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RESEARCH ARTICLE

Emotion Recognition and Differentiation in Cannabis Abstainers Over Time: Assessing the Role of Mental Health Problems and Cannabis Withdrawal

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Introduction: Cannabis is the second most widely-used substance in India, after alcohol. Several researches show how cannabis use can impair emotion recognition capacity, but relatively few researchers have explored this among cannabis abstainers.

Aims: The present study's authors aimed at assessing emotion recognition, emotion differentiation, self-reported anxiety, depression, stress, withdrawal intensity and impact in a sample of men who abstain from cannabis.

Methods: Heavy cannabis users (N = 70 males) were assessed via questionnaires regarding their cannabis use frequency, their age at onset of usage, anxiety, depression, and stress levels as well as their performance on computerised tasks of emotion recognition and discrimination within 24 hours of their admission (T0), then after 15 days of abstinence (T1), and finally after 30 days of abstinence (T2). At T1 and T2, they were also assessed for withdrawal intensity and the impact of withdrawal on daily activities.

Results: Findings revealed that, with abstinence, successive improvement in emotion recognition and emotion differentiation developed, even after accounting for declines in psychological distress from T0 to T1. However, from T1 to T2, further declines in psychological distress and withdrawal impact mainly accounted for this improvement. Happiness was the best recognised and well-differentiated emotion while the poorest discrimination was observed for anger.

Conclusions: This study's findings corroborate and significantly add to the limited existing literature, demonstrating improved emotion recognition and differentiation due to initial cannabis abstinence, but later this improvement proceeds with a decline in distress and withdrawal impact.

Keywords: emotion recognition, emotion differentiation, abstinence, cannabis, withdrawal

Introduction

Human beings have long used psychoactive substances for their euphoric and mood-altering properties. In recent times, however, such use has increased manifold, to the point of addiction, leading to several pathologies, both physical and mental. Cannabis is the world's most popular illicit drug (Degenhardt et al., 2013). As per the recent World Drug Report 2018 (UNODC, 2018), nearly 3.9% of the world population in the age range of 15–64 years are current cannabis users (i.e., in the past 12 months). After alcohol, cannabis and opioids are the next commonly used substances in India. About 2.8% of the population (31 million individuals) in the age group of 10–75 years reports having used any cannabis product within the previous year (Ambekar et al., 2019).

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Cannabis use has a high rate of comorbidity with affective disorders that often emerge during adolescence and young adulthood (Wittchen et al., 2007). However, despite several previous studies examining whether cannabis use increases the risk of anxiety or depression, or whether cannabis use is more common in these conditions, results are inconclusive (National Academies of Sciences, Engineering, and Medicine, 2017). Some researchers have found that cannabis use, particularly heavy use, may increase the risk of subsequent depression (e.g., see review by Gobbi et al., 2019), while others have been unable to draw any firm conclusions (e.g., see review by Botsford et al., 2020). A high risk for cannabis use disorders has been suggested to influence the risk for the development of a major depressive disorder (Smolkina et al., 2017). On the other hand, a repeated cross-sectional study of 16,216 US adults (Gorfinkel et al., 2020) showed that those with depression increased their rates of cannabis use significantly faster than those without depression. Likewise, studies examining the relationship between cannabis use and anxiety show mixed results. Kedzior & Laeber (2014) found in their meta-analysis that cannabis use might increase anxiety risk. Another meta-analysis by Twomey (2017) noted it as a minor risk factor. However, the review by Botsford et al. (2020) found no link between cannabis use and anxiety, while Keatley et al. (2020) and Wittchen et al. (2007) showed anxiety often precedes cannabis use.

A possible mechanism underlying psychiatric comorbidities and mood symptoms in young cannabis users is abnormalities in the affective neural network, resulting in deficits in affective processing (Maple et al., 2019). One commonality of many disorders (including anxiety, depression, bipolar disorder, and psychosis) comorbid with cannabis use is a deficit in facial emotion processing (Bourke et al., 2010; Mogg et al., 2000; Morris et al., 2009), which serves as a critical aspect of functioning in human social networks (Phillips et al., 2003). Previous studies have shown reciprocal relationships between emotion recognition and mental health. While studies show poorer emotion recognition to be associated with anxiety (Easter et al., 2005; Demenescu et al., 2010; Pereira-Lima & Loureiro, 2015), depression (Demenescu et al., 2010; Pereira-Lima & Loureiro, 2015), and stress (Hänggi, 2004), studies also exist showing that these mental health difficulties may result in poor emotion recognition. For instance, by experimentally manipulating state anxiety in a controlled setting, Dyer et al. (2022) recently showed it to be associated with poor facial emotion recognition. Anxiety results in poor emotion recognition, particularly regarding angry faces (Jarros et al., 2012). A meta-analysis by Dalili et al. (2014) noted that depression is linked with a poor recognition of all the basic emotions, except sadness. Another recent meta-analysis found broad deficits in facial emotion recognition among patients with unipolar depression (Krause et al., 2021). Similarly, individuals with stress disorders, such as PTSD, are impaired at recognising facial emotions (Passardi et al., 2019). These findings indicate that anxiety, depression, and stress are strongly correlated with facial emotion recognition.

There is increasing evidence that drugs of abuse alter the processing of emotional information in ways that could be attractive to users. For instance, an investigation shows that tetrahydrocannabinol (THC) reduces the activation of the amygdala in response to threat-related faces, suggesting that THC may modify the salience of emotional stimuli, particularly negative or threatening stimuli (Ballard et al., 2012). This study reported that THC significantly impaired the recognition of facial fear and anger, and marginally impaired the recognition of sadness and happiness, but had no impact on affect ratings of emotional scenes. In another study, comparing the emotion recognition performance of cannabis users to controls, it was seen that cannabis users were slower in recognising the emotions of anger, happiness, and sadness compared to controls and also required more intensity of emotional information for recognition (Platt et al., 2010). A study examining performance during the matching of stimuli with a negative or a positive content indicated that after THC administration, performance accuracy decreased for stimuli with a negative but not for stimuli with a positive emotional content (Bossong et al., 2013). However, studies probing the importance of emotion intensity have yielded mixed findings. One study concluded that cannabis users had greater difficulty identifying more subtle emotions (Platt et al., 2010), while another reported that cannabis users were less accurate than controls only in recognizing more overt, unambiguous emotions (Hindocha et al., 2015). Yet another study found emotion recognition deficits only in more frequent and recent cannabis users (Huijbregts et al., 2014). A recent study (Cservenka & Donahue, 2024) states that young adults who frequently binge drink and use cannabis reported more socio-emotional difficulties and alexithymia symptoms compared to healthy controls, but showed no difference in emotion recognition accuracy.

Previous research on other substance use disorders has also reported facial emotion-processing deficits. For instance, Le Berre (2019) in their review notes that compared to healthy people, people with alcohol use disorder (AUD) have consistently demonstrated misinterpretations of simple and complex facial expressions or exaggerated estimations of emotional intensity in another's facial emotions (Castellano et al., 2015; D'Hondt et al., 2014; Donadon & de Lima Osorio, 2014; Erol et al., 2017; Marinkovic et al., 2009; Maurage, Campanella, Philippot, Martin, & De Timary, 2008; Maurage, Campanella, Philippot, Vermeulen, et al., 2008; Maurage et al., 2011). Along similar lines, two meta-analyses (Bora & Zorlu, 2017; Castellano et al., 2015) reported a significant facial emotion recognition deficit existing among people with AUD, who find it particularly difficult to understand and interpret the emotions of anger and disgust. Among early abstinent AUD patients, it has been observed that while the recognition of happiness remains somewhat unaffected (Bora & Zorlu, 2017), they tend to identify emotions in neutral faces (Kornreich et al., 2013; Kornreich et al., 2016; Philippot et al., 1999). Similar findings are expected concerning abstinent cannabis users.

