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Attentional bias to cannabis stimuli in people with cannabis use disorder

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A R T I C L E I N F O

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A B S T R A C T

Background: Around one in five people who use cannabis develop a cannabis use disorder (CUD) during their lifetime. Attentional bias toward substance-related stimuli is theorised to drive substance-seeking behaviour, contributing to the development of addiction and relapse. There is mixed evidence of cannabis-related attentional bias in individuals with CUD and its association with cannabis quantity, CUD severity, and confounders (e.g., alcohol, nicotine use). We aimed to examine cannabis attentional bias in non-treatment-seeking adults with a CUD ($n = 74$) versus controls ($n = 30$), and in relation to levels of cannabis and nicotine use, adjusting for alcohol use.

Methods: Attentional bias was measured using a visual probe task. To detect attentional bias differences between groups (CUD, controls), we ran linear mixed-effect models with reaction times (RTs) to cannabis versus neutral images as the outcome variable, adjusting for intra-individual variability and stimulus onset asynchrony (SOA, 200/500 ms). Within the CUD group only, we explore the association between attentional bias and cannabis quantity, craving, Cannabis Use Disorder Identification Test – Revised (CUDIT-R) scores, image valence ratings, and nicotine use. All models were adjusted for alcohol use.

Results: No significant effects were found for group, cannabis quantity, craving, CUDIT-R scores, or nicotine use on attentional bias toward cannabis cues.

Conclusion: Findings suggest that non-treatment seekers with CUD do not exhibit attentional bias to cannabis cues. Replication in treatment-seeking samples is needed to determine whether attentional bias has clinical relevance, using objective measures (e.g., eye tracking).

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1. Introduction

Cannabis use disorder (CUD) is characterised by the continued use of cannabis despite the experience of significant distress and/or functional impairment (American Psychiatric Association [APA], 2013), and is estimated to affect 22% of the ~228 million current consumers worldwide (Butterworth et al., 2014; United Nations Office for Drugs and Crime [UNODC], 2023). Symptoms of CUD can include failed attempts to reduce use and cue-induced craving (APA, 2013; Sehl et al., 2021). Frequent cannabis use has been linked to poorer mental health (e.g., depression [Lev-Ran et al., 2014], anxiety [Kedzior & Laeber, 2014] and psychotic symptoms [Di Forti et al., 2019]), impaired cognitive performance (Broyd et al., 2016) and lower educational attainment (Lorenzetti et al., 2020; Morissette et al., 2024); with worse outcomes associated with greater chronicity of cannabis use (Zehra et al., 2018).

Attentional bias (AB), defined as the tendency for substance-related stimuli to disproportionately capture attention, is a key mechanism posited to underscore continued cannabis use and relapse (Field & Cox, 2008). AB is theorised to develop through repeated pairing between cannabis-related cues (e.g., cannabis paraphernalia) and progressive sensitisation of reward pathways due to cannabis intake, strengthening the incentive salience of those cues (Robinson & Berridge, 1993). World trends towards cannabis legalisation, and increased cannabis availability and advertising have been associated with a higher risk of CUD (Cerda et al., 2020; Rup et al., 2020), potentially hindering people's attempts to reduce or cease use due to their attention-grabbing properties (Topbas et al., 2025). Thus, determining whether AB is present in individuals who experience a CUD could prove helpful in informing public health policies and targeted interventions.

Higher frequency of cannabis use has been associated with greater AB toward cannabis cues, particularly in heavier users in treatment (Campbell et al., 2018; Cousijn et al., 2013; Kroon et al., 2023; Ruglass et al., 2019; Vujanovic et al., 2016; Yoon et al., 2019), although methodological differences constrain the evidence. First, the examined cannabis samples vary from "regular users" to people with CUD, with most studies confirming cannabis dependence using now outdated diagnostic and screening tools (e.g., Diagnostic and Statistical Manual of Mental Disorders – 4th edition – text revised [DSM-IV-TR]; APA, 2000; Cousijn et al., 2013; Ruglass et al., 2019; van Hemel-Ruiter et al., 2016; Vujanovic et al., 2016). The inconsistent characterisation limits the comparability of findings and leaves a knowledge gap for practitioners using the latest diagnostic tools (i.e., DSM-5; APA, 2013).

Second, the measurement of AB varies (e.g., Stroop task, visual probe task), and the methods used to calculate AB scores are inconsistent. Most methods subtract the mean reaction times (RTs) to cannabis images from the mean RTs to neutral images, with positive and negative scores indicating AB toward and away from the target stimuli, respectively (Field et al., 2004). These methods do not account for intra-individual variability in RTs, which has been demonstrated in moderate-to-severe CUD (Quinones-Valera et al., 2026). Thus, unique fluctuations within task performance may have been overlooked, inflating statistical error rates.

Third, when using the visual probe task to measure cannabis AB, which presents pairs of substance/neutral stimuli simultaneously, recording individuals' RTs (Field et al., 2004; Field et al., 2006; van Hemel-Ruiter et al., 2016; Vujanovic et al., 2016), key task parameters (i.e., stimuli onset asynchrony or SOA) have been inconsistently accounted for in analyses. Importantly, different SOAs may reflect distinct aspects of AB, including automatic versus sustained processes, measured at $\leq$ 200 and $\geq$ 500 ms, respectively (O'Neill et al., 2020). Therefore, it is critical to account for the influence of SOA to determine the nature of cannabis AB in CUD. Additionally, how the subjective valence of stimuli used affected AB has been rarely examined, with emerging evidence suggesting significant effects (Field et al., 2004; Quinones-Valera et al., 2026).

Fourth, cannabis-related metrics, such as quantity (e.g., joints, grams) and craving, have been inconsistently measured across studies, and their association with AB has seldom been explored (e.g., up to two studies per variable) (Campbell et al., 2018; Field et al., 2004; Kroon et al., 2023; Van Kampen et al., 2020; Yoon et al., 2019). Therefore, it is unclear if cannabis quantity and craving are associated with AB in CUD. Fifth, the role of alcohol and nicotine use on AB in individuals with CUD has been inconsistently examined, despite their co-occurrence (Rabin & George, 2015; Yurasek et al., 2017). Importantly, prior research suggests a "washed-out" effect, where accounting for problematic alcohol/nicotine use eliminated previously evidenced AB deficits in individuals with CUD undergoing treatment (Kroon et al., 2023). Such "washed-out" effect underscores the importance of accounting for alcohol/nicotine use when examining AB in CUD.

The primary aim of this study was to compare AB to cannabis-related versus neutral images between participants with mild-to-severe CUD and non-cannabis-using controls. Based on neuroscientific theories of addiction (Field & Cox, 2008; Robinson & Berridge, 2008; Volkow et al., 2019) and existing evidence (O'Neill et al., 2020), we hypothesised that individuals with CUD would have a stronger AB toward cannabis-related images. We explored associations between AB and cannabis-related variables (i.e., grams/past month, craving, CUDIT-R scores, valence ratings and cigarettes/past month). All analyses were adjusted for SOA, alcohol use and intra-individual variability in RTs. Alcohol use was selected as a covariate since it was reported in both groups; however, nicotine was only reported in the CUD group, therefore explored as a predictor of AB in CUD.

2. Methods

This study was nested within a larger neuroimaging longitudinal project approved by the University of Wollongong Human Research Ethics Committee (HREC ID: 2017/389) and acknowledged by Australian Catholic University's HREC.

2.1. Participants

Participants were recruited from the general community/university campuses in Wollongong, Australia, via flyers and online social media platforms, which included study details and a QR code linking to a questionnaire to determine eligibility. Participants were contacted via phone for detailed screening (Supplementary Methods 1.1 for details on the original sample recruited, participants excluded and power analysis).

