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RESEARCH

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Rumination and drug craving scores in Chinese male patients with methamphetamine and heroin use disorders: a cross-sectional study

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Abstract

Background Rumination is an essential trans-diagnostic process associated with substance use disorders (SUDs) in psychopathology. In China, methamphetamine and heroin have become major illegal drugs, but the role of rumination in their use remains unclear. The objective of this study was to investigate the relationship between rumination subtypes and drug craving in patients with methamphetamine use disorder (MAUD) and 81 patients with heroin use disorder (HUD).

Methods A total of 489 participants, including 408 patients with MAUD and 81 patients with HUD, were recruited from a rehabilitation center. Participants were screened for inclusion criteria, and the Obsessive Compulsive Drug Use Scale (OCDUS) was used to assess drug craving. Rumination was assessed using the Ruminative Responses Scale (RRS), categorized into three dimensions: symptom rumination, brooding, and reflective pondering. Correlational and multiple regression analyses were conducted to examine associations between rumination and craving.

Results Compared to patients with MAUD, patients with HUD had significantly higher RRS and OCDUS total score (42.51 vs 39.71 and 25.99 vs 20.95, both $p < 0.01$). In patients with MAUD, the OCDUS total score was positively correlated with the total score ($r = 0.298$, $p < 0.01$) and all subscale scores of the RRS (for reflective pondering, $r = 0.180$; for brooding, $r = 0.230$; for symptom rumination, $r = 0.325$; all $p < 0.01$). However, in patients with HUD, only symptom rumination was positively associated with the OCDUS total score ($r = 0.247$, $p < 0.05$). Multiple regression showed symptom rumination was independently associated with OCDUS total score in both groups (for patients with MAUD, $\beta = 0.324$, $p < 0.001$; for patients with HUD, $\beta = 0.252$, $p < 0.05$).

Conclusions Our findings suggest that rumination shows different effects on craving in male patients with MAUD and HUD. Moreover, symptom rumination may have a significant influence on the connection between rumination and craving in individuals with MAUD and HUD.

Keywords Methamphetamine, Heroin, Rumination, Drug craving

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Introduction

The persistently high incidence of drug use worldwide continues to pose a significant challenge to both social stability and public health. The World Drug Report 2023, as published by the United Nations Office on Drugs and Crime, indicates that there are regional differences in the main substances disclosed by individuals as their preferred drugs. Cannabis plays a significant role in Europe and the USA [1], alongside crack cocaine [2] and other substances [3]. However, opioids and methamphetamine (MA) are the most commonly used primary substances in East and Southeast Asia [4]. According to the China Drug Situation Report, the number of registered individuals who use drugs in China reached 1.124 million at the end of 2022, accounting for 0.08% of the total population. Of these, 588,000 regularly used MA, and 416,000 used heroin [5]. Therefore, MA and heroin are the predominant drugs used in China, accounting for 89.3% of the total drug-using population. Prevention and treatment of these two drugs remain a prominent area of focus in contemporary drug dependency research.

Substance use disorder (SUD) is a chronic disease marked by obsessive drug-seeking and drug-taking behaviors regardless of the harmful consequences. SUD is one of the most prevalent and deadly psychopathologies [6]. As one of the main drivers of drug-using behavior [7], the DSM-5 establishes drug craving as a diagnostic criterion for SUD, which is defined as follows: "a strong desire for drugs" [8]. Craving has been recognized as a key underlying mechanism, not only as a predictor of drug use and relapse [9] but also as a target for treatment [6].

Previous studies have reported that there are some fundamental differences between opiates and psychostimulants [10]. For example, compared to patients with heroin use disorder (HUD), patients with methamphetamine use disorder (MAUD) exhibit notable psychological craving but less physical dependence [11]. Another study examined the influence of various environments on craving and positive emotion of cocaine and heroin. It found that the same environment could have contrasting effects on the emotional and brain response to psychostimulants and opiates [12]. Furthermore, there is currently a lack of pharmaceutical therapies that have comparable effectiveness for treating both cocaine and opioid addiction [13]. This highlights the need for further study to better understand different aspects of mechanisms behind addiction to opioids and psychoactive substances.

