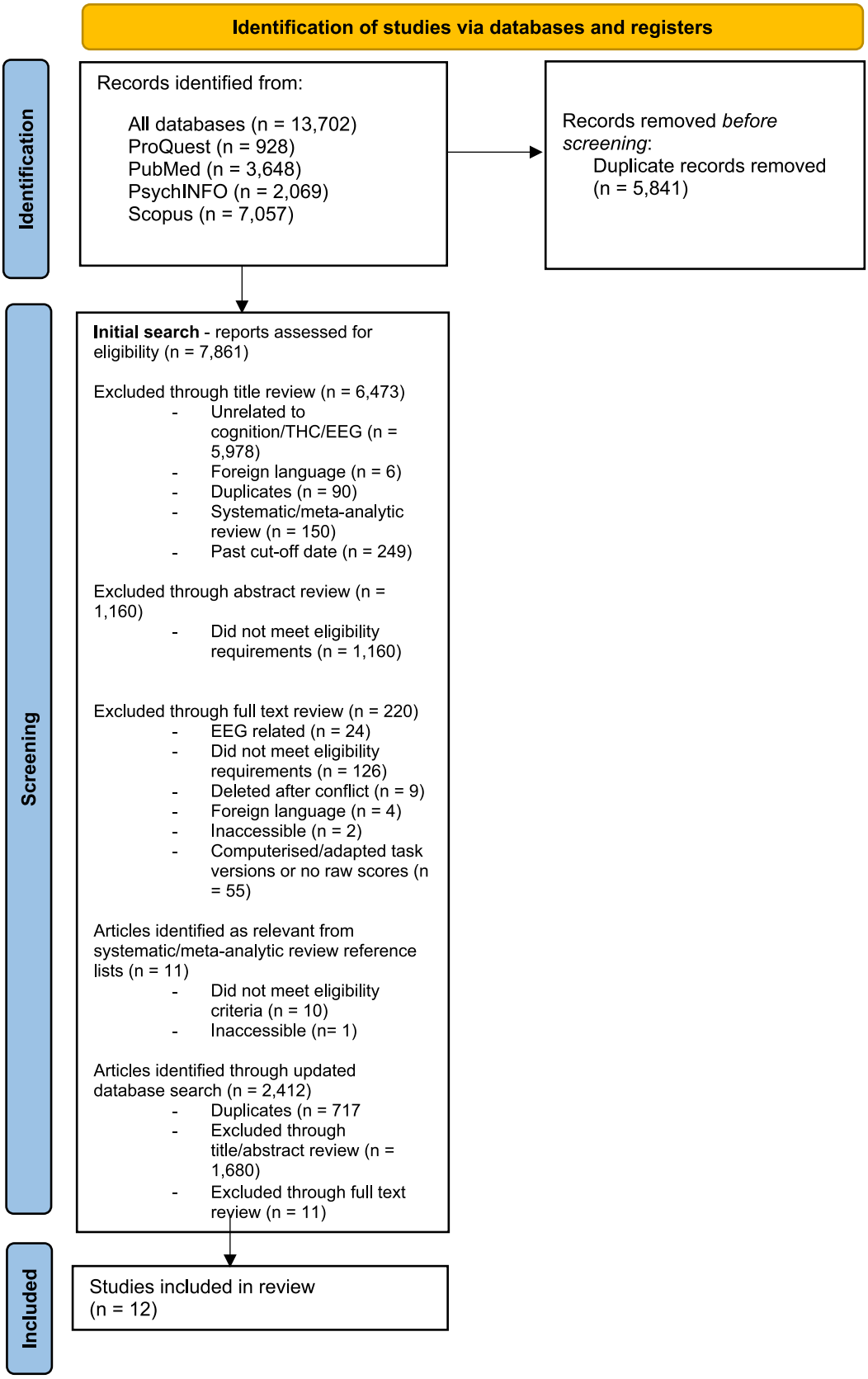

Fig. 1. Search strategy.

Table 1
Study and participant characteristics.