A surge of research interest can also be seen regarding abstinent cannabis users. For instance, a recent study indicated that depressive symptoms and cannabis use-related problems are generally indicative of cannabis withdrawal severity, whereas craving specifically predicted cannabis withdrawal during abstinence (Cousijn & Van Duijvenvoorde, 2018). Cannabis use has also been associated with abnormal facial emotion processing. According to the study of Bayrakçı et al. (2015), cannabis abstainers are less accurate in recognizing and discriminating between emotions. In this study, abstinent cannabis-dependent patients performed significantly worse than controls in the identification of negative facial emotions, but not positive emotions, even after an average abstinence period of 3.2 months.

Given the presence of mixed findings in the literature concerning emotional disorders, such as anxiety and depression associated with cannabis use, their interaction necessitates a further exploration. Further, except for Bayrakçı et al. (2015), emotional processing deficits (such as visual emotion recognition and discrimination) as manifested among abstinent users of cannabis have not been explored. An exploration of anxiety, depression, and stress among such abstainers is also lacking. A gap in the previous studies consists also in that the visual stimuli used in these studies were static in nature, which is less ecologically valid than dynamic stimuli (Dobs et al., 2018). Moreover, in contrast to the more manufactured appearance of fixed faces, dynamic facial cues can communicate a wide range of genuine emotions (Cohn & Schmidt, 2004; Kaulard et al., 2012).

Apart from the above-mentioned gaps in the literature and lack of a comprehensive and sufficient number of studies, it still needs to be seen how changes in the levels of anxiety, depression, stress and emotional processing occur with a gradual increase in the number of days into abstinence from cannabis. Sudden cessation of cannabis consumption can cause withdrawal symptoms that can last up to three weeks or even more in heavy cannabis users (Connor et al., 2021). It would also be interesting to explore how these changes in abstinent users are associated with the intensity and impact of withdrawal symptoms, which set in as abstinence from cannabis progresses. Findings from such explorations would meaningfully contribute to our understanding regarding the emotional difficulties of cannabis abstainers.

Based on the said gaps, the present study aimed at assessing differences in emotion recognition and emotion differentiation among a sample of cannabis abstainers with a history of high cannabis use. The study also explored differences in the levels of self-reported anxiety, depression, and stress among the abstainers as well as the intensity and impact of withdrawal symptoms among them. It was also of interest to see how changes in the perceived levels of anxiety, depression, stress, and/or withdrawal symptoms accounted for variations in emotion recognition and emotion differentiation with an increasing number of days into abstinence. It was hypothesised that the levels of anxiety, depression, stress, and withdrawal symptoms would all decline with the progress of abstinence and these would account for the improvement in emotion recognition and emotion differentiation among cannabis abstainers over time. It was also hypothesised that cannabis abstinence would, in itself, significantly contribute to better emotion recognition and differentiation in addition to improving anxiety, depression, stress, and withdrawal symptoms.

Methods

Participants

The required sample size for conducting a repeated-measures ANOVA was calculated using power analysis. The power analysis calculation using a power of .95, an alpha of .05, and an effect size of .20, the number of groups = 1, and the number of repeated measurements = 3, and correlations among repeated measures equalling .70 revealed a desired total sample size of 41. Therefore, a minimum sample size of about 60–70 was targeted for the recruitment of male participants in the age range of 18 to 60 years to accommodate for missing data or participant attrition across the three time points of assessment. Only male participants were targeted for recruitment, since as per the National Drug Dependence Treatment Center, AIIMS, New Delhi, the prevalence of cannabis use among men in India stands at 5.0% while among women, it stands at only 0.6% (Ambekar et al., 2019). Information on participants' educational attainment (in number of years), their age, and their socio-economic status (assessed using the modified B. G. Prasad socioeconomic scale 2022 for India; Sood et al., 2023) was collected.

Table 1. The Participants' Demographic and Cannabis Use-Related Information

Sample Characteristics (*N* = 70 males)		Range	M *(SD)*
Age (in Years)		18–58	27.39 (8.54)
Years of Education		7–24	13.50 (2.73)
SES in INR*		2666.67–150000	24270.23 (25188.30)
CAST score		7–21	12.60 (3.67)
Age of Onset of Cannabis Use		13–43	21.67 (6.43)
Cannabis (Marijuana) Use Quantity (in Grams)	In a typical session	0.13–5.00	1.54 (1.08)
	On a typical day	0.13–7.00	2.68 (1.72)
	In a typical week	0.25–30.00	11.36 (8.36)
		Frequency	
Form of Cannabis Use	Marijuana	100%	
Cannabis Use Frequency	Once a week	1.4%	
	3–4 times/week	2.9%	
	5–6 times/week	22.9%	
	Once a day	40.0%	
	More than once a day	32.9%	

Note. INR= Indian National Rupee; CAST= Cannabis Abuse Screening Test.
*All the participants belonged to middle, upper-middle, or upper class as per the modified B.G. Prasad classification for India [per capita income in the range 2460-4155 INR= middle class; in the range 4156-8396 INR= upper-middle class; per capita income ≥ 8397 INR= upper class].

Participants were excluded if they had any current or past diagnosis of a mental disorder, used any other drug (except cannabis), had any physical disease, impaired vision or hearing using a Medical Self-Report Form (created for this study) that the participants filled before their screening. Only participants scoring 7 or above on the Cannabis Abuse Screening Test (CAST) were included in the study. Since all the measures used were in English, only participants having a good proficiency of the English language were included.

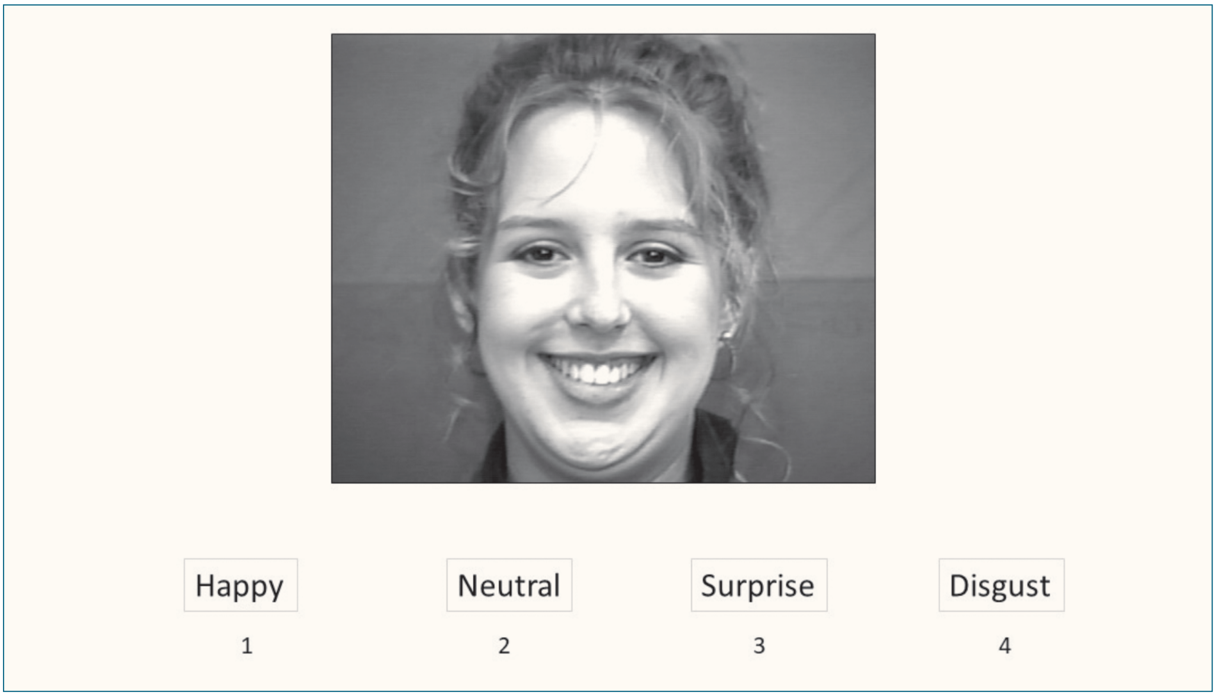
The final sample comprised 70 male participants. Initially, 72 participants consented to participating in the study. However, two participants left the Centre, and consequently the study, after two days and eight days of admission due to financial crisis and not being able to afford the treatment fee. These two participants' data from time T0 were discarded. Descriptive information on the sociodemographic and cannabis use characteristics of the participants is presented in Table 1.