2.2. Eligibility Criteria

The following eligibility criteria were initially established for the larger neuroimaging study. Participants were deemed eligible if they: (i) were aged 18 to 55 years; (ii) had normal/corrected vision; and (iii) were fluent in English. Additionally, CUD participants were required to: (i) use cannabis $\geq$4 days/week for $\geq$ 12 months, and (ii) meet diagnostic criteria for CUD ascertained by the Structured Clinical Interview for DSM-5 Research Version (SCID-5-RV; First, 2015).

Exclusion criteria for *all participants* were: (i) self-reported lifetime history or current diagnosis - or currently meeting criteria for - psychotic, bipolar, and obsessive compulsive-related disorders, or severe alcohol use disorder, assessed by the Mini International Neuropsychiatric Interview (MINI; Sheehan et al., 1998); (ii) self-reported nicotine dependence or a score of $\geq$8 on the Fagerström Test for Nicotine Dependence (FTND; Fagerstrom et al., 2012) and/or self-reported alcohol dependence or a score of $\geq$20 on the Alcohol Use Identification Test (AUDIT; Babor et al., 2001); (iii) current or previous history of prescribed medication for psychiatric disorders; (iv) pregnancy or currently breastfeeding; (v) use of illicit substances (other than cannabis for the CUD group) above recreational levels, defined as: a total of >50 lifetime episodes; use greater than weekly for $\geq$3 months within the past

5 years; >5 lifetime use of methamphetamine or any drug administered intravenously; and use in the last 30 days before testing, (vi) contraindications for MRI scanning or data interpretation (e.g., history of neurological diseases, metal implants, claustrophobia). All participants were asked to refrain from any substances except nicotine for at least 12 hours before testing.

2.3. Assessment Procedure

Face-to-face testing was conducted at the School of Psychology at the University of Wollongong. Participants provided informed written consent before testing, which was conducted across two sessions, each lasting ~3 hours. Participants completed demographic, mental health, and substance use history questionnaires and provided a urine sample for toxicology assessment of substance use and pregnancy status (Supplementary Methods 1.2). Participants completed cognitive testing afterwards, including the visual probe task. The reimbursement totalled $80 AUD.

2.4. Measures

The measures administered to characterise the sample and assessment of experimental variables related to substance use are overviewed in Table 1.

2.4.1. Measurement of AB

AB was measured via the visual probe task (Fig. 1). The rationale behind the task is that faster RTs would be displayed toward stimuli that participants were visually attending to. The task comprised four buffer and 160 critical trials, lasting ~15 minutes. It included 10 pairs of generic cannabis (e.g., cannabis, bongs, joints) and neutral (e.g., stationary) images matched on composition and brightness. Trials began

Table 1
Overview of measures for sample characteristics and substance use-related variables.

Measure		Variable	Number of items	Modality of administration	Scores	Interpretation
Sociodemographic information and IQ	Questionnaire	Age, sex, education years completed	–	Self-report	–	–
	WASI-II (Wechsler, 2011)	IQ	31 items −Vocabulary 30 items −Matrix Reasoning	Tester-administered	–	–
Mental health	BDI-II (Beck et al., 1996)	Depression	21	Self-report	0–63	Minimal = 0–13 Mild = 14–19 Moderate = 20–28 Severe = 29–63
	STAI-Y (Spielberger et al., 1983)	State-anxiety	40	Self-report	20–80	No or low anxiety = 20–37 Moderate anxiety = 38–44 High anxiety = 45+
	PSS (Cohen et al., 1983)	Stress	10	Self-report	0–10	Low = 0–13 Moderate = 14–26 High = +27
	CAPE (Stefanis et al., 2002)	Depressive and psychotic (positive and negative) experiences	42	Tester-administered	–	Higher scores reflect a higher frequency of the experience
Cannabis use and related variables	SCID-5-RV (First, 2015)	Presence of CUD and level of severity	–	Tester-administered	0–11	Mild = 2–3 symptoms Moderate = 4–5 symptoms Severe = 6+
	CUDIT-R (Adamson et al., 2010)	Cannabis-related problems	8	Self-report	0–32	A clinical cut-off of ≥ 13 is suggestive of a possible CUD
	VAS (Aitken, 1969)	Craving pre-to-post the visual probe task	1	Tester-administered	0–10	Higher scores indicate higher level of craving
	MCQ (Heishman, 2009)	Session levels of craving	45	Self-report	–	Higher scores indicate greater craving in the compulsivity, emotionality, expectancy or purposefulness domains
	CWS (Allsop et al., 2011)	Withdrawal symptoms	19	Self-report	5–190	Mild = 5–12 Moderate = 13–24 Moderately severe = 25–36 Severe = 36+
Measures of substance use	TLFB (Sobell & Sobell, 1992)	Cannabis, alcohol, nicotine and other substances use (quantity and frequency over the last month, hours since last use)	Not applicable	Tester-administered	–	–
	AUDIT (Babor et al., 2001; de Meneses-Gaya et al., 2009)	Problematic alcohol consumption	10	Self-report	0–40	A clinical cutoff of ≥ 19 to identify alcohol dependence
	FTND (Fagerstrom et al., 2012)	Nicotine dependence	6	Self-report	0–10	Scores ≥ 3 indicate nicotine dependence
	Semi-structured interview (Lorenzetti et al., 2015; Solowij et al., 2002)	Age of onset Duration of cannabis use	Not applicable	Tester-administered	–	–

Note. IQ = Intellectual Quotient. "–" = Not applicable/Not available. WASI-II = Wechsler Abbreviated Scale of Intelligence – Second Edition. BDI-II = The Beck Depression Index – II. STAI-Y = State-Trait Anxiety Index – Y Form. PSS = Perceived Stress Scale. CAPE = Community Assessment of Psychic Experiences. SCID-5-RV = Structured Clinical Interview for DSM-5 Diagnoses – Research Version. CUDIT–R = Cannabis Use Disorder Identification Test – Revised. VAS = Visual Analogue Scale. MCQ = Marijuana Craving Questionnaire. CWS = Cannabis Withdrawal Scale. TLFB = Timeline Follow-Back. AUDIT = Alcohol Use Identification Test. FTND = Fagerström Test for Nicotine Dependence.