Study	Study design & sample N	Demographics/ health characteristics	Cannabis use history criteria	Cannabis intervention	Administration method	Neuropsychological test data	Timing of assessment
Arkell et al. (2023)	*N* = 40 (18 male)	M (SD) age = 41.38 (12.66) Varied health indications (medicinal cannabis patients)	No cannabis use history criteria but had to be currently prescribed a THC cannabis product. Participants reported using medication on a daily basis	Standard dose of cannabis oil or flower as prescribed. M dose oil = 9.61 mg THC M dose flower = 37 mg THC	Oral Vaporised	CANTAB (Rapid Visual Information Processing & Spatial Working Memory)	3 h post
Bassir Nia et al. (2022)	*N* = 42 (22 male; pooled data from 2 sub-studies)	M (SD) age males = 28.4 (7.8) M (SD) age females = 25 (4.6)	Consumed cannabis at least once	Low dose: 0.015 mg/kg High dose: 0.03 mg/kg	IV	RAVLT	55 min post
Domen et al. (2023)	*N* = 58 (29 in THC/CBD group).	THC/CBD group M (SD) age = 70.5 (6.4) Idiopathic Parkinson's disease	No cannabis use history criteria. Participants were excluded for positive cannabinoid result in urine at baseline	3.3 mg/ml THC and 100 mg/ml CBD oral sesame oil solution.	Oral	TMT (A & B), HVLT-R	60–90 min (oral dose)
D'Souza et al. (2005)	*N* = 35	Diagnosed schizophrenic *n* = 13 M (SD) age = 44.46 (10.4) Healthy controls *n* = 22 M (SD) age = 29 (11.6)	At least 1 previous exposure No cannabis-naive or lifetime history of cannabis use disorder	0 mg, 2.5 mg & 5 mg THC	IV	HVLT	30 min post
D'Souza et al. (2008)	*N* = 28 (17 healthy, 11 frequent users) Note sample size for analysis unclear	M (SD) age = 24.89 (6.98)	Frequent users: ≥100 lifetime uses. Cannabis use within past week and recent exposure >10 x per month	Placebo THC followed by 0.0286 mg/kg THC in Placebo Haloperidol condition	IV	HVLT, CANTAB (Spatial Working Memory)	30 min post
Englund et al. (2013)	Mixed-design, placebo controlled *N* = 24	M (SD) age = 26 (4)	≥1 previous cannabis exposure	1.5 mg THC injection	IV	HVLT-R, Digit Span	40 min post
Hindocha et al. (2017)	Randomised, double-blind, placebo-controlled crossover trial N = 24 (12 female)	M (SD) age = 24.46 (3.96)	Non-dependent but experienced: ≥ 1 x per month & ≤ 3 x per week for past 6 months	66.67 mg Bedrobinol cannabis flower cigarette (16.1 % THC)	Smoked	Delayed Prose Recall (subtest of the Rivermead Behavioural Memory Test)	35 min post (delayed recall at 55 min post)
Lawn et al. (2023)	Randomised, double-blind, placebo-controlled crossover design N = 24 adults (12 female)	Adult sample M (SD) age = 27.77 (1.04)	Cannabis use 0.5–3 days per week, severe cannabis use disorder excluded	Cannabis flower (20.2 % and 0.4 %; 0.107 mg/kg THC)	Vaporised	Delayed Prose Recall (subtest of Rivermead Behavioural Memory Test)	120 min post (delayed recall)
Müller-Vahl et al. (2001)	Placebo-controlled, cross over *N* = 12 (11 males)	M (SD) age = 34 (13) Tourette Syndrome sample	Varied usage history. 7 reported no history of cannabis use	Doses of 5, 7.5 or 10 mg THC capsules	Oral	Digit Span (Hamburg-Wechsler subtest)	60 min post
Pelletti et al. (2021)	Within subjects *N* = 18 healthy young adults (11 male)	M (SD) age = 31.3 (3.2)	Light use: At least 5 lifetime exposures	Three cannabis cigarettes (0.41 % THC, 1.64 mg)	Smoked	TMT (A & B)	Within 7 min post third cigarette
Ranganathan et al. (2017)	Double-blind, randomised placebo-controlled Study 2 *N* = 57	Study 2: M (SD) age = 24.8 (7.9) Study 1 not included due to administering THC after learning trials	At least 1 previous exposure, substance dependence excluded	Study 2: 0.05 mg/kg THC	IV	RAVLT	Study 2: 25 & 95 min (long delayed) post
Ranganathan et al. (2019)	Double-blind, randomised, counterbalanced design Study1: *N* = 74 (Val/Val *n* = 18, Met/Met *n* = 20, Val/Met *n* = 36). Study 2 not included as was based on sub-set sample from study 1	Study 1: M (SD) age Val/Val = 25.6 (9.2) M (SD) age Met/Met = 25 (6.2) M (SD) age Val/Met = 24.9 (7.8)	Varied use history No cannabis naïve, cannabis abstinence for 24 h	0.05 mg/kg THC	IV	CANTAB (Rapid Visual Information Processing & Spatial Working Memory), RAVLT	20 min post

Note. CANTAB = Cambridge Neuropsychological Test Automated Battery; HVLT = Hopkins Verbal Learning Test; HVLT-R = Hopkins Verbal Learning Test-Revised; RAVLT = Rey Auditory Verbal Learning Test; TMT = Trail Making Test.

Table 2
Standardised neuropsychological tests.

Assessment tool	Description	*n*
CANTAB – Rapid Visual Information Processing (RVP)	A measure of sustained attention. Examinees are asked to detect target sequences of digits from the digits appearing on screen in a pseudo-random order.	2
CANTAB – Spatial Working Memory (SWM)	A measure of retention and manipulation of visuospatial information. Examinees are required to locate a yellow 'token' by systematically selecting and eliminating boxes.	3
Digit Span	A measure of short term and working memory. Examinees are to recall as many items as possible in forward or reverse order.	2
Hopkins Verbal Learning Test (HVLT) & revised version (HVLT-R).	A measure of verbal learning and memory. Assesses the examinee's ability to recall a list of words immediately after memorisation and after a 20-min delay.	6
Prose Recall - subtest of Rivermead Behavioural Memory Test	A measure of episodic memory. Examinees listen to a passage of prose (approximately 30s) and recall its contents both immediately and after a delay. Recall is scored systematically based on the amount of 'idea units' recalled.	2
Rey Auditory Verbal Learning Test (RAVLT)	A measure of attention, verbal learning, and verbal memory. Examinees are to immediately recall a 15-word list at 5 separate presentations. This is followed by a second 15-word list (interference), followed by recall of the first list. Delayed recall of the first list is also assessed.	3
Trail Making Test A (TMT A)	A measure of processing speed, visual screening, and selective attention. Examinees are to draw straight lines to connect numbers in ascending order.	3
Trail Making Test B (TMT B)	A measure of processing speed, set-shifting, divided attention, and visual attention. Examinees are to draw straight lines to connect alternating numbers and letters in ascending order. The time taken to finish each pattern is recorded.	3

CS reviewed each article at the full text stage, resulting in three additional studies eligible for inclusion in this review.

2.2. Risk of bias assessment

To address potential bias and methodological quality in the included studies, a systematic assessment was followed (adapted from Higgins et al., 2011). The exclusion criteria, cognitive screening, cannabis intervention, statistical analysis, selective reporting, and other unspecified potential bias were addressed separately for each included article. CS reviewed each study against the pre-specified criteria (see Supplementary File 1 for full details) and determined a classification of 'low risk', 'moderate risk' or 'high risk' for each criterion. KS reviewed these ratings, with disagreements being subsequently discussed and resolved.