Measures

Performance Measures

The Dynamic Visual Emotion Recognition Task. In the visual explicit emotion recognition task (based on Shukla et al., 2019); Figure 1, full-face videos displaying different emotions were presented in the upper centre of the computer screen with four response options (out of the six basic emotions of Happiness, Sadness, Fear, Anger, Surprise, and Disgust) given below. One of the labels was the correct response option denoting the emotion expressed in the facial video while the remaining three were distractor labels. The videos were developed using facial emotion photographs from the Cohn–Kanade AU-Coded Facial Expression Database (see Kanade et al., 2000; Lucey et al., 2010). There were altogether 24 trials (two male and two female faces displaying each of the six basic emotions). Accuracy and response time (RT) were calculated as indices of dynamic visual emotion recognition. Accuracy was quantified as percentage of completion, from 0 to 100%.

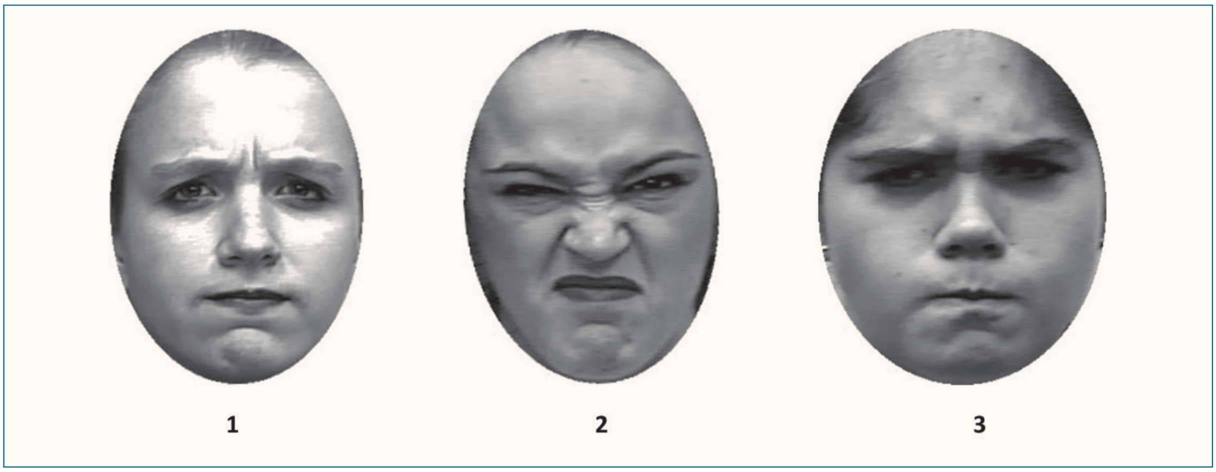
Figure 1. Diagrammatic Representation of the Dynamic Visual Emotion Recognition Task (Images © Jeffrey Cohn)



Note. Example photograph permitted for publication based on the database user agreement.

The Dynamic Visual Emotion Discrimination Task. In the dynamic visual emotion discrimination task, inspired by the "emotional odd-man-out" task developed by Herzmann et al. (2008), each target emotional face video (also developed using photographs from the Cohn–Kanade AU-Coded Facial Expression Database) was placed in a triad with two other facial videos displaying another expression with which it is commonly confused (e.g., a disgusted target face was paired with two angry distractor faces, see Figure 2, and participants were asked to indicate which face displayed the discrepant emotion by pressing the number (1, 2, or 3) corresponding to their response choice using the keyboard. This task presented 144 trials (24 trials: 12 male and 12 female faces; for each emotion category). Participants were given a five-minutes rest pause after 72 trials. The accuracy on the task formed the index of emotion discrimination or emotion differentiation (used interchangeably), which could range from 0–100%. RT was not used as a measure of emotion differentiation on this task as our pilot study on cannabis abstainers (*N* = 16) indicated ceiling effects (i.e., very low RTs ranging between 1.5–4 seconds) on this task, which did not show significant effects in any analysis. Thus, RT was not found to be a meaningful dependent measure for the present study.

Figure 2. Diagrammatic Representation of the Dynamic Visual Emotion Discrimination Task (Images © Jeffrey Cohn)



Note. Example photograph permitted for publication based on the database user agreement.

Self-Report Measures

The Cannabis Abuse Screening Test (CAST). The CAST, developed and validated by Legleye et al. (2007), identifies high risk of cannabis use. It has been validated using DSM-IV cannabis dependence and cannabis use disorders criteria, and has been widely used since. CAST consists of six questions related to the frequency, the degree of dependence, and the consequences of cannabis use. One question asks participants whether they have used cannabis in the last 12 months. If the response is affirmative, they are required to respond to six more questions reflecting back on their last 12 months, the responses to which range from 0 ("Never") to 4 ("Very often"). The overall score is obtained by adding up the scores on the six questions. The scores can range from 0 to 24. An overall score of 0–2 indicates low risk for cannabis abuse; a score of 3–6 indicates moderate risk of abuse; while an overall score of 7 or more is indicative of a high risk of cannabis abuse. Cronbach's alpha reliability of this scale on the present sample was $\alpha = .71$. In this study, CAST was only used to screen for high-risk cannabis users, thereby including those who were at high risk based on a score greater than 7.

The Cannabis Withdrawal Scale (CWS). The CWS (Allsop et al., 2011), comprising 19 items, was used to assess cannabis withdrawal intensity as well as the impact of cannabis withdrawal symptoms on normal daily functioning in the past 24 hours. This scale uses a 10-point Likert-type scale (ranging from 0 = "Not at all" to 10 = "Extremely") for assessing the intensity of the withdrawal symptoms. Respondents are also required to supply a number between 0–10 (using the same scale as for intensity) indicating the magnitude of negative effect that the withdrawal symptoms had on normal daily activities. Both for withdrawal intensity and the negative impact of withdrawal, the minimum and maximum obtainable scores are 0 and 190, respectively. In the present sample, the internal-consistency reliabilities (Cronbach's alpha) of withdrawal intensity at T1 and T2 were $\alpha = .83$ and $\alpha = .77$, respectively, and that of withdrawal impact were $\alpha = .92$ and $\alpha = .92$, respectively.