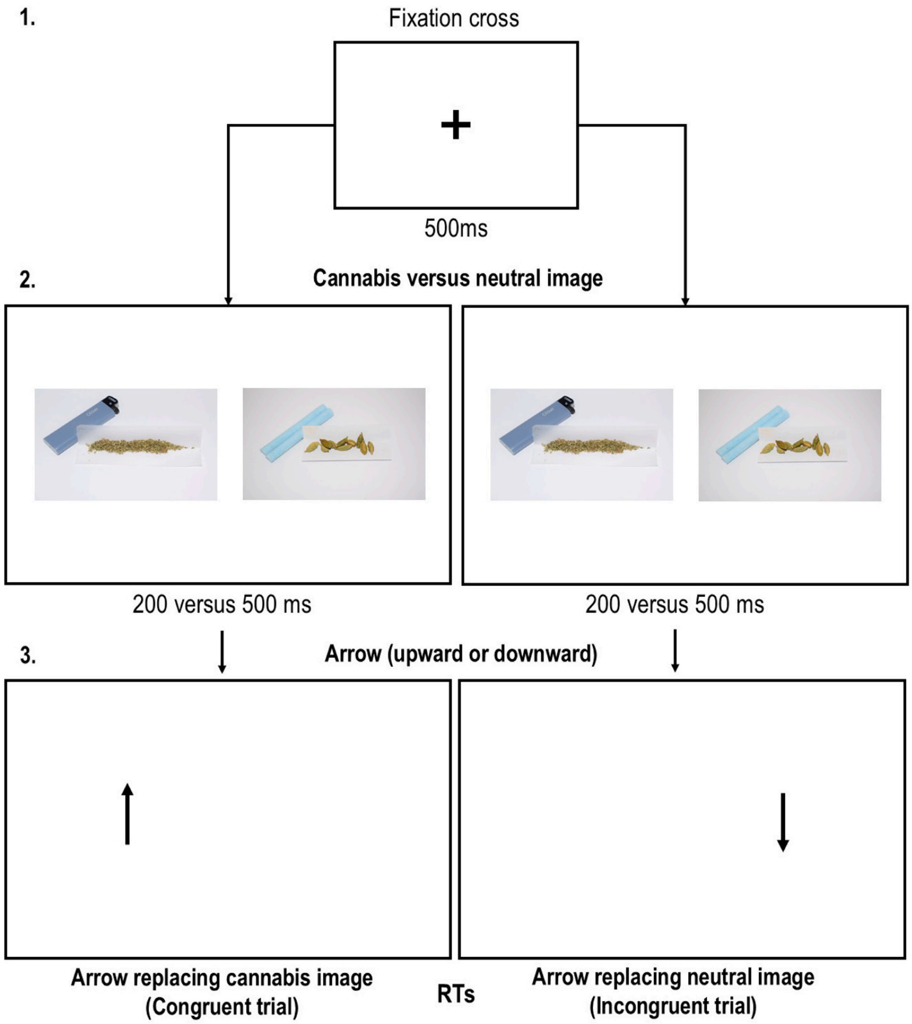

Fig. 1. Example of the visual probe task, with a cannabis trial (left) and a neutral trial (right) (Quinones-Valera et al., 2026) ***Note.*** **Ms = milliseconds. RTs = reaction times.**

with a centred fixation cross (500 milliseconds), followed by one cannabis and neutral image, side by side, for either 200 or 500 milliseconds (SOA) to measure automatic and sustained attention, respectively. Next, a probe (i.e., black arrow pointing upwards or downwards) replaced either the cannabis (i.e. congruent trials) or the neutral image (i.e., incongruent trials).

Participants were instructed to indicate, as quickly and accurately as possible, the probe's orientation with the response key. RTs were recorded. The probe type (up/down) and position (left/right), target position (left/right) and SOA were counterbalanced across the task. The task was programmed with Experiment Builder (SR Research, Kanata, ON, Canada). Reliability results indicated a Cronbach's Alpha between 0.84 and 0.96 and split-half reliability between 0.97 and 0.99 for RTs, across the four key types of trials (i.e., type of image x SOA). For AB scores, Cronbach's Alpha ranged between 0.05 and 0.62, and split-half correlations were between -0.001 and 0.446 (See Supplementary Methods 1.3 and Results 2.1 for more information about the task and its reliability).

2.4.2. Subjective ratings of valence of cannabis and neutral images from the visual probe task

An image rating task, programmed using Experiment Builder (SR Research, Kanata, ON, Canada), was administered to measure participants' appraisal of the subjective valence of the images. A fixation cross appeared for 500 milliseconds, followed by one of the 10 cannabis or neutral images, centred on the screen. Participants rated images on a scale ranging from -3 for "very unpleasant" to 3 for "very pleasant" (Supplementary Methods 1.4 for detailed instructions).

3. Statistical Analyses

3.1. Normality checks and outliers

Variables were examined for normality (Kolmogorov-Smirnov test). Distributions were visually inspected for outliers using Tukey's method (data points 1.5 interquartile range below Q1 and above Q3), which were removed for all analyses. For RTs, incorrect trials (i.e., wrong response key entered), and any individual RTs <200 and >2000 and more than ± 3 standard deviations from the mean at a trial level, were removed.

3.2. Descriptives

Group comparisons were conducted via Chi-Square test for categorical variables (sex), t-test for variables that were normally distributed (stress, CUDIT-R scores), and Mann-Whitney U tests for the remaining non-normally distributed data.

3.3. Aim 1: Group differences in AB

We conducted a linear mixed-effects model to examine the primary aim. The outcome variable was RTs. Subject ID was used as a random intercept, and predictors included: group (CUD, controls); image type (i.e., cannabis, neutral); SOA (200, 500 milliseconds). Interaction terms were group-by-image type to measure AB differences between the CUD and control groups and group-by-image type-by-SOA to examine AB differences between groups as a function of SOA. AUDIT scores were adjusted for as a covariate in all models. A likelihood ratio test was conducted to examine whether there was significant variability in RTs within individuals, comparing two models (with and without Subject ID as the random intercept). A significant effect of the group-by-image type indicates the presence of attentional bias, as such an effect demonstrates that RTs between CUD and control participants depend on image type (cannabis vs neutral).

For comparability purposes with most studies in the field (Cousijn et al., 2013; Kroon et al., 2023; van Hemel-Ruiter et al., 2016; Van Kampen et al., 2020), we additionally calculated AB scores via subtracting – within each participant – their mean RTs to cannabis images from the mean RTs to neutral images (Field et al., 2004). This resulted in a single AB score per participant. We compared these AB scores between CUD and controls.

3.4. Aim 2: Association between level of AB and cannabis-related variables

We ran a series of five linear mixed-effects models to address the secondary exploratory aim, including one moderator in each analysis (cannabis grams/past month, VAS subjective craving, CUDIT-R scores, valence ratings, number of cigarettes/past month). Additional predictors in all models included: image type (cannabis/neutral) and SOA (200/500 milliseconds), along with interaction terms between each moderator and image type. RTs were the dependent variable. AUDIT scores were adjusted for in all models. Bonferroni corrections for multiple comparisons were applied to all aim two analyses, with significance set at $p < 0.01$. The Statistical Package for the Social Sciences was used to complete all statistical analyses for the primary and secondary aims (SPSS version 29; IBM, Chicago, IL, USA). GLIMMPSE 3.1.3 was used to conduct post hoc power analysis (Kreidler et al., 2013) (See Supplementary Methods 1.1 for details).

3.5. Sensitivity analysis

Sensitivity analyses were conducted for the primary and secondary aims to confirm the robustness of the results obtained by removing outliers (±3 standard deviations from the mean) and 44 participants from the CUD group whose performance on the visual probe task may have been affected by use of substances other than cannabis, alcohol and nicotine and other cannabis-related items (e.g., last cannabis consumption within last 12 hours before testing). These participants were retained in the sample to allow greater representation of the broader population of cannabis users, including those with concurrent use of other substances (Hasin & Walsh, 2020) (see Supplementary Methods 1.5 for details). Sensitivity analysis was also conducted for the primary aim by removing AUDIT scores as a covariate to assess the robustness of the findings (see Supplementary Results 2.3).

4. Results

4.1. Sample Characteristics

The sample characteristics are summarised in Table 2, comprising 104 participants (31 females and 73 males), including 74 participants with CUD and 30 controls, with a median age of 23.10 years (range: 18.47–32.46 years). Groups were matched by age and sex and did not significantly differ in their perceived stress levels. The CUD group displayed significantly lower IQ, fewer years of education than controls and showed significantly higher trait anxiety, depression, positive and negative psychotic symptom scores. The CUD group also had significantly higher AUDIT scores, consumed more standard drinks and cigarettes and on more days in the last 30 days, despite showing comparable FTND scores. Six CUD participants (8.10%) and one control (3.33%) endorsed nicotine dependence (FTND score ≥ 3).