2.3. Data extraction

The data was first extracted by CS, which included sample characteristics, study design, cannabis treatment details (e.g., dose, administration method, consumption timeframe), neuropsychological tasks and performance outcomes (including timepoints between THC exposure and task completion). Participant cannabis use history and requirements were also noted. Performance was compared from no cannabis (i.e., baseline, placebo or control group) to post-consumption of THC. Where both baseline and placebo data were provided, baseline performance was used as the comparator. After extraction and calculation of data, TM and KS reviewed the final outcomes for accuracy and comprehensiveness.

2.4. Data analysis

Results are interpreted in the context of magnitude of effects (Cohen's *d*), with 0.2, 0.5 and 0.8 representing small, medium and large magnitude effect sizes, respectively (Cohen, 1988). Where Cohen's *d* values were not reported, effect sizes were calculated using G*Power version 3.1.9.7, using means and standard deviations for each condition. Studies that did not provide sufficient information to calculate the effect size were excluded. For within-subject effect size calculations, a correlation of 0.5 between the no cannabis and cannabis conditions was assumed.

Due to significant heterogeneity observed across data points (due to differences in testing timeframes, dose, administration method and populations studied), the data were synthesised qualitatively. The data were interpreted on the basis of effect sizes rather than whether differences were statistically significant.

3. Results

A total of 84 full-text articles were initially eligible for inclusion in this review, of which 72 were excluded on the basis that adapted or computerised versions of tests were used or inadequate data were available (e.g., raw scores, not reported). As a result, 12 articles remained for qualitative synthesis (Fig. 1). See supplementary File 1 for further details outlining the search and study selection process at each stage (e.g., citation, title and abstract screening). Of the 52 review papers that were identified, 11 additional relevant articles were extracted from the reference lists for review, none of which were eligible for inclusion. Across the 12 full text articles, 8 different (eligible) standardised neuropsychological tasks were utilised. Study characteristic data and definitions of the tasks are reported in Tables 1 and 2, respectively.

3.1. CANTAB – Rapid Visual Information Processing

Based on current data available for RVP, it cannot be ascertained as to whether the test is sensitive to cannabis consumption. Only two studies examined effects on RVP performance, with the first study focusing on a medicinal population (Arkell et al., 2023) and the latter examining effects across healthy individuals with differing catechol-*O*-methyl transferase (COMT) genotypes (i.e., Val/Val, Val/Met and Met/Met; Ranganathan et al., 2019). Signal detection and response latency were superior following cannabis consumption in the medicinal sample (Arkell et al., 2023), potentially highlighting the role of symptom relief. However, it should be noted that effects encapsulated both oral and vaporised methods, and were examined at the 180-min mark, potentially masking differential effects of administration routes. At the 20-min mark, Ranganathan et al. (2019) reported mixed findings across groups and measures. See Table 3 for signal detection data and response latency data.

3.2. CANTAB – Spatial Working Memory

The current available data (albeit limited) suggests that CANTAB SWM may be sensitive to cannabis consumption. A total of 3 studies examined the effects on SWM performance, with Arkell et al. (2023) focusing on a medicinal sample and the remaining studies focusing on healthy individuals (one of which was infrequent users; D'Souza et al.,

Table 3
CANTAB subtests.

Study	No cannabis M(SD)	Cannabis intervention	Post cannabis M(SD)	Overall effect	Effect size (Cohen's *d*)
RVP - RVPA signal detection					
Arkell et al. (2023)	0.9 (0.06)	Mixed medicinal cannabis oil/ flower - Standard dose as prescribed. M dose oil = 9.61 mg THC M dose flower = 37 mg THC	0.93 (0.05)	▲	180 min: 0.54
Ranganathan et al. (2019) Study 1	Placebo Val/Val = 0.9 (0.1) Val/Met = 0.9 (0.1) Met/Met = 0.9 (0.1)	0.05 mg/kg THC IV	Val/Val = 0.97 (0.9) Val/Met = 0.9 (0.1) Met/Met = 0.9 (0.1)	▲ — —	20 min: Val/Val: 0.08 Val/Met: 0 Met/Met: 0
RVP - response latency					
Arkell et al. (2023)	466.85 (108.85)	Mixed medicinal cannabis oil/ flower - Standard dose as prescribed. M dose oil = 9.61 mg THC M dose flower = 37 mg THC	452.95 (80.78)	▲	180 min: 0.14
Ranganathan et al. (2019) Study 1	Placebo Val/Val = 356.5 (49.6) Val/Met = 356.8 (68.3) Met/Met = 360.0 (44.9)	0.05 mg/kg THC IV	Val/Val = 384.8 (52.7) Val/Met = 368.2 (81.8) Met/Met = 366.6 (67.1)	▼ ▼ ▼	20 min Val/Val: 0.55 Val/Met: 0.15 Met/Met: 0.11
SWM – within errors					
D'souza et al. (2008)	1.43 (2.86)	0.0286 mg/ kg THC IV	1.74 (3.79)	▼	30 min: 0.09
Ranganathan et al. (2019) Study 1	Placebo Val/Val = 0.2 (0.5) Val/Met = 0.71 (1.5) Met/Met = 0.1 (0.50)	0.05 mg/kg THC IV	Val/Val = 1.6 (1.4) Val/Met = 0.7 (1.8) Met/Met = 0.6 (0.1)	▼ — ▼	20 min Val/Val: 1.14 Val/Met: 0.01 Met/Met: 1.09
SWM – between errors					
Arkell et al. (2023)	8 (9)	Mixed medicinal cannabis oil/ flower - Standard dose as prescribed. M dose oil = 9.61 mg THC M dose flower = 37 mg THC	7 (9)	▲	180 min: 0.11
D'souza et al. (2008)	15.52 (18.74)	0.0286 mg/ kg THC IV	19.91 (22.3)	▼	30 min: 0.21
Ranganathan et al. (2019) Study 1	Placebo Val/Val = 9 (14.7) Val/Met = 7.8 (11.9) Met/Met = 6.6 (8.2)	0.05 mg/kg THC IV	Val/Val = 17.4 (22.6) Val/Met = 10.7 (13.1) Met/Met = 15.2 (16.8)	▼ ▼ ▼	20 min Val/Val: 0.42 Val/Met: 0.23 Met/Met: 0.59
SWM – total errors					
D'souza et al. (2008)	16.17 (19.38)	0.0286 mg/ kg THC IV	20.48 (23.24)	▼	30 min: 0.20
Ranganathan et al. (2019) Study 1	Placebo Val/Val = 9.0 (14.7) Val/Met = 8.1 (12.4) Met/Met = 6.6 (8.2)	0.05 mg/kg THC IV	Val/Val = 17.9 (22.7) Val/Met = 11.0 (13.5) Met/Met = 14.8 (16.7)	▼ ▼ ▼	20 min Val/Val: 0.45 Val/Met: 0.22 Met/Met: 0.57