Over the past decade, multiple theoretical perspectives have recognized emotional dysregulation as a significant element in the emergence of SUDs and as a moderator of the effects of psychosocial stress [14, 15]. Rumination has been observed to be a crucial transdiagnostic process linked to anxiety disorder, depression [16] and SUDs in psychopathology [17]. Rumination is a cognitive process characterized by repetitive attention on negative emotions and associated events. This includes depressed symptoms and the potential causes and outcomes of these symptoms [18]. Increasing evidence suggests a positive correlation between rumination and more problematic substance use in both cross-sectional [19] and longitudinal studies [20]. The research indicated that girls who scored higher on rumination tended to show an increase in SUD symptoms and to meet the criteria for SUD over the four years [20]. In addition, previous research has shown that craving and rumination during abstinence from SUDs follow a dynamic trajectory, influenced by factors such as the duration of abstinence, stressors, and environmental cues [21]. While craving typically decreases over time [22], it may experience intermittent peaks in animal models, particularly in response to relapse-inducing triggers [23]. In addition, rumination tends to remain relatively stable over time, with limited effects from the length of recovery or short-term interventions [24]. Both craving and rumination are significant predictors of relapse, with their impact modulated by environmental stressors and emotional triggers [21, 25], This suggests that these cognitive processes are not only stable traits but also context-sensitive [26, 27]. The variability in craving and rumination, along with their association with relapse, remains a critical area for further investigation.

Additionally, SUD and comorbid mental health conditions interact reciprocally across different stages of addiction, influencing brain systems associated with craving and compulsive behaviors [28]. Recent studies suggest that drug-induced psychotic episodes, which are more prevalent in MAUD compared to HUD, may amplify emotional dysregulation and rumination, further intensifying drug craving in these populations [29, 30]. The study found that the level of co-rumination can indirectly predict depression symptoms by influencing brooding rumination two year later [31].To address potential confounding effects between rumination and depressive symptoms, researchers have examined rumination as a construct with three dimensions: symptomatic rumination, brooding, and reflective pondering [32].

The symptom rumination partially overlaps with assessments of depressive symptoms, which were associated with both higher rates and earlier initiation of substance use [33]. Brooding refers to the habit of subconsciously measuring one's current condition with unattainable targets, and higher brooding scores are positively associated with heroin dependence [19]. Reflective pondering, which refers to conscious self-reflection as an adaptive means of alleviating depressive symptoms and

problem solving [32, 34], was negatively associated with both cannabis and alcohol use disorders [35]. In our previous study, we found that rumination is one of the negative cognitions that affect the experience of MA craving, especially among individuals with childhood trauma who use MA [36]. Rumination has important implications for the efficacy of cognitive behavioral therapy [31]. However, it is unclear how the three rumination subtypes, which represent different complex cognitive processes, influence the craving for heroin and MA.

This study aimed to address gaps in the literature by investigating rumination and craving in male patients with MAUD and HUD within a Chinese population. Specifically, the study sought to: 1) determine whether male patients with MAUD exhibit higher levels of craving and rumination compared to male patients with HUD; 2) explore the relationship between rumination and craving, with a focus on the roles of the three rumination subtypes (symptom rumination, brooding, and reflective pondering) in male patients with MAUD and HUD; and 3) examine the influence of drug-related variables on the relationship between rumination and craving. By addressing these questions, the study provides insights into the cognitive mechanisms underlying craving in SUDs and offers potential directions for tailored therapeutic interventions.

Methods

Participants

A total of 408 patients with MAUD and 81 patients with HUD participated in this study. They were all male Chinese, from Xin Hua Drug Rehabilitation Center in Sichuan Province, China. We screened all patients in the rehabilitation center, and only those who met the inclusion criteria and did not meet the exclusion criteria were recruited. No a priori sample size calculation was performed to determine the number of participants for this study. Inclusion criteria included: (1) aged 18–55 years; (2) met the DSM-5 diagnostic criteria for MA or heroin use disorder; (3) MA or heroin was the primary drug used in the past three years; and (4) had at least one month of detoxification before enrollment. Participants were excluded if they: (1) had conditions such as intracranial hypertension, cranial defects, or tumors; (2) suffered from serious physical illnesses, including cardiovascular, hepatic, renal, gastrointestinal, infectious, or immunological diseases; (3) had a documented history of psychiatric disorders; and (4) experienced severe neurological disorders or cognitive developmental delays. Given the partial overlap in the sample of individuals who use MA from our previous study [36], the present study represents a secondary analysis.