Daily Sessions, Frequency, Age of Onset, and Quantity of Cannabis Use Inventory (DFAQ-CU). The DFAQ-CU (Cuttler & Spradlin, 2017), among other things, measures average frequency of cannabis usage, the form in which cannabis is used, age of onset, etc. The 33 items/questions on this inventory are distributed across six factors: Daily Sessions Items (Items 20, 25), Frequency Items (Items 2, 3, 6, 7, 8, 9, 10, 11, 12), Age of Onset Items (Items 30, 31b, 31c, 32), Marijuana Quantity Items (Items 17, 18, 19), Concentrate Quantity Items (Items 22, 23, 24), and Edibles Quantity Item (Item 27). The Cronbach's alpha coefficients for the factors range from .69 (Daily Sessions) to .95 (Frequency). The factors have been reported to show convergent, predictive, and discriminant validity (Cuttler & Spradlin, 2017). Item 16 of DFAQ-CU asks participants the form of cannabis that they use regularly, with the options of None, Marijuana, Concentrates (e.g., Oil, Wax, Shatter, Butane Oil, Dabs), Edibles, and Other. Which items they answer next stands dependent upon their response to this item. Since all the participants used cannabis in the form of marijuana only, in addition to answering Items 1–16, they answered 17–21 (items 22–26 were to be answered in case of using Concentrates, and Item 27 was to be answered if one used Edibles) and then Items 28–32. Thus, data is not available for Concentrate Quantity Items (Items 22, 23, 24), and Edibles Quantity Item (Item 27). Cronbach's alphas for the Daily Sessions Items (Items 20, 25) factor could not be calculated as data for Item 25 was missing (which was to be answered only if participants used Concentrates). The internal consistency for the remaining three factors used in the study, i.e., Frequency Items, Age of Onset Items, and Marijuana Quantity Items, were found to be $\alpha = .70$, .76, and .85, respectively.

The Anxiety, Depression and Stress Scale (ADSS). The ADSS (Bhatnagar et al., 2011) contains 48 items assessing anxiety (19 items), depression (15 items), and stress (14 items). It measures seven factors: (1) Physical symptoms, (2) Apprehension, (3) Dryness of mouth (in the anxiety subscale) (4) Inertia-loss of interest and worth (5) Poor emotional control (in the depression subscale) (6) Emotional arousal, and (7) Negative life events (in stress subscale). However, for this study, we used only the total scores of anxiety, depression, and stress. Participants endorse each item as "Yes" (scored 1) or "No" (scored 0). The range of obtainable scores is 0–19 for anxiety, 0–15 for depression, and 0–14 for stress. This scale has a Cronbach's alpha reliability of 0.81 and a Spearman-Brown reliability of 0.89. It has item-total correlations of 0.60, 0.61, and 0.55, for anxiety, depression, and stress, respectively (Bhatnagar et al., 2011). In the present sample, the internal-consistency reliabilities of anxiety at T0, T1, and T2 were $\alpha = .66$, .78, and .86, respectively, that of depression were $\alpha = .84$, .75, and .85, respectively, and that of stress were $\alpha = .73$, .84, and .86, respectively.

Procedure

The Institutional Ethics Committee of Magadh University, Bodh Gaya, Bihar, India (Ref No.: Psy/19/23) approved this study's protocol and procedures. A within-group research design was used to test the hypotheses framed for the present study. To explore the said changes, participants (cannabis abstainers) were assessed at three time points: T0 = Within a few hours of admission to the drug rehabilitation centre (Hitaishi Happiness Home, Patna, Bihar) for rehabilitation and recovery; T1 = After 15 days of abstinence from cannabis while still admitted in the medical facility; and T2 = After 30 days of abstinence from cannabis while still admitted in the medical facility.

The drug rehabilitation centre from where the participants were recruited had a 30-day rehabilitation programme. This was because inpatient detoxification programmes for heavy cannabis users are recommended to last at least 21 days, since cannabis withdrawal syndrome itself lasts between 14–21 days (Bonnet et al., 2014; Bonnet et al., 2016; Budney et al., 2003 Budney & Hughes, 2006). The drug rehabilitation centre further kept the patients under observation for the next nine days, during which further counselling and discussions about life after discharge from the centre also took place, including relapse prevention and availability of help from the centre in such cases.

The time gap of 15 days between two successive assessments of the participants was chosen based on prior research recommendations. For instance, Nunnally & Bernstein (1994) advise that a gap of two weeks to a month should be maintained between the initial test and its subsequent retest to reduce the influence of memory recall. Research indicates that the ideal time span between tests may differ based on the specific construct being studied, its consistency over time, and the characteristics of the target population. However, a two-week interval is most -commonly recommended (Dutil et al., 2017; Streiner at al., 2014). Given these reasons, three equally spaced (15-day) assessments of the participants were planned.

Cannabis users admitting themselves to the drug rehabilitation centre and in the age range of 18–60 years were given an Information Sheet detailing the study on the day of their admission as well as a Medical Report Form (to screen for comorbidities and consumption of other drugs, such as alcohol) to fill and hand over/return should they be interested in participating in the study. This was done after the necessary formalities related to their admission to the rehabilitation centre were completed. It was ensured that the participants understood that denying participation would have no repercussions for them and they would be treated no differently than those admitted participants who consent to take part. If the participants agreed to participate, they were presented with an informed consent form and were requested to read and sign it. The CAST was administered to identify and select for participation those with high levels of cannabis use (score of ≥7). After admission to the said rehabilitation centre, cannabis users were helped to deal with their withdrawal symptoms through counselling and some analgesics and/or paracetamol to counter symptoms of pain and fever, without any other form of medication being administered. They were discharged from the centre after a month of staying there. Thus, the participants were administered the ADSS and the DFAQ-CU on the very first day of their admission into the facility to ascertain their current levels of anxiety, depression, and stress, as well as other relevant information related to their cannabis usage, respectively, before the withdrawal symptoms set in. Following this, both the performance-based measures, viz., The Dynamic Visual Emotion Discrimination Task, and The Dynamic Visual Emotion Recognition Task were administered. The sequence of presentation regarding the two tasks was reversed for half the participants. Before the actual task performance, the participants were given a short practice session on each of the tasks. Participants were allowed rest pauses of 5–15 minutes (as required by them) between tasks.

After a period of two weeks, during which they were on total abstinence from cannabis, the participants were again assessed using the ADSS and the two performance tasks, after being administered the CWS to assess the intensity of withdrawal symptoms and their impact on participants' daily-life activities. The same procedure was repeated again after a further period of two weeks, when the ADSS and the CWS as well as the performance-based measures were administered. After the third assessment, the participants were debriefed regarding the purpose of the study and thanked for their participation.

Statistical Analyses

Bivariate (Pearson's product-moment) correlations were calculated among the examined variables (frequency and quantity of cannabis use, age of onset of cannabis use; anxiety, depression, stress, emotion recognition, and emotion differentiation at T0, T1, and T2; with withdrawal intensity and withdrawal impact at T1 and T2). For comparing levels of anxiety, depression, stress, intensity and impact of withdrawal symptoms over time, as well as for the accuracy and RT on the two tasks, Repeated-Measures ANOVAs were conducted for each variable separately followed by repeated contrast analyses to compare T0 with T1 and T1 with T2. In order to gauge the impact of abstinence from cannabis alone in the change in emotion recognition and differentiation from T0 to T1 and from T1 to T2, repeated-measures ANCOVAs were conducted separately, once with T0 and T1 and again with T1 and T2 scores of emotion recognition and differentiation. As covariates, the difference in scores of anxiety, depression, and stress from T0 to T1 were entered in the first analyses, and the difference scores of anxiety, depression, and stress from T1 to T2 were entered as covariates in the second analysis. Additionally, difference scores of withdrawal intensity and withdrawal impact from T1 to T2 (as withdrawal was measured only at T1 and T2 and not at T0: the time of admission to the rehabilitation facility) were also controlled for in the second analysis. Lastly, using repeated-measures ANCOVA (controlling for covariates as above), it was also explored how emotion recognition and differentiation varied across the time points for each of the six basic emotions. Repeated contrast analyses were used in ANOVA/ANCOVA analyses. The assumptions for all the statistical tests applied were checked for and found to be met.