4.2. Cannabis use and related problems

Table 3 presents cannabis use patterns. The CUD group consumed cannabis on most days, on the 30 days before testing and abstained from cannabis 25 hours on average before baseline. Withdrawal symptoms were mild and cannabis craving levels were relatively low. The CUD group reported using cannabis for the first time significantly earlier than controls.

Within the control group, 56.7% endorsed trying cannabis in their lifetime and using cannabis for a total of 6 lifetime occasions on average.

Table 2
Overview of sample characteristics.

Variable		CUD N Total [females]		Control N Total [females]		Group differences $x^a/t^b/U^c$	p
N Total [females]		74 [20]		30 [11]		0.948^a	0.330
		M (SD)	**Range**	***M (SD)***	**Range**	$x^a/t^b/U^c$	p
Age, years		23.38 (3.34)	18.47–32.46	22.41 (2.90)	13–21	−1.327^c	0.184
Education, years		14.96 (1.95)	11–21	16.05 (2.07)	6.50–25	−2.442^c	0.015*
IQ, WASI-II		115.65 (10.28)	88–136	126 (8.20)	84–135	−4.592^c	0.001***
State anxiety, STAI-Y		33.55 (9.19)	20–69	29.37 (8.43)	20–56	−2.590^c	0.010*
Perceived stress, PSS		15.52 (5.92)	5–30	10.25 (6.87)	1–30	3.534^b	0.773
CAPE symptomsfrequency	Positive psychotic	25.61 (3.79)	20–35	21.37 (1.56)	20–25	−5.746^c	0.001***
	Depressive	13.61 (13)	8–20	11.30 (2.94)	8–20	−3.524^c	0.001***
	Negative psychotic	23.56 (5.11)	14–35	19.47 (5.27)	14–40	−3.973^c	0.001***
Alcohol	AUDIT	7.26 (4.23)	0–22	4.07 (3.34)	0–12	−3.623^c	0.001**
	Days of use past/month, TLFB	4.36 (5.23)	0–24	2.66 (2.71)	0–8	−1.263^c	0.206
	Drinks past/month, TLFB	22.70 (30.93)	0–157	10.27 (14.56)	0–52	−2.221^c	0.026*
Nicotine	FNTD	1.73 (1.18)	1–6	1.80 (1.30)	1–4	−0.048^c	0.962
	Days of use past/month, TLFB	9.14 (12.34)	0–30	0.10 (0.54)	0–3	−4.953^c	0.001***
	N cigarettes past/month, TLFB	55.69 (155.55)	0–1200	0.17 (0.93)	0–5	−4.508^c	0.001***

Note. IQ = Intelligence Quotient. WASI-II = Wechsler Abbreviated Scale of Intelligence, 2nd Edition; STAI-Y = State-Trait Anxiety Inventory; PSS = Perceived Stress Scale; CAPE = Community Assessment of Psychic Experiences; AUDIT = Alcohol Use Disorder Identification Test; TLFB = Timeline Follow-back; FTND = Fagerström Test for Nicotine Dependence.
*$p < 0.05$. **$p < 0.01$. ***$p < 0.001$.

Table 3
Overview of cannabis use and related problems, reaction times to cannabis and neutral images and AB scores.

Variable		CUD (n = 74)		Controls (n = 30)		Group differences		
		***M* (*SD*)**	**Range (min–max)**	***M* (*SD*)**	**Range (min–max)**	***U***	***p***	***r***
CUD symptoms, SCID-5-RV		5.39 (2.33)	2–11	–	–	–	–	–
CUDIT-R		17.77 (5.22)	7–30	–	–	–	–	–
Cannabis	Days of use/past month, TLFB	24.96 (6.08)	5–30	–	–	–	–	–
	Grams/past month, TLFB	19.08 (24.05)	0.50–152.50	–	–	–	–	–
Craving	MCQ	39.97 (12.36)	20–64	15.33 (5.77)	12–22	−2.830	0.005**	−0.277
	VAS pre-visual probe task	3.99 (2.64)	0–10	0.86 (0.38)	0–1	−3.342	0.001***	−0.328
	VAS post-visual probe task	4.41 (2.82)	0–10	0.86 (0.38)	0–1	−3.491	0.001***	−0.342
Withdrawal, CWS		9.15 (6.94)	0–30	0.50 (0.70)	0–1	−2.157	0.031*	−0.212
Age of onset	First use, total years	16.65 (2.68)	10.75–27	18.47	15–20.92	−2.889	0.004**	−0.283
	At least monthly, total years	18.46 (2.81)	12.50–28	–	–	–	–	–
THC-COOH in urine, ng/mL		61.80 (76.77)	0–375.48	–	–	–	–	–
Reaction times	Cannabis images	511.23 (56.42)	407.90–658.76	493.76 (50.41)	456.31–492.70	−1.399	0.162	–
	Neutral images	511.69 (57.69)	394.99–661.05	493.28 (51.59)	457.14–498.53	−1.686	0.092	–
AB scores		0.46 (17.08)	−86–37.55	−0.48 (10.17)	−22.10–21.23	−0.868	0.385	–
ValenceRatings	Cannabis images	0.83 (1.36)	−3–3	−1.15 (1.32)	−3–3	−6.969	0.001***	−0.683
	Neutral images	−0.34 (1.16)	−3–3	−0.09 (1.24)	−3–3	−1.116	0.264	–

Note. CUD = Cannabis use disorder. SCID-5-RV = Structured Clinical Interview for DSM-5 Diagnoses Research Version; CUDIT-R = The Cannabis Use Disorder Identification Test–Revised; TLFB = Timeline Follow-back; MCQ = Marijuana Craving Questionnaire; VAS = Visual Analogue Scale; CWS = Cannabis Withdrawal Scale; THC-COOH = 11-Nor-9-carboxy-Δ9-tetrahydrocannabinol; ng/mL = Nanograms per millilitre. AB = Attentional bias computed as the formula mean RTs neutral images minus mean RTs cannabis images (Field et al., 2004).
*p < 0.05. **p < 0.01. ***p < 0.001.

Only two controls reported having a history of using cannabis monthly in the past, with a mean of 2.75 days/month. Six controls endorsed a maximum of two occasions of use over the last 12 months.

4.3. Group Differences in subjective valence ratings for cannabis and neutral images

Ratings of subjective valence for the CUD and control groups are displayed in Table 2. CUD participants rated cannabis images as significantly more pleasant than controls, whereas neutral images were rated similarly in both groups. CUD participants also rated cannabis images as significantly more pleasant than neutral images (Z = -6.701, p <.001, η^2 = 12.11), which contrasted with controls, who rated neutral images as significantly more pleasant than cannabis images (Z = -3.886, p<.001, η^2=12.29).

4.4. Group Differences in RTs to cannabis and neutral images and AB scores

Fig. 2 and Table 3 overview group differences in RTs to cannabis and neutral images and AB scores. RTs towards cannabis and neutral images did not differ significantly between groups. AB scores for the CUD group (mean=0.46) and controls (mean=-0.48) did not significantly deviate from zero (Z=0.924, p=.356 and Z=-0.504, p=.614, respectively) or differ between groups, indicating no AB existed in either group.

4.5. Main and interaction effects of group, image type and SOA on RTs, adjusting for AUDIT scores

The likelihood ratio test was significant (p<0.0001), and the intercept significantly differed from zero, indicating significant intra-individual variability. Additionally, there was a significant main effect of SOA on the outcome variable, with RTs being significantly faster at 500 milliseconds compared to 200 milliseconds (F=103.006, SE = 3.176, t(8721.037) = 6.209, p<0.001), although not as a function of image type. We did not find any other significant main effects or interactions (Supplementary Results 2.2). These results were unaltered after sensitivity analyses, without outliers and comorbid substance use (See Supplementary Results 2.3).