Note. The "▼" icon indicates performance was worse in the cannabis condition, whilst "▲" indicates that performance was better in the cannabis condition. The "—" icon indicates no effect.

2008). In the two studies that examined effects on total errors within the 20–30-min timeframe, the number of errors were greater in the cannabis condition compared to the no cannabis condition, with differences ranging from small to moderate magnitude effects (D'Souza et al., 2008; Ranganathan et al., 2019). Data for within, between and total errors are reported in Table 3.

3.3. Digit Span

Data from two studies suggest Digit Span may be sensitive to cannabis consumption, with differences ranging from small-to-moderate to moderate magnitude effects. However, it should be noted that the latter sample comprised only 12 participants with Tourette's Syndrome and varied usage histories. Data are reported in Table 4.

3.4. Hopkins Verbal Learning Test & Hopkins Verbal Learning Test-Revised

There is evidence to suggest that HVLT (or HVLT-R) is sensitive to cannabis consumption, with some studies reporting large magnitude effects 30–40 min following consumption. D'Souza et al. (2008) reported small magnitude differences at the 30-min mark, although the sample consisted of frequent users of cannabis who may have developed tolerance to the substance. Data are reported in Table 4.

3.5. Delayed Prose Recall

Two studies observed poorer performance on the Delayed Prose Recall task following cannabis relative to no cannabis. Both studies revealed moderate and large magnitude effects respectively, suggesting

Table 4
Memory tests.

Study	No cannabis M(SD)	Cannabis intervention	Post cannabis M(SD)	Overall effect	Effect size (Cohen's *d*)
Digit Span - n correct					
Englund et al. (2013)	Baseline: Forward: 7.5 (1.2) Reverse: 5.9 (1.2)	1.5 mg THC, IV	Forward: 6.6 (1.2) Reverse: 5.2 (1.5)	▼	40 min: Forward: 0.75 Reverse: 0.51
Müller-Vahl et al. (2001)	Placebo: 11.3 (1.70)	Oral THC. Dose varied for each person depending on weight, age, sex and history of cannabis use. Received either 5, 7.5 or 10 mg of THC	10.80 (2.0)	▼	60 min:0 .27
HVLT/HVLT-R – total immediate recall					
Domen et al. (2023)	24.27 (SE 1.11)	3.3 mg/ml THC, Oral	22.24 (SE 1.20)	▼	180 min: 0.38 (reported in paper)
D'Souza et al. (2005)	Placebo 19.8 (6)	2.5 mg or 5 mg THC IV	2.5 mg: 10.3 (8) 5 mg: 7.8 (7.4)	▼ ▼	30 min: Low dose: 1.32 High dose: 1.76
D'Souza et al. (2008)	Placebo 27.61 (5.25)	0.0286 mg/ kg THC IV	26.52 (4.53)	▼	30 min: 0.22
Englund et al. (2013)	30.4 (3.0)	1.5 mg THC IV	27 (5.5)	▼	40 min: 0.71
Delayed Prose Recall - number of items recalled					
Hindocha et al. (2017)	Placebo 9.45 (2.65) SE = 0.54	66.67 mg cannabis flower cigarette (16.1 % THC)	8.32 (2.74) SE = 0.56	▼	55 min: 0.42
Lawn et al. (2023)	Placebo 9.29 (3.19)	0.107 mg/ kg THC vaporised	6.06 (3.41)	▼	120 min: 0.98
RAVLT - number of words recalled					
Bassir et al. (2022)	Placebo Males: 59.5 (2.2) Females: 61.4 (2.15)	IV, Low dose: 0.015 mg/ kg High dose: 0.03 mg/kg	Low dose: Males: 56.4 (2.26) Females: 58.5 (2.62) High dose: Males: 57.7 (2.42) Females: 58.7 (2.81)	▼ ▼ ▼	55 min: **Low dose** Males: 1.39 Females: 1.2 **High dose** Males: 0.78 Females: 1.06
Ranganathan et al. (2017) Study 2	Placebo 55.5 (9.64)	0.05 mg/kg THC IV	44.86 (13.09)	▼	25 & 95 min (long delayed) post: 0.91
Ranganathan et al. (2019) Study 1	Placebo Val/Val: 54.6 (12.6) Val/Met: 56.1 (10.3) Met/Met: 65.6 (6.0)	0.05 mg/kg THC IV	Val/Val: 41.4 (19.4) Val/Met: 47.6 (13.7) Met/Met: 44.5 (12.6)	▼ ▼ ▼	20 min: Val/Val: 0.77 Val/Met: 0.69 Met/Met: 1.93
RAVLT - short delay recall					
Ranganathan et al. (2017) Study 2	Placebo 11.69 (2.72)	0.05 mg/kg THC IV	9.33 (4.22)	▼	25 & 95 min (long delayed) post: 0.64
Ranganathan et al. (2019) Study 1	Placebo Val/Val: 10.5 (3.6) Val/Met: 12.0 (2.5) Met/Met: 12.6 (1.7)	0.05 mg/kg THC IV	Val/Val: 9.7 (4.1) Val/Met: 9.7 (4.1) Met/Met: 9.5 (4.3)	▼ ▼ ▼	20 min: Val/Val: 0.21 Val/Met: 0.64 Met/Met: 0.83
RAVLT - long delay recall					
Ranganathan et al. (2017) Study 2	Placebo 11.45 (2.9)	0.05 mg/kg THC IV	9.04 (4.29)	▼	25 & 95 min (long delayed) post: 0.64
Ranganathan et al. (2019) Study 1	Placebo Val/Val: 10.9 (4.0) Val/Met: 11.5 (3.9) Met/Met: 12.3 (1.9)	0.05 mg/kg THC IV	Val/Val: 9.8 (4.8) Val/Met: 9.3 (4.3) Met/Met: 9.5 (3.9)	▼ ▼ ▼	20 min: Val/Val: 0.25 Val/Met: 0.53 Met/Met: 0.83