This rehabilitation center is managed on an inpatient basis and has no access to drugs or alcohol. Semi-structured interviews were conducted to collect drug use history and clinical features of patients. Abstinence is calculated from the patient's admission to the rehabilitation center and is recorded by a follow-up psychiatrist. Upon admission to the rehabilitation center, patients initially undergo a physical detoxification program, which includes drug treatments (such as methadone therapy) to ease withdrawal symptoms associated with drug abstinence. This phase typically lasts from one to several months. After at least one month of abstinence, patients undergo a rehabilitation program, typically lasting 1–2 years. The goal of this program is to reinforce the detoxification effects, address psychological dependence, and restore social functioning. Our programs offer behavioral and psychological interventions, along with skills training, to assist patients in reintegrating into society.

This study was conducted in accordance with ethical guidelines and was approved by the Institutional Review Board of the Institute of Psychology, Chinese Academy of Sciences. Prior to participation, all participants provided informed consent, with clear explanations about the purpose of the study, procedures involved, and their right to withdraw at any time without penalty. Participant confidentiality was ensured through the anonymization of all data, and personal identifiers were removed to maintain privacy. Data was stored securely, accessible only to authorized researchers.

Measurement

Demographic and clinical data

A semi-structured questionnaire was administered to gather basic information and clinical features from participants, including age at first drug use, length of drug use, drug dosage, and duration of abstinence. Our survey was conducted by trained researchers who met the reliability requirements for the study.

Ruminative Response Scale (RRS)

Rumination is a cognitive process characterized by repeated focus on one's negative emotions and corresponding events [37]. The Ruminative Response Scale (RRS) is a questionnaire of 22 items designed to measure variations in an individual's tendency towards rumination. The 22 items describe responses to symptoms, causes, possible consequences, and self-reflections of depressed mood [18]. The Chinese version of the RRS references Treynor's three-factor model and assesses rumination in three different dimensions: symptom rumination, brooding, and reflective pondering [32]. This model's clinical validity and reliability in a Chinese

population have been considered satisfactory [36]. Our study showed a Cronbach's alpha of 0.84 for the RRS.

Obsessive–Compulsive Drug Use Scale (OCDUS)

The OCDUS is a self-report scale that consists of 13 items and assess a subject's general craving for drugs over one week [38]. The OCDUS-CV (Chinese version of the OCDUS) was used to categorize drug craving into three dimensions: frequency of craving, interference with drugs, and control of drugs [39]. Increased scores of OCDUS correlate with heightened severity of drug craving. The OCDUS-CV has been demonstrated to be an effective and reliable measurement for drug craving in patients with SUD. In our study, the Cronbach's alpha for this scale was 0.81.

Data analysis

All data were analyzed using SPSS 26.0. To assess the normality of continuous variables, we conducted the Kolmogorov–Smirnov one-sample test. For variables that did not meet the assumption of normality, the Box-Cox transformation was applied prior to further analysis. We tested for homoscedasticity using Levene's test to ensure that the assumption of equal variances was met for parametric tests. Missing data were handled using pairwise deletion. We ensured that the proportion of missing data did not exceed 5% to avoid introducing bias. Independent samples t-tests were chosen for continuous variables to compare means between the methamphetamine and heroin groups because they are appropriate for assessing differences when normality and homogeneity of variances are met. For categorical variables, chi-square tests were applied as they are well-suited for comparing proportions between two independent groups. ANCOVA was used to examine differences in RRS scores and OCDUS scores between the MA and heroin groups while controlling for demographic characteristics as covariates, including age, BMI, drinking history, and marital status. This method was selected because it allows for the control of these covariates, which could potentially influence the outcomes, thereby providing a clearer interpretation of the group differences. Furthermore, for OCDUS, additional controls were made for clinical data related to drug use, including number of drugs used, duration of drug use, and duration of abstinence. The relationship between rumination and substance craving was assessed by Pearson correlation analysis in the MA and heroin groups, respectively. Bonferroni correction for multiple testing was applied.