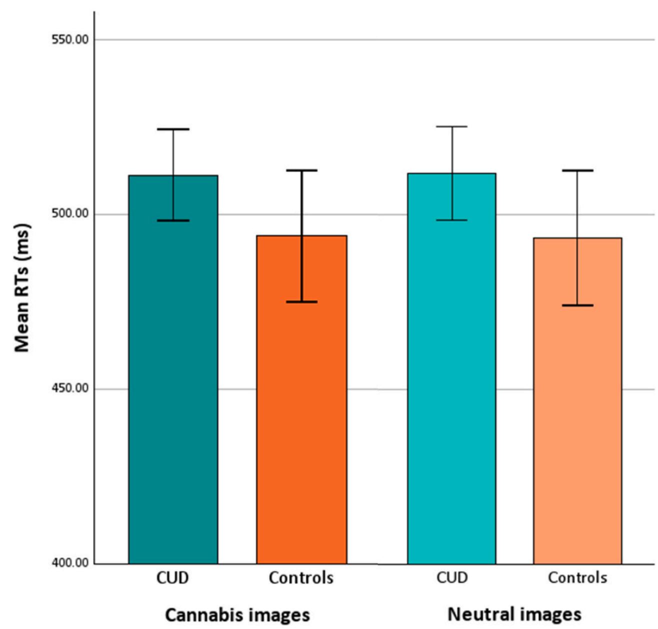

Fig. 2. Mean RTs (in milliseconds) to cannabis and neutral images per CUD and control groups. *Note.* Error bars: 95% CI. Ms = milliseconds. RTs = reaction times. CUD = cannabis use disorder.

4.6. Associations between AB (defined as RTs to cannabis versus neutral images), and cannabis use and related problems

The results indicated the intercept was significantly different from zero and a main significant effect of SOA on RTs in all analyses (p<0.001), with faster RTs at 500 milliseconds compared to 200. When examining the association between AB and cannabis quantity, we found a significant main effect of alcohol on RTs (p<0.001, β=0.198) (Supplementary Results 2.4). Additionally, we found a significant main effect of craving (p<0.001, β=1.96), CUDIT-R scores (p=0.029, β=-0.444) and number of cigarettes on RTs (p<0.001, β=-0.042 (Supplementary Results 2.5, 2.6 and 2.7). However, these effects were small and not observed as a function of image type, indicating no significant associations with cannabis AB. These results remained the same after conducting sensitivity analyses, without outliers and comorbid substance use.

5. Discussion

This study examined AB toward cannabis-related images in participants with mild-to-severe CUD, recruited from the general community. Contrary to our hypothesis, we did not find evidence of AB in participants with CUD compared to controls, based on RTs to cannabis versus neutral images, adjusting for SOA and alcohol use. Similarly, in the CUD group, we did not find any significant associations between cannabis AB and cannabis quantity, craving, CUDIT-R scores, valence ratings and nicotine use.

The absence of AB differs from other studies in similar-aged samples and abstinent for multiple days (Cousijn et al., 2013; Kroon et al., 2023), as well as in abstinent (Ruglass et al., 2019) and non-abstinent older CUD participants (Vujanovic et al., 2016; Yoon et al., 2019). Our results also differ from those obtained in samples of individuals with cannabis abuse/dependence as per DSM-IV criteria, of unclear abstinence status, using the visual probe task (van Hemel-Ruiter et al., 2016). However, our results *are* consistent with findings obtained in adolescents and young adults in treatment and those abstinent for longer periods (>8 days) (Van Kampen et al., 2020) and with earlier findings of cannabis attentional bias measured via the visual probe task (Field et al., 2004; Field et al., 2006). Importantly, our non-significant results are consistent with studies on non-treatment seekers where intra-individual variability was adjusted for in the statistical framework used (Field et al., 2006; Quinones-Valera et al., 2026). Thus, these mixed findings could arise from variability in sample characteristics such as mean age, severity of CUD, treatment status and duration of abstinence. Meta-analyses and meta-regressions of the latest evidence prove useful to confirm the role of moderators in cannabis AB in CUD.

Within the CUD group, craving (positively), CUDIT-R scores and number of cigarettes in the past month (negatively) significantly affected RTs, although not as a function of image type (cannabis, neutral), and therefore, these variables do not affect AB. Of note, participants' cannabis craving significantly increased pre-to-post the visual probe task (p=0.007, η^2=12.097), suggesting the cannabis images were craving-inducing, although potentially not enough to elicit cannabis AB (mean score of 4.41/10). Cannabis craving is theorised to have a mutually excitatory association with AB (Field & Cox, 2008). However, the evidence is mixed, with some studies finding AB in high-craving samples (Field et al., 2004; Kroon et al., 2023), whilst others failed to find such associations (Cousijn et al., 2013; Van Kampen et al., 2020). The role of craving on AB requires further examination.

Similarly, despite the CUD group rating cannabis images as significantly more pleasant than neutral images compared to controls, the ratings were not associated with cannabis AB, consistent with previous evidence in a non-treatment-seeking CUD sample (Quinones-Valera et al., 2026). Our findings contrast with theoretical frameworks, which posit valence as deterministic of the attention-grabbing properties of stimuli (Lang et al., 2000; Robinson & Berridge, 1993). Given the evidence of associations between valence and nicotine AB (Mogg et al., 2003), further investigation of the relationship between valence and cannabis AB is warranted.

The findings of this study must be interpreted in light of potential methodological limitations. First, we might have been underpowered to detect subtle effects for the primary and secondary analyses in this non-treatment-seeking sample. Secondly, participants were asked to refrain from cannabis use for at least 12 hours before testing, which may be a brief duration for an AB to manifest. Evidence of AB is reported in studies with more prolonged abstinence periods from cannabis and alcohol (≥ 3.5 days) (Cousijn et al., 2013; Kroon et al., 2023; Ruglass et al., 2019), and recent use may attenuate AB (Monem & Fillmore, 2019).

Additionally, whilst the visual probe task showed good internal consistency for RTs, reliability for actual AB scores was poor, in line with existing literature (Ataya et al., 2012; Jones et al., 2018). Thus, concurrent use of direct measures of AB (e.g., dual probe task [Grafton et al., 2021], eye tracking) and personalised stimuli to enhance potential image salience (Yoon et al., 2019) is warranted in future research, as another limitation of the current study was the use of generic, non-personalised cues. How previous environmental exposure to cannabis-related stimuli affects AB in CUD requires further examination, given evidence that tobacco exposure predicts AB (Oliver & Drobes, 2012). Similarly, the role of alcohol use in cannabis AB requires further elucidation, given their co-occurrence (Yurasek et al., 2017), as well as evidence of alcohol exposure influencing attentional bias towards other substance-related cues, including tobacco and cocaine (Field et al., 2005; Montgomery et al., 2010). Lastly, the observed faster RTs during longer SOA (500 milliseconds) could be explained by additional limitations of the visual probe paradigm, where RTs phenomena other than AB could influence the results. Variable foreperiods (i.e., the interval between a warning and an imperative stimulus) increase participants' uncertainty/expectancy of stimulus occurrence, thus resulting in slower RTs at shorter SOA and faster RTs at longer SOA, with the latter allowing for more preparation and motor readiness (Han & Proctor, 2022).

In conclusion, AB might not be a key feature in this young sample of individuals with a CUD (as per DSM-5 criteria), comprised of non-treatment-seeking individuals, predominantly university students. Instead, AB may be limited to those with more severe cannabis-related problems, in treatment and abstinent for several days (Kroon et al., 2023). This study replicated findings obtained previously, where AB was absent when accounting for intra-individual variability in non-treatment-seeking adults (Quinones-Valera et al., 2026). Replication studies, using sound statistical frameworks and valid tasks are required to confirm if AB is associated with CUD.

