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RESEARCH ARTICLE

Emotional processing deficits in chronic cannabis use: A replication and extension

Chandni Hindocha, Olivia Wollenberg, Virginia Carter Leno, Beatriz O Alvarez, H Valerie Curran and Tom P Freeman
Clinical Psychopharmacology Unit, University College London, Gower Street, London, WC1E 6BT, UK
tom.freeman@ucl.ac.uk

ABSTRACT
Heavy cannabis use is associated with interpersonal problems that may arise in part from the inaccurate perception of emotional faces. Only one study reports impairments in emotional facial affect processing in heavy cannabis users; however, it is not clear whether these findings were attributable to differences between cannabis users and controls in schizotypy or gender, rather than from cannabis use itself. A total of 25 frequent cannabis users and 34 non-using controls completed an emotional processing task in an independent groups design. We asked participants to identify the emotions on faces morphed from neutral to 100% intensity, for six basic emotions. We measured percentage hit rate, sensitivity and response bias. Schizotypy was indexed using the Schizotypal Personality Questionnaire. Cannabis users showed lower accuracy and sensitivity on the emotional recognition task. Gender and schizotypy did not differ between the two groups. Men showed lower accuracy on the emotional processing task, but impairments in cannabis users remained when covarying for gender. Schizotypy negatively correlated with sensitivity scores, but this was unreliable when accounting for the groups. Chronic cannabis users showed generalised impairment in emotional processing. These results appeared as independent of the emotional processing deficits amongst men, and were not related to schizotypy.

KEYWORDS: Cannabis, drug use, emotional processing, facial affect, gender, response bias, schizotypy, sensitivity

Introduction

Recognising and responding to non-verbal cues of facial emotion is essential for building interpersonal relationships (Carton et al., 1999); however, this ability is impaired in many psychiatric disorders, including depression (Joorman and Gotlib, 2006) and anxiety (Winton et al., 1995). These deficits are also associated with behavioural problems, including risk-taking and addiction (Bediou et al., 2012; Dalgleish, 2004; Davidson et al., 2000), and are seen in users of several drugs of abuse (Goldstein and Volkow, 2011).

Cannabis is the most widely-used illicit substance, with an estimated 181 million users worldwide (United Nations Office on Drugs and Crime, 2013). When administered acutely, the main psychoactive constituent of *Cannabis* (delta-9-tetrahydrocannabinol) can impair emotional face recognition (Bossong et al., 2013) and is associated with changes in task-related BOLD (blood oxygen level dependent) signal (Bossong et al., 2013; Fusar-Poli et al., 2009). Young cannabis users self-report difficulty identifying the feelings of others (Dorard et al., 2008); however, few studies have investigated the long-term effects of cannabis use on emotional processing, using objective measures. Gruber et al. (2009) report a reduction in anterior cingulate and amygdalar BOLD activation in response to affective face stimuli among frequent cannabis users, relative to controls, but find no behavioural differences in the task across the two groups. In contrast, Platt et al. (2010) find evidence for slower emotional recognition in frequent cannabis users, compared to controls, using a dynamic face-morphing paradigm. Platt et al. (2010) conjecture that the deficit seen in chronic cannabis users may be due to elevated schizotypy, which was previously reported in cannabis-using individuals (Bailey and Swallow, 2004; Skosnik et al., 2001) and is associated with emotional processing deficits (Van't Wout et al., 2004); however, they did not take a psychometric measure of schizotypy, leaving this possibility unexplored. Moreover, the cannabis- using group in Platt et al. (2010) were younger and consisted of more male subjects than the control group. Both gender and age contribute to differences in emotional facial affect processing (Gunning-Dixon et al., 2003; Montagne et al., 2005), which offer other alternative explanations for impairments in emotional processing.

The current study aimed to replicate the deficits in emotional processing observed by Platt et al. (2010) in cannabis users, using a static recognition task. Furthermore, it aimed to extend these findings by exploring whether they were reliable among groups that do not differ in demographic variables and whether they were associated with gender, age, depression and/or schizotypy.

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Methods and materials *Design and participants*

Participants were frequent cannabis users (*n* = 25) and non- cannabis using controls (*n* = 34). To be in the study's cannabis user group, candidates were eligible if they used cannabis more than 20 days per month, for the last 6 months prior to testing. Control participants were eligible if they had never smoked cannabis more than twice in any month of their lifetime.