Note. The "▼" icon indicates performance was worse in the cannabis condition, whilst "▲" indicates that performance was better in the cannabis condition. The "—" icon indicates no effect.

that task may be sensitive to cannabis consumption at 60–120 min post inhalation. Note however, Hindocha et al. (2017) did not report data for study 1. Data on Delayed Prose Recall are reported in Table 4.

3.6. Rey Auditory Verbal Learning Test

The available evidence suggests the RAVLT is sensitive to cannabis consumption, with the majority of differences exhibiting large magnitude effects. However, it should be noted this data is reported from the same authors. Data for the total number of words recalled, short and delayed recall, are reported in Table 4.

3.7. Trail Making Test A

Both Pelletti et al. (2021) and Domen et al. (2023) observed improvements in TMT A latency following cannabis consumption. Data on TMT A are reported in Table 5.

3.8. Trail Making Test B

There is a lack of evidence to determine whether TMT B is sensitive to cannabis consumption, with both studies reporting contrasting results. Data on TMT B are reported in Table 5.

4. Discussion

This study systematically reviewed evidence on the acute effects of

Table 5
Trail Making Test.

Study	No cannabis M(SD)	Cannabis intervention	Post cannabis M(SD)	Overall effect	Effect size (Cohen's d)
TMT A – time to complete					
Domen et al. (2023)	39.1 (SE 3.56)	3.3 mg/ml THC	36.62 (SE 4.71)	▲	180 min:0 .16 (reported in paper)
Pelletti et al. (2021)	18.72 (1.87)	Three smoked cannabis cigarettes (0.41 % THC, 1.64 mg).	17.44 (2.66)	▲	Within 7 min:0 .54
TMT B – time to complete					
Domen et al. (2023)	92.66 (SE 14.39)	3.3 mg/ml THC	103.01 (SE 13.46)	▼	180 min: 0.29 (reported in paper)
Pelletti et al. (2021)	38 (11.75)	Three smoked cannabis cigarettes (0.41 % THC, 1.64 mg).	37.59 (11.25)	—	Within 7 min:0 .04

Note. The "▼" icon indicates performance was worse in the cannabis condition, whilst "▲" indicates that performance was better in the cannabis condition. The "—" icon indicates no effect.

cannabis on cognitive function, with the aim of identifying standardised neuropsychological test measures sensitive to the effect of THC consumption. Despite the large number of studies identified in this review, few studies used validated and standardised neuropsychological tests, with only 8 tests being utilised in more than one study. Of these remaining tests, the CANTAB SWM subtest, HVLT, Prose Recall and RAVLT were most sensitive to cannabis consumption, albeit with significant heterogeneity across studies that precludes the ability to synthesise such data meta-analytically. For example, the data varied in the timing of effects, dosage and population of interest, rendering it impractical to make direct comparisons or summarise effects. While these findings highlight the potential utility for standardised neuropsychological tests in detecting cannabis consumption, there is a clear lack of data from studies using standardised neuropsychological tests to examine the effects of cannabis on cognition. As such, the sensitivity of isolated standardised neuropsychological tests in detecting cannabis consumption is yet to be established. Indeed, such knowledge is vital for the development of behavioural measures of impairment to assist in identifying the window in which consumers should avoid undertaking safety-related tasks such as driving.

To our knowledge, this review is the first to examine whether specific standardised neuropsychological tests are sensitive to cannabis consumption. Previous reviews have focused solely on characterising effects on broad cognitive domains, revealing acute negative effects of THC on information processing speed, divided and sustained attention, working memory and inhibitory control (e.g., McCartney et al., 2021). While previous reviews have identified the magnitude and duration of such effects on broad domains, the sensitivity of isolated test measures have not been established. Based on the limited data available in this review, it was found that CANTAB SWM, HVLT, Prose Recall and RAVLT were most sensitive to acute cannabis consumption, although significant heterogeneity was observed across studies in terms of the dosage administered, the duration between consumption and testing, and the sample of interest (varying in cannabis use histories and comorbidities). It needs to be noted that these findings are based on limited data. Further, the lack of data identified in the review overall prevented evidence on other cognitive test measures from being summarised, potentially leading to the omission of other sensitive test measures. The lack of data highlights the urgent need for research to identify validated and standardised measures of neurocognitive impairment associated with THC intoxication to enable accurate detection of potential functional impairments to the performance of safety-related tasks in medicinal and recreational cannabis users.