Declaration of generative AI and AI-assisted technologies in the manuscript preparation process

During the preparation of this work, the author(s) used Grammarly in order to complete grammar checks. After using this tool/service, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the published article.

CRediT authorship contribution statement

Marianna Quinones-Valera: Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Madeleine I. Fraser:** Writing – review & editing, Supervision, Conceptualization. **Nadia Solowij:** Writing – review & editing, Investigation, Funding acquisition, Conceptualization. **Antonio Verdejo-Garcia:** Writing – review & editing, Conceptualisation, Funding acquisition. **Janna Cousijn:** Writing – review & editing, Methodology. **Gabrielle Abbott:** Writing – review & editing, Data curation. **Suraya Dunsford:** Writing – review & editing, Data curation. **Anastasia Paloubis:** Writing – review & editing, Data curation. **Eugene McTavish:** Writing – review & editing, Data curation. **Jessica R. Ramamurthy:** Writing – review & editing, Data curation. **Andrew Jones:** Writing – review & editing, Methodology. **Gary Chan:** Writing – review & editing, Methodology. **Lisa Greenwood:** Writing – review & editing, Project administration, Data curation, Conceptualization. **Victoria Manning:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Conceptualization. **Valentina Lorenzetti:** Writing – review & editing, Supervision, Methodology, Funding acquisition, Conceptualization.

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Authors contribution

- Marianna Quinones-Valera developed the theoretical framework of the manuscript, contributed to data entry, databasing and data quality checks for the project, drove the running of the statistical analyses, created the first draft and led the subsequent revisions, under the supervision of Valentina Lorenzetti, Victoria Manning and Madeleine Fraser.
- All authors edited the manuscript.
- Nadia Solowij, Lisa Greenwood, Suraya Dunsford, and Gabrielle Abbott managed operations of the study.
- Lisa Greenwood, Suraya Dunsford, and Gabrielle Abbott supported data collection.
- Madeleine Fraser provided input into the theoretical framework, clinical relevance and revisions of the manuscript.
- Anastasia Paloubis, Eugene McTavish, Gabrielle Abbott and Jessica R. Ramamurthy drove data entry and QCs of all data.
- Nadia Solowij and Valentina Lorenzetti designed and led the study as CIs and obtained funding.
- Antonio Verdejo-Garcia contributed to the study design and funding acquisition.
- Lisa Greenwood supported the protocol design, ethics, managed the running of the project and all students and staff involved in data collection.
- Andrew Jones and Gary Chan contributed to the development of the statistical framework in previous work, which informed the current study.
- Victoria Manning and Valentina Lorenzetti revised the first full draft of the manuscript and all subsequent drafts and provided high-level input into the manuscript's theoretical framework and clinical relevance.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Valentina Lorenzetti reports financial support was provided by National Health and Medical Research Council (ID 1130079). Nadia Solowij reports financial support was provided by National Health and Medical Research Council (ID 1130079). Lisa Greenwood reports financial support was provided by National Health and Medical Research Council (ID 1130079). Valentina Lorenzetti reports financial support was provided by Al and Val Rosenstrauss Research Fellowship. Valentina Lorenzetti reports financial support was provided by National Health & Medical Research Council (ID 2016833). Marianna Quinones-Valera reports financial support was provided by Australian Government Research Training Program (RTP) Stipend scholarship. Antonio Verdejo-Garcia reports financial support was provided by National Health & Medical Research Council (ID 2009464). Gary Chan reports financial support was provided by Australian National Health and Medical Council (ID GNT2033119). Victoria Manning reports financial support was provided by National Health and Medical Research Council. Victoria Manning reports financial support was provided by VicHealth. Victoria Manning reports financial support was provided by Victoria Department of Health. Victoria Manning reports financial support was provided by Victorian Responsible Gambling Foundation. Victoria Manning reports financial support was provided by National Centre for Clinical Research on Emerging Drugs. Victoria Manning reports financial support was provided by HCF. Victoria Manning reports financial support was provided by Philanthropic Organisations. Victoria Manning reports a relationship with Victoria Manning that includes: board membership, consulting or advisory, equity or stocks, and funding grants. Corresponding author is a Senior editor of the journal Addiction - Valentina Lorenzetti Co-author is a Regional Editor for the journal Addiction - Janna Cousijn Co-author is a Deputy Statistical and Methodology Editor for the journal Addiction - Gary Chan Co-author is an Associate Editor (Clinical) for the journal European Addiction Research and Academic and Editorial board member for the journal Drug and Alcohol Review – Victoria Manning If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.addbeh.2026.108838.

Data availability

Data will be made available upon reasonable request.

References

Adamson, S. J., Kay-Lambkin, F. J., Baker, A. L., Lewin, T. J., Thornton, L., Kelly, B. J., & Sellman, J. D. (2010). An improved brief measure of cannabis misuse: The Cannabis Use Disorders Identification Test-Revised (CUDIT-R). *Drug Alcohol Depend, 110*(1–2), 137–143. https://doi.org/10.1016/j.drugalcdep.2010.02.017

Aitken, R. C. (1969). Measurement of feelings using visual analogue scales. *Proceedings of the Royal Society of Medicine, 62*(10), 989–993. https://doi.org/10.1177/003591576906201005

Allsop, D. J., Norberg, M. M., Copeland, J., Fu, S., & Budney, A. J. (2011). The Cannabis Withdrawal Scale development: Patterns and predictors of cannabis withdrawal and distress. *Drug and Alcohol Dependence, 119*(1–2), 123–129. https://doi.org/10.1016/j.drugalcdep.2011.06.003

American Psychiatric Association. (2000). Diagnostic and Statistical Manual of Mental Disorders (4th ed.). doi: 10.1176/ajp.152.8.1228.

American Psychiatric Association. (2013). Diagnostic and statistical manual of mental disorders (5th ed.). doi: 10.1176/appi.books.9780890425596.

Ataya, A. F., Adams, S., Mullings, E., Cooper, R. M., Attwood, A. S., & Munafo, M. R. (2012). Internal reliability of measures of substance-related cognitive bias. *Drug and Alcohol Dependence, 121*(1–2), 148–151. https://doi.org/10.1016/j.drugalcdep.2011.08.023

Babor, T., Higgins-Biddle, J., Saunders, J., & Monteiro, M. (2001). The Alcohol Use Disorders Identification Test. *World Health.* Organization.

Beck, A. T., Steer, R. A., & Brown, G. (1996). Beck Depression Inventory–II (BDI-II). *In Psychological Assessment.* https://doi.org/10.1037/t00742-000

Broyd, S. J., van Hell, H. H., Beale, C., Yucel, M., & Solowij, N. (2016). Acute and Chronic Effects of Cannabinoids on Human Cognition-A Systematic Review. *Biological Psychiatry, 79*(7), 557–567. https://doi.org/10.1016/j.biopsych.2015.12.002

Butterworth, P., Slade, T., & Degenhardt, L. (2014). Factors associated with the timing and onset of cannabis use and cannabis use disorder: Results from the 2007 Australian National Survey of Mental Health and Well-Being. *Drug and Alcohol Review, 33*(5), 555–564. https://doi.org/10.1111/dar.12183

Campbell, D. W., Stewart, S., Gray, C. E. P., Ryan, C. L., Fettes, P., McLandress, A. J., & Dell'Aquila, R. (2018). Chronic cannabis use and attentional bias: Extended attentional capture to cannabis cues. *Addictive Behaviors, 81*, 17–21. https://doi.org/10.1016/j.addbeh.2018.01.008

Cerda, M., Mauro, C., Hamilton, A., Levy, N. S., Santaella-Tenorio, J., Hasin, D., Wall, M. M., Keyes, K. M., & Martins, S. S. (2020). Association Between Recreational Marijuana Legalization in the United States and Changes in Marijuana Use and Cannabis Use Disorder From 2008 to 2016. *JAMA Psychiatry, 77*(2), 165–171. https://doi.org/10.1001/jamapsychiatry.2019.3254

Cohen, S., Kamarck, T., & Mermelstein, R. (1983). A global measure of perceived stress. *Journal of Health and Social Behavior, 24*(4), 385–396.