Inclusion criteria for all participants:

(a) Fluent English;
(b) Normal (corrected to normal) colour vision;
(c) Age above 18 years old.

Study exclusion criteria were no self-reported, past nor present, clinically diagnosed:

(a) Mental health problems;
(b) Substance use problems; nor
(c) Learning impairments; and
(d) No self-reported illicit substance use, other than cannabis, more than twice a month (lifetime).

Study participants were instructed to be drug-free for the 24 hours prior to testing and this was verified through self-report. All participants provided written, informed consent and ethical approval was granted by The Graduate School at University College London.

Assessments

Emotional Processing Task. This computer-based task assessed static facial affect recognition.

The faces used were taken from the NimStim Face Stimulus Set (Tottenham et al., 2009) and created with Abrosoft Fantamorph software (version 4.0). We used 2 male and 2 female faces to portray six basic emotions: happiness, sadness, anger, disgust, fearfulness, surprise and neutrality. Faces varied in the intensity of emotion portrayed, between 0% (neutral) and 100%, in 20% increments. Neutral faces always portrayed 100% intensity. Approximately 200 fucidial markers were positioned on the actors' neutral face, around main facial features. Markers were placed onto the actor's emotional expression and then morphed between 0% and 100% of emotional intensity, and the stills were taken at 20% increments (Harmer et al., 2003).

Stimuli were presented in the centre of a white background. Study subjects indicated which emotion the facial expression portrayed, as quickly and as accurately as possible, with no feedback (except on seven practice trials preceding the task). Following the offset of a black fixation cross (250 ms), subjects were presented with a single face for 500 ms and then they pressed a label key corresponding to an emotion. Any response, as long as it was on a labelled key, led to the next stimulus onset. We showed a total of 124 stimuli with four trials performed per intensity. Trials were randomised, with the exception that two faces of one emotion were not shown more than twice in series.

Participants completed self-reported measures of the Severity of Dependence Scale (SDS) (Gossop et al., 1995), Schizotypal Personality Questionnaire (SPQ) (Raine 1991), Spot the Word Task (a measure of premorbid IQ) (Baddeley et al., 1993) and the Beck Depression Inventory (BDI) (Beck et al., 1965). Participants were also given a semi-structured interview about the history of their drug use.

Procedure

First, participants were screened by telephone for inclusion and exclusion criteria. After providing written informed consent participants completed the SDS, a semi-structured interview on their past drug use, emotional processing task, BDI, SPQ and finally, the Spot the Word Task. Participants were paid for their time and debriefed.

Statistical analyses

Data were analysed using the Statistical Package for the Social Sciences (SPSS version 19) (IBM). Chi-square and *t*-tests were implemented to analyse demographics, drug use and psychological well-being. Data pertaining to recent recreational drug use, other than cannabis, related only to those whom reported having tried the drug, having used it more than 1 day per month and had used that drug in the last 30 days. Signal detection analyses were used to analyse emotional processing data, in order to detect differences in subjects' sensitivity to changes in emotional expressions (Snodgrass and Corwin, 1988).

Hit rate was scored as the number of correctly-identified emotions divided by the total number of possible hits. Sensitivity (Pr) and Response bias (Br) were also calculated (non-parametric versions of the more commonly-used indices of d' and C), as parametric data were not normally distributed. As per Snodgrass and Corwin (1988), a correction was applied to correct for zero. Participants' Pr to differences between emotions under conditions of uncertainty is understood as the probability that a stimulus crosses a recognition threshold (Kamboj et al., 2012). Pr is calculated by subtracting the number of false alarms (p(FA)), which constitute selecting an emotion, when it is not that emotion; from the number of hits (p(HIT)), which is selecting an emotion, when it is that emotion. The more sensitive one is to changes in emotional expression, the larger the value of Pr.

Br is calculated as p(FA)/(1-Pr). A higher Br value represents a liberal response; lower values indicates a more conservative approach to selecting an emotional expression.