This review has found that inconsistent use of sensitive and specific cognitive tests has led to limited progress in understanding the effects of THC on cognitive function. Many studies identified in this review were excluded on the basis of using adapted or non-standardised measures of cognitive function, for which the psychometric properties could not be ascertained. A key prerequisite for identifying diagnostic markers of cognitive changes due to disease or an external factor (e.g., pharmacological agent) impacting on neurological function is that the measure(s) of cognitive function have appropriate validity and reliability. Published standards for the reporting of diagnostic test accuracy of cognitive tests exist (e.g., Noel-Storr et al., 2014) and are designed to enhance scientific identification of cognitive test markers for different diseases and conditions.

Whilst many studies identified through the search utilised controlled experimental designs and standardised doses, future work would benefit from exploring effects in drug-naïve populations. With the increasing legalisation of cannabis across multiple nations, there is the emerging opportunity to undertake dose-controlled randomised controlled trials of cannabis in drug-naïve populations to clarify the effects of acute THC intoxication on cognitive functions associated with driving. Future research would also benefit from exploring effects in naïve users compared to medicinal users to explore the role of tolerance and symptom relief in mitigating effects. The use of other medications or illicit cannabis would also need to be partitioned out, given their confounding effects on performance. However, such research can only be undertaken with the use of measures of cognitive function with established reliability and validity, as well as known sensitivity to subacute impairment and specificity to driving deficits associated with THC intoxication.

4.1. Limitations

There are limitations to consider when interpreting the present findings, including the fact there was limited data to synthesise results meta-analytically. Significant heterogeneity was observed across studies, impeding the capacity to group data points of a similar nature. Previous work notes that factors such as dose, route of administration, symptom relief and tolerance can moderate the acute effects of THC on cognitive function (outlined in Ramaekers et al., 2021), potentially leading to differences in magnitude of effects across studies. For example, the acute effects of THC on cognition may be less prominent in tolerant users compared to recreational or new users (e.g., Arkell et al., 2023; McCartney et al., 2021; Olla et al., 2021; Theunissen et al., 2012). On a similar note, cognitive tests were often administered following the completion of other tasks (e.g., MRI scan or other non-validated tasks), potentially leading to the assessment of delayed effects that may not be considered peak acute effects. In addition, some data points for a given test were derived from the same sample. It should also be noted that many tasks were excluded on the basis that they utilised adapted or computerised versions of cognitive tests. However, the exclusion of such tests should be considered a strength of the study, as the psychometric properties of such tests may not be established.

In conclusion, based on the limited data available, the CANTAB subtest SWM, HVLT, Prose Recall and RAVLT were identified as tests most sensitive to cannabis consumption. There is a clear need for future

research to utilise standardised neuropsychological assessments in examining the effects of cannabis on cognitive function.

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CRediT authorship contribution statement

K.B. Stefanidis: Writing – original draft, Supervision, Project administration, Methodology, Formal analysis, Conceptualization. **C. Schiemer:** Writing – original draft, Investigation, Formal analysis, Data curation. **T. Mieran:** Writing – original draft, Investigation, Formal analysis, Data curation. **M.J. Summers:** Writing – review & editing, Supervision, Methodology.

Declaration of competing interest

The authors report there are no conflicts of interest to disclose.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jad.2024.10.051.

References

Arkell, T.R., Vinckenbosch, F., Kevin, R.C., Theunissen, E.L., McGregor, I.S., Ramaekers, J.G., 2020. Effect of cannabidiol and Δ9-tetrahydrocannabinol on driving performance: a randomized clinical trial. JAMA 324 (21), 2177–2186. https://doi.org/10.1001/jama.2020.21218.

Arkell, T.R., Spindle, T.R., Kevin, R.C., Vandrey, R., McGregor, I.S., 2021. The failings of per se limits to detect cannabis-induced driving impairment: results from a simulated driving study. Traffic Inj. Prev. 22 (2), 102–107. https://doi.org/10.1080/15389588.2020.1851685.

Arkell, T.R., Manning, B., Downey, L.A., Hayley, A.C., 2023. A semi-naturalistic, open-label trial examining the effect of prescribed medical cannabis on neurocognitive performance. CNS Drugs 37 (11), 981–992. https://doi.org/10.1007/s40263-023-01046-z.

Bassir Nia, A., Orejarena, M.J., Flynn, L., Luddy, C., D'Souza, D.C., Skosnik, P.D., et al., 2022. Sex differences in the acute effects of intravenous (IV) delta-9 tetrahydrocannabinol (THC). Psychopharmacology 239 (5), 1621–1628. https://doi.org/10.1007/s00213-022-06135-3.

Bosker, W.M., Kuypers, K.P.C., Theunissen, E.L., Surinx, A., Blankespoor, R.J., Skopp, G., et al., 2012. Medicinal Δ9-tetrahydrocannabinol (dronabinol) impairs on-the-road driving performance of occasional and heavy cannabis users but is not detected in Standard Field Sobriety Tests. Addiction 107 (10), 1837–1844. https://doi.org/10.1111/j.1360-0443.2012.03928.x.

Brooks-Russell, A., Brown, T., Friedman, K., Wrobel, J., Schwarz, J., Dooley, G., et al., 2021. Simulated driving performance among daily and occasional cannabis users. Accid. Anal. Prev. 160, 106326. https://doi.org/10.1016/j.aap.2021.106326.

Cohen, J., 1988. Statistical Power Analysis for the Behavioral Sciences. Routledge.