Results

Results from the bivariate correlations revealed significant negative correlations of cannabis use frequency with accuracy of emotion recognition at T2 (r = -.32, p = .041) and a significant positive correlation with stress at T2 (r = .40, p = .010) (see Appendix Table 1). Quantity of cannabis use showed a significant relationship only with depression at T0 (r = .44, p = .005). Age of onset of cannabis use did not show any significant correlation with any outcome measure of psychological distress (anxiety, depression, and stress), withdrawal symptoms (intensity and impact), or scores on performance measures (accuracy and RT of emotion recognition and accuracy of emotion differentiation). For more correlations among the variables in this study, see Appendix Table 1.

Pearson's correlations of anxiety, depression, and stress were positive and significant in terms of emotion recognition and emotion differentiation at different time-points (see Appendix Table 1). Since this was contrary to expectations, quadratic associations of the said variables were also explored and found to be significant for the same pairs of variables for which linear associations were held.

Results of the repeated-measures ANOVA to explore differences in emotion recognition across the three time-points (T0, T1, T2) revealed a significant effect of time-since-abstinence on the accuracy of emotion recognition, F (2, 136) = 19.48, p < .001, η_p^2 = .225, such that the mean accuracy of emotion recognition increased significantly from T0 to T1 (p < .001) and from T1 to T2 (p = .008; see Table 2 for means). These differences across time were not significant for the time taken (RT) in the correct recognition of emotions, F (2, 136) = 2.91, p = .058, η_p^2 = .043. Similar abstinence-duration-related improvements as for emotion recognition were observed in emotion discrimination among cannabis abstainers, F (2, 136) = 32.43, p < .001, η_p^2 = .333, from T0 to T1 (p = .002) and T1 to T2 (p < .001) (see Table 2 for means).

Table 2. Participants' Mean Scores on Performance and Self-Report Measures Across the Three Time Points

		Cannabis abstinence duration		
		M *(SD)*		
Variable	Parameter	T0	T1	T2
Emotion Recognition	Accuracy[a]	31.96 (11.17)	39.95 (19.80)	45.65 (21.88)
	Response time[b]	8.80 (8.19)	4.41 (3.74)	5.10 (4.76)
Emotion Discrimination	Accuracy[a]	65.25 (19.37)	71.82 (15.33)	81.13 (11.11)
Mental Health Problems	Anxiety	8.97 (3.27)	7.97 (3.84)	3.00 (3.58)
	Depression	11.57 (3.37)	11.36 (2.89)	3.51 (3.48)
	Stress	10.56 (2.76)	10.44 (3.34)	4.13 (3.68)
Cannabis Withdrawal	Withdrawal intensity	–	4.21 (1.04)	1.27 (0.94)
	Withdrawal impact	–	3.14 (0.94)	0.82 (0.80)

Note. T0 = 0 days into abstinence; T1 = 15 days into abstinence; T2 = 30 days into abstinence.
[a] In percentage. [b] In seconds.

Repeated-measures ANOVA exploring the differences in self-reported anxiety across the three time-points revealed a significant effect of time-since-abstinence on anxiety, $F\,(2, 138) = 102.79$, $p < .001$, $\eta_p^2 = .598$, such that the mean anxiety scores decreased significantly from T0 to T1 ($p = .014$) and from T1 to T2 ($p < .001$; see Table 2 for means). This pattern, however, did not hold for levels of depression, $F\,(2, 138) = 186.08$, $p < .001$, $\eta_p^2 = .729$; and stress, $F\,(2, 138) = 131.04$, $p < .001$, $\eta_p^2 = .655$), where significant decline was noted from T1 to T2 only (both *p*s < .001) and not from T0 to T1 ($p = .579$ and .735, respectively).

In order to understand the contribution of abstinence from cannabis to improving emotion recognition and discrimination, two separate repeated-measures ANCOVAs were conducted considering two time-points at a time (T0 & T1 and T1 & T2) and controlling for the difference in anxiety, depression, and stress from T0 to T1, as well as for the difference in anxiety, depression, stress, withdrawal intensity, and withdrawal impact from T1 to T2 (see Table 3). From T0 to T1, findings revealed that even after controlling for the change in anxiety, depression, and stress (even though this decline was not significant for depression and stress), a significant improvement in visual emotion recognition occurred, $F\,(1, 64) = 18.75$, $p < .001$, $\eta_p^2 = .227$. However, from T1 to T2, findings indicated that after controlling for the difference in anxiety, depression, stress, and withdrawal intensity and impact, the difference between the accuracy of emotion recognition from T1 to T2 turned non-significant, $F\,(1, 62) = 2.24$, $p = .140$, $\eta_p^2 = .035$. It was observed that stress, and withdrawal intensity and impact did not affect the change in emotion recognition significantly, $p = .605$, .097, and .117, respectively, and the decline in anxiety and depression ($p = .025$ and $p = .002$, respectively) primarily accounted for the improvement in visual emotion recognition from T1 to T2.

Table 3. Results of Repeated-Measures ANCOVA for the Accuracy of Emotion Recognition and Emotion Differentiation After Controlling for the Change in Anxiety, Depression, Stress, Withdrawal Intensity and Withdrawal Impact

	Accuracy of Emotion Recognition					
	T0 to T1			T1 to T2		
Variables	$F\,(1, 64)$	p	η_p^2	$F\,(1, 62)$	p	η_p^2
Time	18.75	**<.001**	.227	2.24[a]	.140	.035
Anxiety	14.40	**<.001**	.184	5.25	**.025**	.079
Depression	.91	.344	.014	10.69	**.002**	.149
Stress	.16	.688	.003	.21	.605	.003
Withdrawal Intensity	–	–	–	2.84	.097	.045
Withdrawal Impact	–	–	–	2.53	.117	.040
	Accuracy of Emotion Differentiation					
	T0 to T1			T1 to T2		
Variables	$F\,(1, 64)$	p	η_p^2	$F\,(1, 59)$	p	η_p^2
Time	8.98	**.004**	.126	.82[b]	.369	.014
Anxiety	5.72	**.020**	.084	2.48	.121	.040
Depression	.03	.861	<.001	1.83	.181	.030
Stress	1.16	.286	.018	.05	.818	.001
Withdrawal Intensity	–	–	–	.00	.962	<.001
Withdrawal Impact	–	–	–	.62	.436	.010

Note. T0 = 0 days into abstinence; T1 = 15 days into abstinence; T2 = 30 days into abstinence.
Values in BOLD are statistically significant.
[a] Significant [F (1, 67) = 7.53, p = .008] before controlling for covariates.
[b] Significant [F (1, 65) = 35.04, p < .001] before controlling for covariates.