We conducted separate 7x2 mixed model analyses of variance (ANOVA) on hit rate, Pr and Br with seven emotions (surprise, disgust, sadness, anger, happiness, fear, neutrality) as the within- subjects factors and the group (cannabis and control) as the between-subjects factor. For variables showing significant effects of group, we explored associations with gender, age, schizotypy and depression across the full sample, using Pearson correlations and independent sample *t*-tests. Any significant relationships were added to ANOVA models, as a between-subjects variable or covariates, in order to investigate whether they remained significant when accounting for the existing effects of group, and whether significant group effects were negated when accounting for these variables. When Mauchly's Test of Sphericity was significant, Greenhouse Geisser corrections were used and the degrees of freedom were rounded to the nearest integer. One female cannabis user was excluded, due to a technical failure. In

Table 1. Group means (SD) for participants' demographics and drug use.

	Cannabis users (n = 25)	Controls (n = 34)	T/χ^2 statistic
Age (years)	22.52 (2.57)	22.15 (2.78)	NS
Gender ratio (m:f)	19:6	20:14	NS
BDI-II (total)	4.24 (3.67)	5.12 (5.17)	NS
SPQ (total)	11.88 (10.08)	11.06 (7.33)	NS
Spot the Word (total)	49.21 (7.90)	49.91 (5.09)	NS
Years alcohol used	8.16 (2.61)	6.06 (3.22)	b
Alcohol use (days/month)	10.52 (6.55)	6.83 (5.85)	a
Days since last use of alcohol	3.44 (4.42)	7.17 (12.00)	NS
Tobacco used (n)	22	10	NS
Days since last use of tobacco	1.5 (3.21)	5.6 (8.91)	NS
Cocaine used (n)	4	0	N/A
Days since last use of cocaine	9.25 (4.11)	–	N/A
Ecstasy used (n)	5	2	NS
Days since last use of ecstasy	16.4 (10.78)	2.00 (1.41)	NS
Years cannabis used	7.24 (3.03)	–	–
Cannabis use (days/month)	25.84 (4.18)	–	–
Days since last use of cannabis	1.56 (1.45)	–	–
SDS (total)	4.68 (2.79)	–	–

[a]$p \leq 0.05$. [b]$p \leq 0.01$

BDI-II: Beck Depression Inventory, version 2; m:f: male-to-female ratio; n: number; N/A: not applicable; NS: not statistically significant; SD: standard deviation; SDS: Severity of Dependence Scale; SPQ: Schizotypal Personality Questionnaire.

Table 2. Group means (SD) for hit rate values on the emotional processing task.

	Cannabis users (n = 25)		Controls (n = 34)	
	Hit rate (%)	False alarm rate (%)	Hit rate (%)	False alarm rate (%)
Surprise	76.4 (8.0)	6.93 (2.45)	73.2 (11.9)	5.23 (3.27)
Disgust	40.4 (21.4)	3.70 (3.19)	51.5 (18.6)	3.65 (2.33)
Sadness	60.8 (18.6)	4.15 (2.70)	66.3 (16.5)	3.10 (2.73)
Anger	69.8 (10.4)	8.33 (4.78)	75.2 (9.1)	6.64 (3.55)
Happiness	65.6 (8.1)	.56 (1.16)	71.7 (7.5)	.44 (.76)
Fear	30.4 (17.9)	2.81 (3.35)	38.3 (17.5)	4.14 (3.47)
Neutral	81.0 (20.8)	20.0 (8.25)	90.8 (15.4)	17.2 (4.02)
Total	58.0 (6.72)	46.5 (7.85)	63.6 (6.42)	40.4 (6.43)

each ANOVA model, we excluded participants scoring > 3 standard deviations (SDs) away from the mean for that particular measure.

Results

Participants and demographics

Groups did not differ in age, gender, nor their scores on the BDI, SPQ or Spot the Word task (Table 1). All participants had tried alcohol, apart from one control. Groups did not differ in the days since last alcohol use, but we found that the cannabis group used alcohol for more days per month ($t(57) = 2.27$; $p = .027$) and years ($t(57) = 2.68$; $p = .0\ 10$) than the controls. A total of 10 controls and 22 cannabis users were regular tobacco smokers ($\chi 2(7) = 10.54$; $p = .160$), but groups did not differ on recent tobacco use ($t(10.1) = 1.41$; $p = .188$). Ecstasy was used by 2 controls and 5 cannabis users within the last 30 days: The groups did not differ in the number of days since last use of ecstasy ($t(5) = 1.78$; $p = .135$). A total of 4 cannabis users and 0 controls had used cocaine in the last 30 days. No participants had used speed, ketamine nor heroin in the last 30 days.