Domen, C.H., Sillau, S., Liu, Y., Adkins, M., Rajkovic, S., Bainbridge, J., et al., 2023. Cognitive safety data from a randomized, double-blind, parallel-group, placebo-controlled phase IIb study of the effects of a cannabidiol and Δ9-tetrahydrocannabinol drug on Parkinson's disease-related motor symptoms. Mov. Disord. 38 (7), 1341–1346. https://doi.org/10.1002/mds.29447.

Drummer, O.H., Gerostamoulos, D., Di Rago, M., Woodford, N.W., Morris, C., Frederiksen, T., et al., 2020. Odds of culpability associated with use of impairing drugs in injured drivers in Victoria, Australia. Accid. Anal. Prev. 135, 105389. https://doi.org/10.1016/j.aap.2019.105389.

D'Souza, D.C., Abi-Saab, W.M., Madonick, S., Forselius-Bielen, K., Doersch, A., Braley, G., et al., 2005. Delta-9-tetrahydrocannabinol effects in schizophrenia: implications for cognition, psychosis, and addiction. Biol. Psychiatry 57 (6), 594–608. https://doi.org/10.1016/j.biopsych.2004.12.006.

D'Souza, D.C., Braley, G., Blaise, R., Vendetti, M., Oliver, S., Pittman, B., et al., 2008. Effects of haloperidol on the behavioral, subjective, cognitive, motor, and neuroendocrine effects of Δ-9-tetrahydrocannabinol in humans. Psychopharmacology 198 (4), 587–603. https://doi.org/10.1007/s00213-007-1042-2.

Englund, A., Morrison, P.D., Nottage, J., Hague, D., Kane, F., Bonaccorso, S., et al., 2013. Cannabidiol inhibits THC-elicited paranoid symptoms and hippocampal-dependent memory impairment. J. Psychopharmacol. 27 (1), 19–27. https://doi.org/10.1177/0269881112460109.

Hartman, R.L., Brown, T.L., Milavetz, G., Spurgin, A., Pierce, R.S., Gorelick, D.A., et al., 2015. Cannabis effects on driving lateral control with and without alcohol. Drug Alcohol Depend. 154, 25–37. https://doi.org/10.1016/j.drugalcdep.2015.06.015.

Herrmann, E.S., Cone, E.J., Mitchell, J.M., Bigelow, G.E., LoDico, C., Flegel, R., Vandrey, R., 2015. Non-smoker exposure to secondhand cannabis smoke II: effect of room ventilation on the physiological, subjective, and behavioral/cognitive effects. Drug Alcohol Depend. 151, 194–202. https://doi.org/10.1016/j.drugalcdep.2015.03.019.

Higgins, J.P.T., Altman, D.G., Gøtzsche, P.C., Jüni, P., Moher, D., Oxman, A.D., et al., 2011. The Cochrane Collaboration's tool for assessing risk of bias in randomised trials. BMJ 343, d5928. https://doi.org/10.1136/bmj.d5928.

Hindocha, C., Freeman, T.P., Xia, J.X., Shaban, N.D.C., Curran, H.V., 2017. Acute memory and psychotomimetic effects of cannabis and tobacco both 'joint' and individually: a placebo-controlled trial. Psychol. Med. 47 (15), 2708–2719. https://doi.org/10.1017/S0033291717001222.

Karschner, E.L., Schwilke, E.W., Lowe, R.H., Darwin, W.D., Herning, R.I., Cadet, J.L., Huestis, M.A., 2009. Implications of plasma Δ9-tetrahydrocannabinol, 11-Hydroxy-THC, and 11-nor-9-Carboxy-THC concentrations in chronic cannabis smokers. J. Anal. Toxicol. 33 (8), 469–477. https://doi.org/10.1093/jat/33.8.469.

Lawn, W., Trinci, K., Mokrysz, C., Borissova, A., Ofori, S., Petrilli, K., et al., 2023. The acute effects of cannabis with and without cannabidiol in adults and adolescents: a randomised, double-blind, placebo-controlled, crossover experiment. Addiction 118 (7), 1282–1294. https://doi.org/10.1111/add.16154.

Lezak, M.D., 2004. Neuropsychological Assessment. Oxford University Press, USA.

Li, G., Brady, J.E., Chen, Q., 2013. Drug use and fatal motor vehicle crashes: a case-control study. Accid. Anal. Prev. 60, 205–210. https://doi.org/10.1016/j.aap.2013.09.001.

Marcotte, T.D., Umlauf, A., Grelotti, D.J., Sones, E.G., Mastropietro, K.F., Suhandynata, R.T., et al., 2023. Evaluation of field sobriety tests for identifying drivers under the influence of cannabis: a randomized clinical trial. JAMA Psychiatr. 80 (9), 914–923. https://doi.org/10.1001/jamapsychiatry.2023.2345.

McCartney, D., Arkell, T.R., Irwin, C., McGregor, I.S., 2021. Determining the magnitude and duration of acute Δ9-tetrahydrocannabinol (Δ9-THC)-induced driving and cognitive impairment: a systematic and meta-analytic review. Neurosci. Biobehav. Rev. 126, 175–193. https://doi.org/10.1016/j.neubiorev.2021.01.003.

McCartney, D., Arkell, T.R., Irwin, C., Kevin, R.C., McGregor, I.S., 2022. Are blood and oral fluid Δ9-tetrahydrocannabinol (THC) and metabolite concentrations related to impairment? A meta-regression analysis. Neurosci. Biobehav. Rev. 134, 104433. https://doi.org/10.1016/j.neubiorev.2021.11.004.

McLeod, D.R., Griffiths, R.R., Bigelow, G.E., Yingling, J., 1982. An automated version of the digit symbol substitution test (DSST). Behav. Res. Methods Instrum. 14 (5), 463–466. https://doi.org/10.3758/BF03203313.