Similar analyses for emotion differentiation revealed that from T0 to T1, increase in emotion recognition accuracy occurred above and beyond the effect of decrease in anxiety, depression, and stress levels from T0 to T1, F (1, 64) = 8.98, p =.004, η_p^2 = .126, of which it was only the decline in anxiety that significantly affected the improvement in emotion differentiation, p = .020 (see Table 3). From T1 to T2, however, the improvement in emotion differentiation was not due to abstinence, F (1, 59) = .82, p = .369, η_p^2 = .014, and was accounted for by the combined effect of change in anxiety, depression, stress, withdrawal intensity, and withdrawal impact.

Emotion-wise analyses showed that the best recognised emotions were happiness and anger and the most poorly recognised ones were sadness, surprise, and fear at all the time points (see Table 4 for means). The recognition of fear and disgust increased significantly with increase in abstinence duration from T0 to T1, while for surprise and sadness, it increased consistently over time; i.e., from T0 to T1 and then from T1 to T2. Increases in recognising other emotions over time were not significant (see Table 4).

With respect to emotion differentiation, the best accuracy of differentiation was noted for surprise, followed by happiness and fear (see Table 4 for means). The poorest discrimination was observed for anger and disgust for all the time points of assessment (Table 4). With increase in abstinence, the differentiation accuracy for happiness, sadness, surprise, and disgust increased significantly from T0 to T1, but not from T1 to T2. Increases in differentiating other emotions over time were not significant (see Table 4).

Table 4. Results of Repeated-Measures ANOVA Comparing Emotion-Wise Mean Emotion Recognition and Emotion Differentiation Scores Across the Three Time Points

	Accuracy of Emotion Recognition			Comparison of Mean Difference Across Successive Time-Points							
Emotions	T0 Mean (*SD*)	T1 Mean (*SD*)	T2 Mean (*SD*)	T0-T1	F (1,64)	*p*	η_p^2	T1-T2	F (1,64)	*p*	η_p^2
Happiness	55.36 (19.92)	59.56 (28.66)	65.00 (23.85)	-4.20	3.16	.080	.047	-5.44	1.12	.295	.018
Sadness	9.64 (8.70)	19.48 (19.24)	25.36 (15.22)	-9.84	9.69	**.003**	.132	-5.88	4.74	**.033**	.072
Fear	26.07 (17.77)	34.19 (22.40)	36.43 (23.96)	-8.12	5.81	**.019**	.083	-2.24	0.26	.609	.004
Anger	47.50 (31.61)	51.83 (34.37)	64.64 (31.42)	-4.33	1.32	.255	.020	-12.81	0.02	.890	<.001
Surprise	21.07 (18.37)	33.82 (32.26)	40.71 (38.35)	-12.75	16.16	**<.001**	.202	-6.89	6.20	**.016**	.092
Disgust	32.14 (19.10)	40.81 (20.22)	41.78 (19.84)	-8.67	9.13	**.004**	.125	-0.97	0.82	.369	.013
	Accuracy of Emotion Differentiation			**Comparison of Mean Difference Across Successive Time-Points**							
Emotions	T0 Mean (*SD*)	T1 Mean (*SD*)	T2 Mean (*SD*)	T0-T1	F (1,63)	*p*	η_p^2	T1-T2	F (1,63)	*p*	η_p^2
Happiness	69.40 (21.85)	76.37 (18.81)	86.07 (9.83)	-6.97	7.32	**.009**	.104	-9.70	0.38	.541	.006
Sadness	63.15 (22.51)	68.53 (22.19)	80.53 (17.11)	-5.38	6.45	**.014**	.093	-12.00	2.07	.156	.033
Fear	70.48 (23.45)	75.62 (19.63)	87.08 (13.18)	-5.14	3.44	.068	.052	-11.46	0.54	.467	.009
Anger	57.92 (18.72)	61.99 (17.49)	70.71 (15.64)	-4.07	3.42	.069	.052	-8.72	0.15	.701	.003
Surprise	73.75 (22.26)	81.72 (16.43)	90.42 (11.58)	-7.97	8.41	**.005**	.118	-8.70	0.24	.624	.004
Disgust	56.78 (17.12)	61.94 (18.16)	71.96 (11.93)	-5.16	6.68	**.012**	.096	-10.02	0.03	.873	<.001

Note. T0 = 0 days into abstinence; T1 = 15 days into abstinence; T2 = 30 days into abstinence.
The accuracy of emotion recognition for each emotion category has been calculated according to the formula= [(No. of trials of that emotion correctly identified/4) x 100], since there were altogether four trials (2 male and 2 female faces) for each emotion. A similar method was used for calculating the accuracy of emotion differentiation for each emotion category; i.e., (Total no. of correctly differentiated trials for that emotion/ 24) x 100.
Values in BOLD are statistically significant.

Discussion

The present study aimed to explore how visual emotion recognition and emotion discrimination change with the increase in the number of days into cannabis abstinence and how far this change has accounted for a variation in levels of self-reported anxiety, depression, and stress over time, as well as the withdrawal symptoms' intensity and impact. Heavy cannabis users admitting themselves to a rehabilitation facility to receive therapeutic help in giving up cannabis addiction were followed for one month of their stay in the facility. They were tested at three time points: T0 (at the time of admission), T1 (on the 15th day of their stay), and T2 (on the 30th day of their stay) for the levels of anxiety, depression, and stress, as well as for their performance on computerised tasks of emotion recognition and discrimination. At T1 and T2, the intensity and impact of withdrawal symptoms were also assessed. This is the first study, to the best of our knowledge, that explored the relative contribution of abstinence from cannabis and the decline in psychological distress and withdrawal symptoms to the improvement in emotion recognition and discrimination. Unlike most previous studies, this study employed more ecologically valid stimuli by presenting participants with facial emotion videos for emotion recognition rather than static faces.

The prominent finding emerging from the study was that while abstinence from cannabis has its beneficial effects in improving emotion recognition and discrimination over and above the effects of decline in psychological distress in the first two weeks of abstinence, further enhancement in emotion recognition and discrimination in the following two weeks proceeds through a decline in psychological distress and intensity and impact of withdrawal symptoms. Our findings that both emotion recognition and emotion differentiation show improvement after 15 days of cannabis abstinence, even after accounting for the role of decline in depression, anxiety, and stress, constitutes a new finding that previous research has not reported.

Overall, anxiety declined significantly from T0 to T1 and from T1 to T2, but a significant decline in depression and stress was noted only from T1 to T2. Since anxiety scores could vary between 0–19, a mean score of approx. 9 at T0 could be considered a moderately high level of anxiety, which subsequently declined to 3 at T2, indicating a low level of anxiety. Depression scores could range between 0–15 and a score of approx. 12 denoted high levels of depression at T0, which declined to 3.5 at T2, indicating a low level of depression. Similarly, stress (where scores could range between 0–14) was high at T0 with a mean of 10.6, but reduced to low stress at T2.

Our findings resonate with those of a recent study conducted on adolescent cannabis users, who reported significant successive weekly declines in their anxiety and depression throughout the assessment period of four weeks (Cooke et al., 2021). A similar decline in depressive symptoms was noted after three weeks of cannabis abstinence in another study as well (Jacobus et al., 2017).