Emotional processing task

Hit rate. We found the main effects of emotion ($F(4,202) = 149.75$; $p < .001$) and group ($F(6,53) = 9.90$; $p = .003$) reflected poorer accuracy in cannabis users (Table 2). There was no interaction between emotion and group. Due to the fact that there were only four trials per cell, we did not include the intensity of

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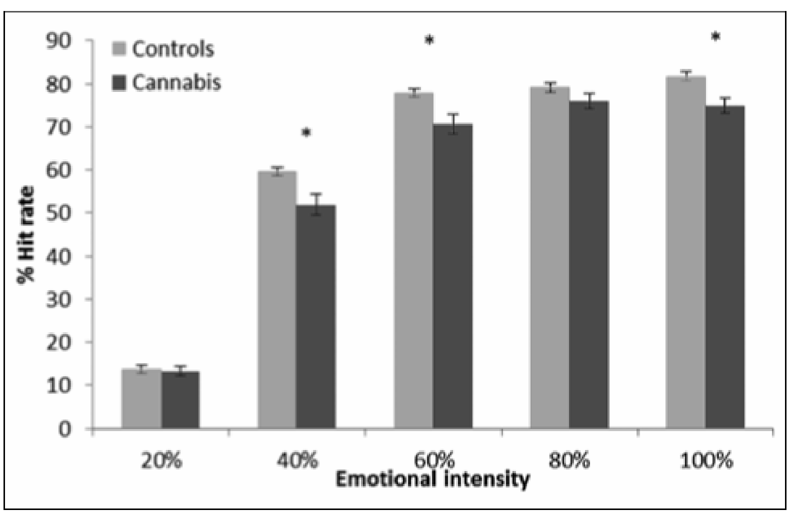

Figure 1. *Group means (± SEM) for percentage hit rate across all emotions, for each intensity, in the emotional processing task. Asterisks show group differences at p < 0.05.*

emotion as a factor; however, exploration of the data suggested that the impairment in cannabis users was driven by their performance at 40%, 60% and 100% intensity ($t(58) = 2.73$; $p = .008$; $t(58) = 2.80$; $p = .007$; and $t(58) = 2.97$; $p = .004$, respectively), as seen in Figure 1.

Sensitivity

The main effects of emotion ($F(4,223) = 63.69$; $p < .00 1$) and group emerged ($F(1,53) = 11.85$; $p = .001$) upon data analysis, indicating lower Pr scores in cannabis users, compared to controls (Figure 2(a)). The emotion by group interaction was not significant.

Response bias

A main effect of emotion was found ($F(3,155) = 117.30$; $p < .001$) but there was no main effect of group nor interaction between emotion and group (Figure 2(b)). The same pattern of results were found when outliers > 3 SD were included in analyses of hit rate and either Pr (4 controls) or Br (1 cannabis user, 2 controls). Moreover, the same patterns of results were found when the neutral faces were excluded from the ANOVA.

Exploratory analyses

We investigated the total hit rate and sensitivity scores for their association with gender, age, schizotypy, depression and alcohol use. We found gender differences for hit rate, with a mean percentage hit rate of 59.18% (± 7.43) in male subjects and 64.60% (± 4.77) in female subjects ($t(53) = 2.87$; $p = .006$). Similarly, an effect of gender emerged for sensitivity, with male subjects scoring 0.54 (± 0.08) and female subjects, 0.59 (± 0.05) ($t(53) = 2.21$; $p = .03 1$). Gender was included as a between-subjects factor, in an ANOVA model comparing hit rate in cannabis users and controls. A significant effect of gender was found ($F(1,51) = 6.24$; $p = .016$), but the main effect of group was still significant ($F(1,51) = 5.21$; $p = .027$), and no interaction between gender and group emerged. Adding gender to the analysis of sensitivity did not indicate that there