In addition, multiple Stepwise regression analysis was conducted to identify the most significant predictors of drug craving while accounting for potential confounders. This method allows for an iterative selection process that includes or excludes variables based on their statistical contribution to the model. OCDUS total score was used as the dependent variable, and potential confounding variables including demographic or drug-related behavioral variables were used as independent variables.

Results

Comparison of demographic characteristics in patients with MAUD and HUD

Table 1 indicates the comparison of demographic characteristics between patients with MAUD and HUD. There were notable differences between individuals with MAUD and HUD regarding age, BMI, status in marriage, history of alcohol consumption, and history of suicide attempts (all $p < 0.05$). Patients with MAUD were notably younger (34.32 ± 6.98 years vs 45.47 ± 6.32 years) and exhibited a higher BMI (24.04 ± 3.22 kg/m^2

Table 1 Demographic characteristics of patients with methamphetamine use disorder ($n = 408$) and heroin use disorder ($n = 81$)

Characteristics	Methamphetamine ($n = 408$)	Heroin ($n = 81$)	t/χ^2	p
Age (years)	34.32 ± 6.98	45.47 ± 6.32	−13.34	< 0.001
Education years	9.64 ± 2.29	9.26 ± 1.94	1.39	0.165
BMI (kg/m^2)	24.04 ± 3.22	23.01 ± 3.00	2.62	0.009
Smoke (smoker/nonsmoker)	400/9	79/2	0.02	0.881
Drink (drinker/nondrinker)	140/269	16/65	6.53	0.011
Marital status			12.59	0.002
Single	170	24		
Married/Cohabiting	116	16		
Divorced/Widowed	124	41		
History of suicide			28.23	< 0.001
No suicide	376	59		
Suicidal ideation	20	13		
Suicidal Behavior	10	9		

vs. 23.01 ± 3.00 kg/m^2) than patients with HUD. Alcohol consumption was significantly more common in patients with MAUD (45% vs. 20%, $\chi^2 = 6.45$, $p < 0.05$), possibly indicating different patterns of polydrug use. Interestingly, patients with HUD had a higher rate of suicide attempts (22% vs. 7%; $\chi^2 = 28.23$, $p < 0.001$), underlining the need for targeted mental health interventions in this group.

Comparison of substance use characteristics and rumination in patients with MAUD and HUD

Table 2 compares the clinical characteristics of drug use, rumination, and craving between the two groups. Patients with HUD reported longer drug use duration (243.85 ± 81.25 vs. 97.23 ± 6.26 months, $t_{(488)} = -21.806$, $p < 0.001$) and higher monthly drug consumption (56.67 ± 68.08 mg vs. 10.63 ± 22.02 mg, $t_{(482)} = -11.036$, $p < 0.001$) compared to patients with MAUD. These findings may indicate the chronic and escalating nature of heroin addiction. Figure 1 shows the Difference in RRS and OCDUS total scores between patients with MA and heroin use disorder. Patients with HUD scored higher on symptom rumination (9.17 ± 2.04 vs 8.93 ± 2.42, $F = 17.859$, $p < 0.001$), brooding (10.83 ± 2.16 vs 10.21 ± 2.50, $F = 10.291$, $p = 0.001$), and RRS total scores (42.51 ± 7.84 vs 39.71 ± 8.90, $F = -2.604$, $p < 0.001$), suggesting a greater tendency for maladaptive cognitive patterns. They also reported stronger drug cravings, as measured by OCDUS total score (25.99 ± 6.57 vs 20.95 ± 48.60, $F = -6.566$, $p < 0.01$) and craving frequency