In this study, participants demonstrated a very poor accuracy of emotion recognition at T0 (approx. 32%), which gradually increased over time (T1: approx. 40%; T2: approaching 46%). This recognition rate was much less than that obtained by Bayrakçı et al. (2015) at 3.2 months of abstinence; i.e., 61.1%. Given the steady rise in emotion recognition every fortnight (although the increase from T1 to T2 was not significant after controlling for the change in mental health problems and withdrawal symptoms), it is possible that this percentage might reach a level similar to that obtained by Bayrakçı et al. The accuracy of emotion differentiation stood much better than that of emotion recognition, being approx. 65% at T0. Emotion differentiation revealed a significant change over time from T0 to T1, but not from T1 to T2 – when controlled for the change in mental health problems and withdrawal symptoms. Results regarding the accuracy of emotion differentiation are quite similar (81.1% at T2) to the ones reported by Bayrakçı et al. (2015), which came to 81.3% at 3.2 months of abstinence. Overall, despite improvements in emotion recognition and emotion differentiation with an increase in the duration of abstinence, such improvements may still be significantly worse than those for healthy controls, as Bayrakçı et al. (2015) observed.

Improvements in emotion recognition and differentiation were seen from T0 to T1, even after controlling for mental health problems, although the decline in depression and stress from T0 to T1 was not significant. This finding lines up with the results of a systematic review and meta-analysis by Scott and colleagues (2018) who identified that cognitive deficits associated with the use of cannabis diminish with a longer duration of abstinence (more specifically, >72 hours). Thus, in combination with the findings of Scott et al. (2018), our findings suggest that the cognitive and emotional deficits associated with cannabis use may not be persistent and tend to diminish with an increase in the length of cannabis abstinence. Withdrawal symptoms (including anxiety) typically appear within 1–3 days of not consuming cannabis, peaking between days 2–6, and mostly lasting between 4–14 days (Budney et al., 2008).

The current study's findings indicating that emotion processing improves over time with cannabis abstinence are comparable with the broader literature on substance use disorders, particularly those involving alcohol use disorder (AUD). Even early abstinent AUD patients continue to struggle with emotion recognition, often misinterpreting neutral faces as having emotional content (Kornreich et al., 2013; Kornreich et al., 2016; Philippot et al., 1999), although recognition of happiness tends to remain relatively intact (Bora & Zorlu, 2017), as noted in our study, too. In comparison, the current study on cannabis users reveals a more optimistic abstinence trajectory, indicating improvements in emotion recognition and differentiation over time. This suggests that, unlike AUD where emotional processing deficits may persist even in abstinence, cannabis-related deficits in emotion processing may be more reversible with sustained abstinence. It is important to note here that in previous studies (Kornreich et al., 2013; Kornreich et al., 2016), abstinent AUD patients were recruited in their third or fourth week of alcohol detoxification. Compared to these participants, our sample of cannabis abstainers started demonstrating improved emotion recognition and differentiation early on. These findings contribute to a nuanced understanding of how different substances impact emotional processing and recovery, highlighting that while both alcohol and cannabis use disorders impair emotional recognition, the potential for recovery in emotional processing abilities might be more pronounced in abstinent cannabis users. Furthermore, the decline in anxiety, depression, and stress over time in this present study is likely to result not only from the progressing detoxification of the body due to cannabis abstinence but also from the medical and therapeutic support and counselling available at the centre.

Findings pertaining to specific emotion categories stand also partly in line with previously reported findings. For instance, our study shows that positive emotions (happiness and surprise) are best recognised and differentiated while negative emotions (anger and disgust) are the worst recognised. This lies somewhat in line with the findings related to other substance use disorders, where a previous meta-analytic study (Bora & Zorlu, 2017) reports that the recognition of happiness tends to remain relatively intact in recent AUD abstainers. Bayrakçı et al. (2015) reported similar findings regarding a better recognition of positive emotions and poorer recognition of negative emotions in cannabis abstainers over a one-month duration. However, our findings show that the negative emotion of fear is also better recognised (similar to happiness), a finding that runs in contrast to that reported by Bayrakçı et al. (2015). The present results concerning emotion differentiation add to the literature as no previous study, to our knowledge, has comparatively explored emotion differentiation across the six emotion categories among cannabis abstainers. It is surprising, though, that the emotion of surprise that remained one of the worst recognised was one of the best differentiated (along with happiness and fear) from other emotions. The emotion of happiness was both best recognised and one of the best differentiated (along with surprise). Further, previous studies have shown that THC, the main psychoactive component in cannabis, when administered acutely blunts amygdala activity, particularly pertaining to negative as opposed to positive emotions (Ballard et al., 2012; Phan et al., 2008). This suggests that discontinuing cannabis consumption would improve emotion recognition as observed in the present study. Despite the improvement in emotion recognition over time, however, negative emotions were still less accurately identified than were positive emotions, probably because of the more damaging effect earlier cannabis use had on the recognition of negative emotions.

It should be noted that the cross-sectional correlations between mental health problems and emotion-processing were somewhat inconsistent with the findings discussed above. Anxiety and stress at the three time points correlated positively with emotion recognition at the respective time points. These symptoms also revealed a significant and positive correlation with emotion differentiation at T1, whereas depression correlated positively with emotion recognition at T2. These findings (particularly for anxiety and stress) stand at odds with those identified using ANCOVAs. A possible reason for these counterintuitive findings may be that apart from their linear relationship being significant, their quadratic relationship was also significant, suggesting a U-shaped relationship between emotion recognition/differentiation and anxiety, depression, or stress. Thus, it is likely that very low or very high levels of mental health problems are associated with poorer emotion-processing during cannabis abstinence, while optimal levels are associated with better emotion recognition and differentiation. However, an in-depth exploration of the possible reasons is beyond the scope of this discussion.

Strengths and Limitations

The present study extends and adds to the limited literature on the emotional impacts of cannabis abstinence. Its research highlights that an enhanced ability to recognize and distinguish emotions is associated with a reduction in psychological distress and complete cessation of cannabis use during the initial two weeks of abstinence, which improves gradually as time passes. This progress in emotion recognition and discrimination is evident across all six basic emotions with an increasing duration of abstinence. However, certain limitations of the study need to be realised. First, the sample size was moderate. Even though the research met the minimum sample size requirement suggested by a priori sample size calculations, a larger sample would have allowed for subgroup analyses with respect to demographic variables regarding age, education, SES, etc. Second, the findings remain limited by the fact that they are based on men participants only and cannot be generalised to women, especially since the latest studies (e.g., Sullivan et al., 2022) show sex differences in the impact of cannabis on emotion processing, and therefore the effect of abstinence from cannabis may also be sex-specific. Third, we assessed participants at three time points only, because of which an earlier estimate of the withdrawal symptoms' intensity and impact was not available until day 15 of the abstinence. Fourth, the internal consistency of anxiety (subscale of ADSS) at T0 was below the recommended cut-off of 0.70. The same was true for the Frequency items factor of CAST. This low level of reliability warrants careful interpretation for the related findings. Fifth, the use of self-report measures to screen for a current or past diagnosis of mental health disorder could not have been more accurate than a clinical interview or diagnosis by a trained clinician would have been. Future research should aim to employ the latter, more valid, measures to screen participants for mental health problems. Sixth, the research did not follow up on the participants after discharge and no further assessments were done after they left the rehabilitation center, which, had it been done, could have yielded further insights. It is recommended that future researchers undertake follow-ups (preferably, more than one) to better gauge any changes in emotion recognition and differentiation as well as other indices of mental health that may impact such emotional processing. Seventh, a cannabis non-user control group could have better controlled for and perhaps eliminated the possible learning effect on the emotion processing tasks that may have occurred over time. Finally, a causal relationship between emotion recognition/discrimination and psychological distress/withdrawal symptoms cannot be ascertained due to the study's design. Therefore, future research should also explore whether an improvement in emotion recognition and discrimination impacts or predicts a decline in psychological distress.