Müller-Vahl, K., Koblenz, A., Jöbges, M., Kolbe, H., Emrich, H., Schneider, U., 2001. Influence of treatment of Tourette syndrome with Δ9-tetrahydrocannabinol (Δ9-THC) on neuropsychological performance. Pharmacopsychiatry 34 (01), 19–24.

Noel-Storr, A.H., McCleery, J.M., Richard, E., Ritchie, C.W., Flicker, L., Cullum, S.J., et al., 2014. Reporting standards for studies of diagnostic test accuracy in dementia: the STARDdem Initiative. Neurology 83 (4), 364–373. https://doi.org/10.1212/wnl.0000000000000621.

Odell, M.S., Frei, M.Y., Gerostamoulos, D., Chu, M., Lubman, D.I., 2015. Residual cannabis levels in blood, urine and oral fluid following heavy cannabis use. Forensic Sci. Int. 249, 173–180. https://doi.org/10.1016/j.forsciint.2015.01.026.

Olla, P., Rykulski, N., Hurtubise, J.L., Bartol, S., Foote, R., Cutler, L., et al., 2021. Short-term effects of cannabis consumption on cognitive performance in medical cannabis patients. Appl. Neuropsychol. Adult 28 (6), 647–657. https://doi.org/10.1080/23279095.2019.1681424.

Ouzzani, M., Hammady, H., Fedorowicz, Z., Elmagarmid, A., 2016. Rayyan—a web and mobile app for systematic reviews. Syst. Rev. 5 (1), 210. https://doi.org/10.1186/s13643-016-0384-4.

Pelletti, G., Barone, R., Giorgetti, A., Garagnani, M., Rossi, F., Fais, P., Pelotti, S., 2021. "Light cannabis" consumption in a sample of young adults: preliminary pharmacokinetic data and psychomotor impairment evaluation. Forensic Sci. Int. 323, 110822. https://doi.org/10.1016/j.forsciint.2021.110822.

Ramaekers, J.G., Moeller, M.R., van Ruitenbeek, P., Theunissen, E.L., Schneider, E., Kauert, G., 2006. Cognition and motor control as a function of Δ9-THC concentration in serum and oral fluid: limits of impairment. Drug Alcohol Depend. 85 (2), 114–122. https://doi.org/10.1016/j.drugalcdep.2006.03.015.

Ramaekers, J.G., Mason, N.L., Kloft, L., Theunissen, E.L., 2021. The why behind the high: determinants of neurocognition during acute cannabis exposure. Nat. Rev. Neurosci. 22 (7), 439–454. https://doi.org/10.1038/s41583-021-00466-4.

Ranganathan, M., Radhakrishnan, R., Addy, P.H., Schnakenberg-Martin, A.M., Williams, A.H., Carbuto, M., et al., 2017. Tetrahydrocannabinol (THC) impairs encoding but not retrieval of verbal information. Prog. Neuro-Psychopharmacol. Biol. Psychiatry 79, 176–183. https://doi.org/10.1016/j.pnpbp.2017.06.019.

Ranganathan, M., De Aquino, J.P., Cortes-Briones, J.A., Radhakrishnan, R., Pittman, B., Bhakta, S., D'Souza, D.C., 2019. Highs and lows of cannabinoid-dopamine interactions: effects of genetic variability and pharmacological modulation of catechol-O-methyl transferase on the acute response to delta-9-tetrahydrocannabinol in humans. Psychopharmacology 236 (11), 3209–3219. https://doi.org/10.1007/s00213-019-05273-5.

Rogeberg, O., 2019. A meta-analysis of the crash risk of cannabis-positive drivers in culpability studies—avoiding interpretational bias. Accid. Anal. Prev. 123, 69–78. https://doi.org/10.1016/j.aap.2018.11.011.

Spindle, T.R., Martin, E.L., Grabenauer, M., Woodward, T., Milburn, M.A., Vandrey, R., 2021. Assessment of cognitive and psychomotor impairment, subjective effects, and blood THC concentrations following acute administration of oral and vaporized

cannabis. J. Psychopharmacol. 35 (7), 786–803. https://doi.org/10.1177/02698811211021583.
Strauss, E., Sherman, E.M., Spreen, O., 2006. A compendium of neuropsychological tests: administration, norms, and commentary. Am. Chem. Soc.
Theunissen, E.L., Kauert, G.F., Toennes, S.W., Moeller, M.R., Sambeth, A., Blanchard, M. M., Ramaekers, J.G., 2012. Neurophysiological functioning of occasional and heavy cannabis users during THC intoxication. Psychopharmacology 220, 341–350.
United Nations Office on Drugs and Crime, 2022. World Drug Report. Retrieved 13 July from. https://www.unodc.org/res/wdr2022/MS/WDR22_Booklet_3.pdf.
Van Waes, V., Beverley, J., Siman, H., Tseng, K.Y., Steiner, H., 2012. CB1 cannabinoid receptor expression in the striatum: association with corticostriatal circuits and developmental regulation. Front. Pharmacol. 3. https://doi.org/10.3389/fphar.2012.00021.
Wechsler, D., 1955. Wechsler Adult Intelligence Scale Manual. Psychological Corporation.

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Corrigendum

Corrigendum to "Identifying standardised neuropsychological test measures sensitive to cannabis consumption: A systematic review" [J. Affect. Disord. Volume 369 (2025), pages 772–781]

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The authors have identified the inadvertent inclusion of the study by Englund et al. (2013) in the analysis. We subsequently noted that Englund et al. (2013) specified the use of synthetic THC in their methodology and thus were not eligible for review. The authors regret this error and apologise for any inconvenience caused.

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