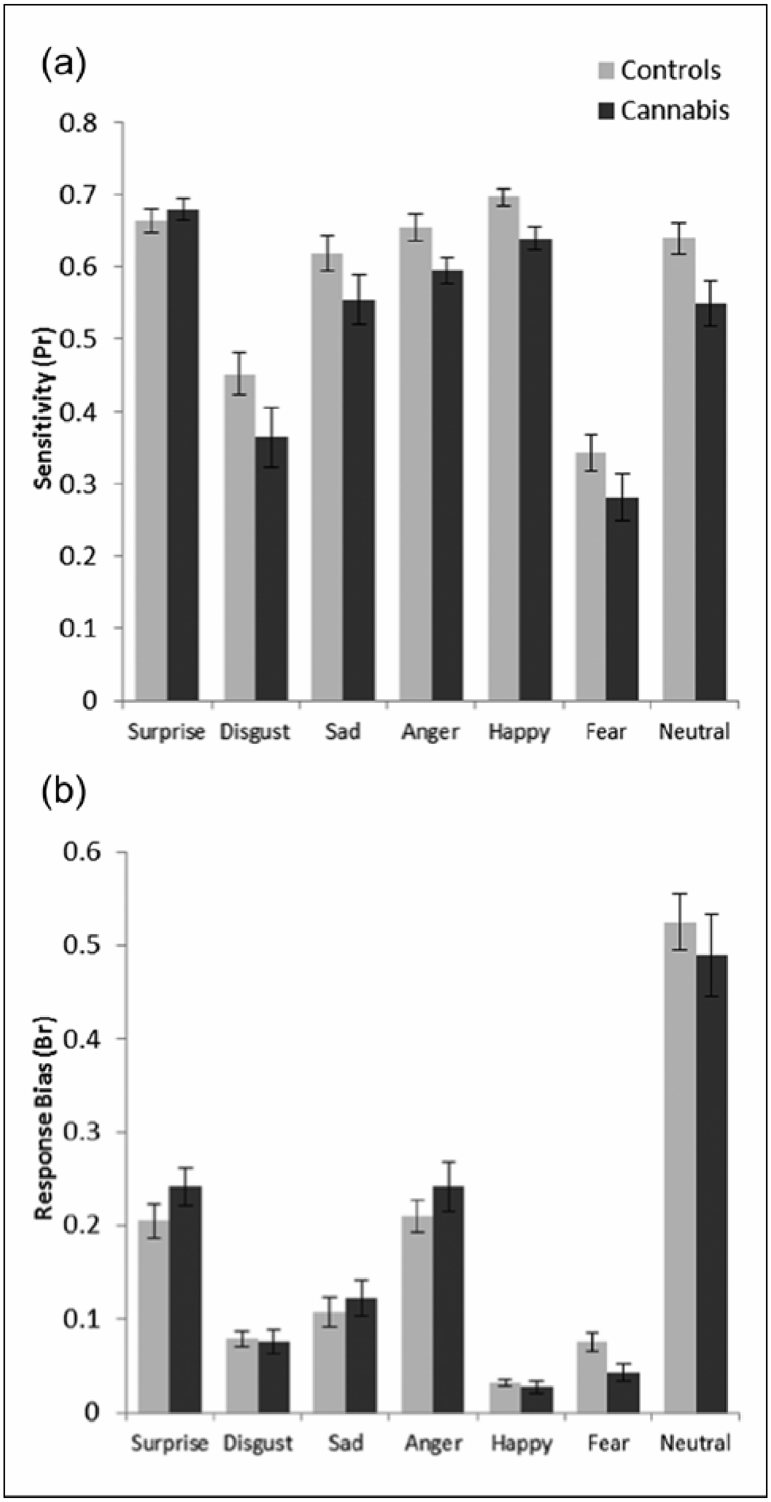

Figure 2. *Group mean (± SEM) for (a) Pr and (b) Br values on the emotional processing task. Br: Response bias; Pr: sensitivity; SEM: standard error of the mean.*

were significant effects of gender, nor a gender by group interaction, but the effect of group remained significant ($F(1,51) = 6.53$; $p = .014$).

SPQ scores were not associated with total hit rate, but had a negative relationship to sensitivity ($r = -0.303$; $p = .023$). When added to an ANOVA comparing cannabis users and controls on sensitivity, the relationship between schizotypy and sensitivity was no longer significant; however, the main effect of group was still evident (F(1,52) = 10.87; p = .002). Both hit rate and sensitivity were not associated with age, BDI scores, nor alcohol use (days per month, years used).

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Correlations within the cannabis group

Days per month, years used, days since last use and SDS scores did not correlate with the percentage hit rate nor sensitivity scores.