Cousijn, J., Watson, P., Koenders, L., Vingerhoets, W. A., Goudriaan, A. E., & Wiers, R. W. (2013). Cannabis dependence, cognitive control and attentional bias for cannabis words. *Addictive Behaviors, 38*(12), 2825–2832. https://doi.org/10.1016/j.addbeh.2013.08.011

de Meneses-Gaya, C., Zuardi, A. W., Loureiro, S. R., & Crippa, J. A. S. (2009). Alcohol Use Disorders Identification Test (AUDIT): An updated systematic review of psychometric properties. *Psychology & Neuroscience, 2*(1), 83–97. https://doi.org/10.3922/j.psns.2009.1.12

Di Forti, M., Quattrone, D., Freeman, T. P., Tripoli, G., Gayer-Anderson, C., Quigley, H., Rodriguez, V., Jongsma, H. E., Ferraro, L., La Cascia, C., La Barbera, D., Tarricone, I., Berardi, D., Szoke, A., Arango, C., Tortelli, A., Velthorst, E., Bernardo, M., Del-Ben, C. M.,…Group, E.-G. W. (2019). The contribution of cannabis use to variation in the incidence of psychotic disorder across Europe (EU-GEI): A multicentre case-control study. *Lancet Psychiatry, 6*(5), 427–436. https://doi.org/10.1016/S2215-0366(19)30048-3

Fagerstrom, K., Russ, C., Yu, C. R., Yunis, C., & Foulds, J. (2012). The Fagerstrom Test for Nicotine Dependence as a predictor of smoking abstinence: A pooled analysis of varenicline clinical trial data. *Nicotine & Tobacco Research, 14*(12), 1467–1473. https://doi.org/10.1093/ntr/nts018

Field, M., Mogg, K., & Bradley, B. P. (2004). Cognitive bias and drug craving in recreational cannabis users. *Drug and Alcohol Dependence, 74*(1), 105–111. https://doi.org/10.1016/j.drugalcdep.2003.12.005

Field, M., Mogg, K., & Bradley, B. P. (2005). Alcohol increases cognitive biases for smoking cues in smokers. *Psychopharmacology, 180*(1), 63–72. https://doi.org/10.1007/s00213-005-2251-1

Field, M., Eastwood, B., Bradley, B. P., & Mogg, K. (2006). Selective processing of cannabis cues in regular cannabis users. *Drug and Alcohol Dependence, 85*(1), 75–82. https://doi.org/10.1016/j.drugalcdep.2006.03.018

Field, M., & Cox, W. M. (2008). Attentional bias in addictive behaviors: A review of its development, causes, and consequences. *Drug and Alcohol Dependence, 97*(1–2), 1–20. https://doi.org/10.1016/j.drugalcdep.2008.03.030

First, M., Williams, J., Karg, R., & Spitzer, R. (2015). *Structured Clinical Interview for DSM-5 - Research Version (SCID-5 for DSM-5, Research Version; SCID-5-RV)*. In American Psychiatric Association.

Grafton, B., Teng, S., & MacLeod, C. (2021). Two probes and better than one: Development of a psychometrically reliable variant of the attentional probe task. *Behaviour Research and Therapy, 138*, Article 103805. https://doi.org/10.1016/j.brat.2021.103805

Han, T., & Proctor, R. W. (2022). Revisiting variable-foreperiod effects: Evaluating the repetition priming account. *Atten Percept Psychophys, 84*(4), 1193–1207. https://doi.org/10.3758/s13414-022-02476-5

Hasin, D., & Walsh, C. (2020). Cannabis Use, Cannabis Use Disorder, and Comorbid Psychiatric Illness: A Narrative Review. *Journal of Clinical Medicine, 10*(1). https://doi.org/10.3390/jcm10010015

Heishman, S. S., & E.. (2009). Assessment of Cannabis Craving Using the Marijuana Craving Questionnaire. In E. Onaivi (Ed.), *Marijuana and Cannabinoid Research: Methods and Protocols* (pp. 209–215). Humana Press Inc.

Jones, A., Christiansen, P., & Field, M. (2018). Failed attempts to improve the reliability of the alcohol visual probe task following empirical recommendations. *Psychology of Addictive Behaviors, 32*(8), 922–932. https://doi.org/10.1037/adb0000414

Kedzior, K. K., & Laeber, L. T. (2014). A positive association between anxiety disorders and cannabis use or cannabis use disorders in the general population–a meta-analysis of 31 studies. *BMC Psychiatry, 14*, 136. https://doi.org/10.1186/1471-244X-14-136

Kreidler, S. M., Muller, K. E., Grunwald, G. K., Ringham, B. M., Coker-Dukowitz, Z. T., Sakhadeo, U. R., Baron, A. E., & Glueck, D. H. (2013). GLIMMPSE: Online Power Computation for Linear Models with and without a Baseline Covariate. *Journal of Statistical Software, 54*(10). https://doi.org/10.18637/jss.v054.i10

Kroon, E., Kuhns, L., Dunkerbeck, A., & Cousijn, J. (2023). The who and how of attentional bias in cannabis users: Associations with use severity, craving and interference control. *Addiction, 118*(2), 307–316. https://doi.org/10.1111/add.16059

Lang, P. J., Davis, M., & Ohman, A. (2000). Fear and anxiety: Animal models and human cognitive psychophysiology. *Journal of Affective Disorders, 61*(3), 137–159. https://doi.org/10.1016/s0165-0327(00)00343-8

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. https://doi.org/10.1017/S0033291713001438

Lorenzetti, V., Solowij, N., Whittle, S., Fornito, A., Lubman, D. I., Pantelis, C., & Yucel, M. (2015). Gross morphological brain changes with chronic, heavy cannabis use. *The British Journal of Psychiatry, 206*(1), 77–78. https://doi.org/10.1192/bjp.bp.114.151407

Lorenzetti, V., Hoch, E., & Hall, W. (2020). Adolescent cannabis use, cognition, brain health and educational outcomes: A review of the evidence. *European Neuropsychopharmacology, 36*, 169–180. https://doi.org/10.1016/j.euroneuro.2020.03.012

Mogg, K., Bradley, B. P., Field, M., & De Houwer, J. (2003). Eye movements to smoking-related pictures in smokers: Relationship between attentional biases and implicit and explicit measures of stimulus valence. *Addiction, 98*(6), 825–836. https://doi.org/10.1046/j.1360-0443.2003.00392.x

Monem, R., & Fillmore, M. T. (2019). Alcohol administration reduces attentional bias to alcohol-related but not food-related cues: Evidence for a satiety hypothesis. *Psychology of Addictive Behaviors, 33*(8), 677–684. https://doi.org/10.1037/adb0000522

Montgomery, C., Field, M., Atkinson, A. M., Cole, J. C., Goudie, A. J., & Sumnall, H. R. (2010). Effects of alcohol preload on attentional bias towards cocaine-related cues. *Psychopharmacology, 210*(3), 365–375. https://doi.org/10.1007/s00213-010-1830-y