Conclusion, Implications, and Future Directions

In conclusion, improved emotion recognition and differentiation proceeds through the decline in psychological distress and zero cannabis usage for the first two weeks of abstinence, while for the next two weeks these improvements proceed through further declines in psychological distress and withdrawal symptoms. Happiness stood as the best recognised and well-differentiated emotion. The worst recognised emotions of sadness and fear evinced significant increases in recognition accuracy within the first 15 days of cannabis abstinence while another of the poorly-recognised emotions, namely surprise demonstrated significant increases in recognition accuracy with the increase in cannabis abstinence at every successive time-point; i.e., after the first 15 days of abstinence, and then further increases after the second 15-day abstinence period. Surprise was also the best differentiated emotion, followed closely by happiness and fear.

This study underscores the potential benefits of cannabis abstinence on emotional well-being, emphasizing its positive impact on emotion recognition and discrimination. This insight could be valuable in the development of targeted interventions within cannabis rehabilitation programs. The findings suggest that improvements in emotion recognition extend beyond mere abstinence, emphasizing the importance of addressing psychological distress and withdrawal symptoms in the rehabilitation process. Treatment strategies should focus on holistic well-being rather than solely relying on abstinence. The findings further imply that the enhanced ability to recognize and differentiate emotions may serve as an indicator of progress during the rehabilitation period. Incorporating regular assessments of emotion recognition skills may offer a dynamic measure of recovery and guide treatment adjustments. Further, the finding of continued improvements involving cannabis abstinence in emotion recognition and differentiation suggests implications for improved socio-emotional processing and healthy interpersonal relationships, since the accurate recognition of others' emotions would facilitate better emotional responses. This would help in initiating and sustaining more meaningful interpersonal interactions, possibly breaking the cycle of addiction (which is mostly seen as an escape from stress and loneliness) and fostering sustained abstinence from cannabis. It would also help prevent later relapse and lead to further improvements in emotion recognition.

Future research could delve into demographic variables like age, education, and socioeconomic status to understand potential variations in emotional outcomes during cannabis abstinence. This could contribute to more personalized treatment approaches. Longitudinal studies extending beyond one month could provide a more comprehensive understanding of the prolonged emotional impact of cannabis abstinence. This could include assessing emotional changes over an extended period to capture sustained improvements. Longitudinal studies could also assess whether emotion recognition impairments persist in cannabis abstainers compared to active cannabis users and non-users. Future research should include female participants. This would contribute to a more comprehensive understanding of how cannabis abstinence affects emotion processing across sexes. To address the limitation of the withdrawal symptoms' delayed assessment, future studies could incorporate earlier evaluations. This would allow for a more nuanced understanding of the temporal dynamics of withdrawal symptoms and their correlation with emotional changes. Lastly, further research is required on the relationship between mental health and emotion processing during cannabis abstinence to better understand their association.

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No conflict of interest has been declared by the authors.

Ethical statement
This manuscript is the authors' original work.
All participants engaged in the research voluntarily and anonymously.
Their data are stored in coded materials and databases without personal data.
The studies involving human participants were reviewed and approved by the Institutional Ethics Committee, Magadh University, Bodh Gaya (Ref No.: Psy/19/23).

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A. KUMARI ET AL. Emotion Recognition and Differentiation in Cannabis Abstainers Over Time

Appendix

Table 1. Pearson's Product-Moment Correlations of Various Variables in the Study Related to Cannabis Use, Emotional Processing, and Mental Health Problems

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1. Frequency of Cannabis Use	1																							
2. Quantity of Cannabis Use	.53***	1																						
3. Age of Onset Of Cannabis Use	.21	.16	1																					
4. Anxiety (T0)	-.26	-.14	-.02	1																				
5. Anxiety (T1)	-.05	-.08	.04	.58***	1																			
6. Anxiety (T2)	.15	.12	.05	.22	.55***	1																		
7. Depression (T0)	.25	.44**	-.14	.15	.01	.10	1																	
8. Depression (T1)	-.08	.26	-.20	.25*	.12	-.03	.48***	1																
9. Depression (T2)	.28	.09	.07	.24*	.49***	.84***	.23	.06	1															
10. Stress (T0)	.08	.04	.00	.25	.39***	.24*	.37***	.18	.20	1														
11. Stress (T1)	.01	-.08	.02	.30*	.54***	.18	-.02	.27*	.04	.59***	1													
12. Stress (T2)	.40*	.12	.11	.10	.49***	.81***	.16	-.02	.81***	.28*	.19	1												
13. Withdrawal Intensity (T1)	-.03	.09	-.16	.48***	.54***	.41***	.41***	.35**	.37**	.47***	.35**	.40**	1											
14. Withdrawal Intensity (T2)	.14	.09	-.07	.22	.34**	.72***	.28*	.12	.75***	.24*	.14	.73***	.62***	1										
15. Withdrawal Impact (T1)	-.05	.01	-.18	.31*	.29*	.28*	.41***	.24*	.37**	.36**	.10	.29*	.81***	.55***	1									
16. Withdrawal Impact (T2)	.15	.11	-.12	.08	.28*	.68***	.25*	.11	.75***	.17	.06	.70***	.52***	.91***	.57***	1								
17. Emotion Recognition Accuracy (T0)	.02	-.25	.09	.29*	.52***	.43***	-.06	-.14	.41***	.29*	.34**	.48***	.15	.26*	-.02	.14	1							
18. Emotion Recognition Accuracy (T1)	-.30	-.04	.05	.30*	.61***	.48***	-.06	-.14	.35**	.32**	.29*	.41***	.30*	.26*	.13	.17	.49***	1						
19. Emotion Recognition Accuracy (T2)	-.32*	-.23	.10	.14	.54***	.40***	-.19	-.08	.27*	.18	.27*	.40***	.17	.18	.01	.11	.44***	.66***	1					
20. Emotion Recognition RT (T0)	.10	.09	-.12	.04	-.08	-.08	.11	.15	.13	-.25*	-.31*	-.11	.07	-.04	.20	.03	-.12	-.19	-.03	1				
21. Emotion Recognition RT (T1)	.16	.18	.01	-.03	.20	.07	-.14	.13	.06	-.21	.09	.09	-.05	-.10	-.05	-.06	.09	-.01	.22	.02	1			
22. Emotion Recognition RT (T2)	-.11	-.19	-.05	.07	-.23	-.13	-.02	-.03	.03	-.19	-.30*	-.11	-.06	-.00	.11	-.03	-.12	-.05	-.17	-.02	-.07	1		
23. Emotion Differentiation (T0)	.11	-.04	.01	-.01	.20	.11	-.19	-.06	-.01	.12	.24	.12	-.07	-.20	-.12	-.19	.26*	.05	.16	-.16	.15	-.19	1	
24. Emotion Differentiation (T1)	-.03	-.12	-.10	.14	.41***	.19	-.15	-.06	.03	.06	.24*	.16	.04	-.06	-.05	-.14	.37**	.26*	.36**	-.14	.27*	-.23	.51***	1
25. Emotion Differentiation (T2)	-.08	-.07	-.02	.17	.41***	.14	-.06	-.03	.01	.29*	.36**	.11	.09	-.13	.02	-.18	.28*	.34**	.34**	-.11	.14	-.42***	.46***	.61***

Note. T0 = 0 days into abstinence; T1 = 15 days into abstinence; T2 = 30 days into abstinence; RT = response time.
*$p < .05$; **$p < .01$; ***$p < .001$.