Discussion

We aimed to investigate emotional processing deficits, which have previously been observed in cannabis users (Platt et al., 2010) and which suggest that frequent cannabis users show a generalised impairment in recognising human emotional expression. Our results shed further light on this impairment and suggest that this deficit cannot be explained by differences between cannabis users and non-using controls in the areas of age, gender, depression nor schizotypy.

Emotional processing deficits are evident in heavy users of a range of drugs (Goldstein and Volkow, 2011). The long-term effects of cannabis on emotional recognition are largely unknown, but young cannabis users report difficulty in identifying the feelings of others (Dorad et al., 2008) supporting our findings and those of Platt et al. (2010) that suggest these impairments are evident and may compromise interpersonal relationships in these individuals.

Alternative explanations for emotional processing deficits in cannabis users in a previous study were: they were significantly younger and consisted of more males than controls (Platt et al., 2010). Furthermore, these users were not assessed for schizotypy, which is often elevated in cannabis users (Bailey and Swallow, 2004; Skosnik et al., 2001) and is associated with emotional processing deficits (Van't Wout et al., 2004). Our study was able to exclude age, gender, depression and schizotypy as explanations for emotional processing deficits. Although schizotypy was negatively correlated with sensitivity, this effect was not reliable when accounting for group differences on sensitivity. Similarly, our findings of lower sensitivity scores in male subjects were not reliable, when considering effects of group. Interestingly, the effect of gender remained significant and independently predicted accuracy, when accounting for group. As is typically found, the cannabis using group consisted of more males than females. Future studies could investigate the relationship between gender and cannabis use on emotional processing further, by focusing recruitment on female cannabis users.

We found that cannabis users were impaired in the number of emotions correctly identified and the sensitivity to differences between emotions. These differences contrast those of Platt et al. (2010), who found an effect of cannabis use in response bias. This may be due to inherent differences in task design. In this static task, stimuli are shown for 500 ms before a response could be made, precluding speed-accuracy trade off. Speeded reaction times can influence signal detection parameters (Pleskac and Busemeyer, 2010) and are used to index performance on the Dynamic Emotion Expression Recognition task (Platt et al., 2010). Furthermore, Platt et al. (2010) found that cannabis users require a greater intensity of emotion before accurate emotion discrimination and concludes that this is a deficit in the processing of subtle emotions. We showed here that cannabis users were more impaired than controls at recognising emotional faces at 40%, 60% and 100% of emotional intensity. As such, cannabis users seem to be impaired at both relatively ambiguous and unambiguous emotional expressions, which is in contrast to Platt et al. (2010).

Acutely administered tetrahydrocannabinol (THC) is reported to impair discrimination of unambiguous threat faces of 100% emotional intensity (Ballard et al., 2012); therefore, future research should further investigate the role of emotional intensity in the facial affect recognition of cannabis users. In this study, cannabis users were impaired on all emotions except perhaps surprise, in comparison to controls. Although the interaction between emotion and group was not significant, the fact that surprise was apparently protected against impairment in emotional recognition warrants further research.

This study had some limitations. Firstly, cannabis users reported alcohol use for more days per month and years than controls; however, alcohol use was unrelated to emotional processing and our groups were well balanced for age, gender and the Spot the Word Task, an estimate of premorbid verbal intelligence quotient (IQ), and did not differ in depression nor schizotypy scores. Moreover, although this study focused on gender and schizotypy, other factors may have also mediated the relationship between cannabis use and emotional processing, such as anxiety, level of social interaction or loneliness; and further studies should try to identify the roles of related psychopathologies. Secondly, although the cannabis users were instructed to remain abstinent from drugs for at least 24 hours before testing, this was not objectively tested (e.g. in saliva samples) (Morgan et al., 2010), and it is also unclear to what extent these impairments might persist after a longer duration of abstinence (Pope et al., 2001). Thirdly, although we examined the possible associations with demographics and self-reported psychological wellbeing as alternative explanations for these findings, the cross-sectional nature of this study made it difficult to identify the role of cannabis use as a causal predictor of emotional processing deficits.

In summary, our results show that cannabis users displayed a generalised impairment in the ability to recognise and discriminate between emotional faces, and further show that this was not attributable to differences in gender nor schizotypy.

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Conflict of interest

The authors declare that there are no conflict of interest.

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