Morissette, S. B., Blessing, A., Russell, P., & Hale, W. (2024). Cannabis use disorder uniquely predicts educational impairment in college students over and above other mental health disorders. *Journal of American College Health, 72*(9), 3196–3203. https://doi.org/10.1080/07448481.2022.2155058

O'Neill, A., Bachi, B., & Bhattacharyya, S. (2020). Attentional bias towards cannabis cues in cannabis users: A systematic review and meta-analysis. *Drug and Alcohol Dependence, 206*, Article 107719. https://doi.org/10.1016/j.drugalcdep.2019.107719

Oliver, J. A., & Drobes, D. J. (2012). Visual search and attentional bias for smoking cues: The role of familiarity. *Experimental and Clinical Psychopharmacology, 20*(6), 489–496. https://doi.org/10.1037/a0029519

Quinones-Valera, M., Chan, G., Fraser, M. I., Jones, A., Freeman, T. P., Hindocha, C., Thomson, H., McTavish, E., Sehl, H., Clemente, A., Cousijn, J., Labuschagne, I., Rendell, P., Terrett, G., Greenwood, L. M., Poudel, G., Suo, C., Manning, V., & Lorenzetti, V. (2026). Attentional bias in people with moderate-to-severe cannabis use disorder. *Comprehensive Psychiatry, 146*, Article 152658. https://doi.org/10.1016/j.comppsych.2025.152658

Rabin, R. A., & George, T. P. (2015). A review of co-morbid tobacco and cannabis use disorders: Possible mechanisms to explain high rates of co-use. *The American Journal on Addictions, 24*(2), 105–116. https://doi.org/10.1111/ajad.12186

Robinson, T., & Berridge, K. (1993). The neural basis of drug craving: An incentive-sensitization theory of addiction. *Brain Research Reviews, 18*, 247–291. https://doi.org/10.1016/01650173(93)90013-P

Robinson, T. E., & Berridge, K. C. (2008). Review. The incentive sensitization theory of addiction: Some current issues. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences, 363*(1507), 3137–3146. https://doi.org/10.1098/rstb.2008.0093

Ruglass, L. M., Shevorykin, A., Dambreville, N., & Melara, R. D. (2019). Neural and behavioral correlates of attentional bias to cannabis cues among adults with cannabis use disorders. *Psychology of Addictive Behaviors, 33*(1), 69–80. https://doi.org/10.1037/adb0000423

Rup, J., Goodman, S., & Hammond, D. (2020). Cannabis advertising, promotion and branding: Differences in consumer exposure between 'legal' and 'illegal' markets in Canada and the US. *Preventive Medicine, 133*, Article 106013. https://doi.org/10.1016/j.ypmed.2020.106013

Sehl, H., Terrett, G., Greenwood, L. M., Kowalczyk, M., Thomson, H., Poudel, G., Manning, V., & Lorenzetti, V. (2021). Patterns of brain function associated with cannabis cue-reactivity in regular cannabis users: A systematic review of fMRI studies. *Psychopharmacology, 238*(10), 2709–2728. https://doi.org/10.1007/s00213-021-05973-x

Sheehan, D. V., Lecrubier, Y., Sheehan, K. H., Amorim, P., Janavs, J., Weiller, E., Hergueta, T., Baker, R., & Dunbar, G. C. (1998). The Mini-International Neuropsychiatric Interview (M.I.N.I.): The development and validation of a structured diagnostic psychiatric interview for DSM-IV and ICD-10. *The Journal of Clinical Psychiatry, 59*, 34–57.

Sobell, L., & Sobell, M. (1992). Timeline Follow-Back: A technique for assessing self-reported alcohol consumption. In Measuring Alcohol Consumption. Humana Press. doi: doi: 10.1007/978-1-4612-0357-5_3.

Solowij, N., Stephens, R. S., Roffman, R. A., Babor, T., Kadden, R., Miller, M., Christiansen, K., McRee, B., Vendetti, J., & Marijuana Treatment Project Research, G. (2002). Cognitive functioning of long-term heavy cannabis users seeking treatment. *Journal of the American Medical Association, 287*(9), 1123–1131. https://doi.org/10.1001/jama.287.9.1123

Spielberger, C. D., Gorsuch, R., Lushene, R., Vagg, P., & Jacobs, G. (1983). Manual for the state-trait anxiety scale. *Consulting Psychologists*. https://doi.org/10.1037/t06496-000

Stefanis, N. C., Hanssen, M., Smirnis, N. K., Avramopoulos, D. A., Evdokimidis, I. K., Stefanis, C. N., Verdoux, H., & Van Os, J. (2002). Evidence that three dimensions of psychosis have a distribution in the general population. *Psychological Medicine, 32* (2), 347–358. https://doi.org/10.1017/s0033291701005141

Topbas, Z. S., Albayrak Gunday, E., Simsek, N., & Usta, E. (2025). Does Attentional Bias Predict Relapse in Addiction? A Systematic Review of Longitudinal Studies. *Brain and Behavior: A Cognitive Neuroscience Perspective, 15*(3), Article e70300. https://doi.org/10.1002/brb3.70300

United Nations Office for Drugs and Crime. (2023). World Drug Report. https://www.unodc.org/unodc/en/data-and-analysis/world-drug-report-2023.html.

van Hemel-Ruiter, M. E., Wiers, R. W., Brook, F. G., & de Jong, P. J. (2016). Attentional bias and executive control in treatment-seeking substance-dependent adolescents: A cross-sectional and follow-up study. *Drug and Alcohol Dependence, 159*, 133–141. https://doi.org/10.1016/j.drugalcdep.2015.12.005

Van Kampen, A. D., Cousijn, J., Engel, C., Rinck, M., & Dijkstra, B. A. G. (2020). Attentional bias, craving and cannabis use in an inpatient sample of adolescents and young adults diagnosed with cannabis use disorder: The moderating role of cognitive control. *Addictive Behaviors, 100*, Article 106126. https://doi.org/10.1016/j.addbeh.2019.106126

Volkow, N. D., Michaelides, M., & Baler, R. (2019). The Neuroscience of Drug Reward and Addiction. *Physiological Reviews, 99*(4), 2115–2140. https://doi.org/10.1152/physrev.00014.2018

Vujanovic, A. A., Wardle, M. C., Liu, S., Dias, N. R., & Lane, S. D. (2016). Attentional bias in adults with cannabis use disorders. *Journal of Addictive Diseases, 35*(2), 144–153. https://doi.org/10.1080/10550887.2015.1116354

Wechsler, D. (2011). Wechsler Abbreviated Scale of Intelligence-Second Edition. *APA PsycTests*. https://doi.org/10.1037/t15171-000

Yoon, J. H., San Miguel, G. G., Vincent, J. N., Suchting, R., Haliwa, I., Weaver, M. F., Schmitz, J. M., & Lane, S. D. (2019). Assessing attentional bias and inhibitory control in cannabis use disorder using an eye-tracking paradigm with personalized stimuli. *Experimental and Clinical Psychopharmacology, 27*(6), 578–587. https://doi.org/10.1037/pha0000274

Yurasek, A. M., Aston, E. R., & Metrik, J. (2017). Co-use of Alcohol and Cannabis: A Review. *Current Addiction Reports, 4*(2), 184–193. https://doi.org/10.1007/s40429-017-0149-8

Zehra, A., Burns, J., Liu, C. K., Manza, P., Wiers, C. E., Volkow, N. D., & Wang, G. J. (2018). Cannabis Addiction and the Brain: A Review. *J Neuroimmune Pharmacol, 13* (4), 438–452. https://doi.org/10.1007/s11481-018-9782-9