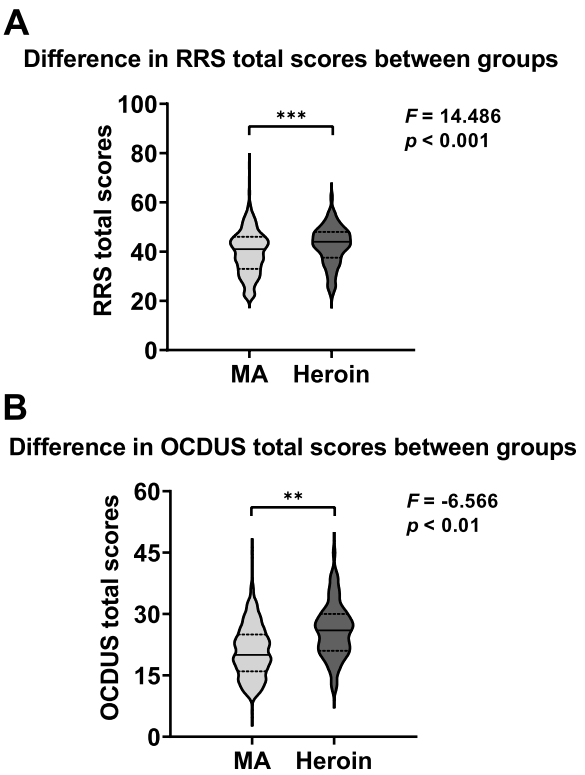

Fig. 1 Difference in RRS (**A**) and OCDUS (**B**) total scores between patients with methamphetamine use disorder ($n = 408$) and heroin use disorder ($n = 81$)

Table 2 Clinical and substance use characteristics of patients with methamphetamine use disorder ($n = 408$) and heroin use disorder ($n = 81$)

Characteristics	Methamphetamine ($n = 408$)	Heroin ($n = 81$)	*t/F*	*p*
Duration of drug use (months)	97.23 ± 6.26	243.85 ± 81.25	−21.806	< 0.001
Quantity of use per month (milligram/month)	10.63 ± 22.02	56.67 ± 68.08	−11.036	< 0.001
Abstinence duration (months)	12.21 ± 5.70	14.13 ± 4.99	−2.773	0.006
Onset age of drug use (years)	25.10 ± 7.30	23.75 ± 6.44	1.540	0.124
RRS				
Symptom Rumination	8.93 ± 2.42	9.17 ± 2.04	17.859	[a] < 0.001
Brooding	10.21 ± 2.50	10.83 ± 2.16	10.291	[a] 0.001
Reflective Pondering	20.57 ± 5.08	22.51 ± 4.86	3.530	[a] 0.061
RRS Total score	39.71 ± 8.90	42.51 ± 7.84	14.486	[a] < 0.001
OCDUS-CV				
Interference of Drug	8.29 ± 3.05	11.07 ± 3.61	−7.263	[b] 0.222
Frequency of Craving	6.96 ± 3.05	8.43 ± 3.11	−3.947	[b] 0.001
Control of Drug	5.69 ± 2.20	6.48 ± 1.89	−3.031	[b] 0.05
OCDUS Total score	20.95 ± 48.60	25.99 ± 6.57	−6.566	[b] 0.003

[a] ANCOVA of RRS data to adjust for age, BMI, drinking history, marital status

[b] ANCOVA of OCDUS data to adjust for age, BMI, drinking history, marital status, quantity of use, duration of drug use and abstinence duration

Table 3 Matrix of correlation coefficients between drug craving and rumination in patients with methamphetamine use disorder

	Reflective Pondering	Brooding	Symptom Rumination	RRS Total
Interference of Drug	0.189***	0.243***	0.329***	0.306***
Frequency of Craving	0.161**	0.227***	0.257***	0.251***
Control of Drug	0.026	0.003	0.114*	0.076
OCDUS Total score	0.180***	0.230***	0.325***	0.298***

* Significant at $p < 0.05$

** Significant at $p < 0.01$

*** Significant at $p < 0.001$

Table 4 Matrix of correlation coefficients between drug craving and rumination in patients with heroin use disorder

	Reflective Pondering	Brooding	Symptom Rumination	RRS Total
Interference of Drug	−0.034	0.067	0.212	0.141
Frequency of Craving	0.136	0.13	0.289**	0.250*
Control of Drug	−0.09	−0.016	−0.023	−0.042
OCDUS Total score	0.02	0.094	0.247*	0.184

* Significant at $p < 0.05$

** Significant at $p < 0.01$

(8.43 ± 3.11 vs 6.96 ± 3.05, $F = -3.947$, $p = 0.001$). These findings suggest that patients with HUD may experience more intense cravings and negative thought patterns, which could complicate recovery. No significant differences were observed in drug control (6.48 ± 1.89 vs 5.69 ± 2.20, $F = -3.031$, $p = 0.05$) or drug interference scores (11.07 ± 3.61 vs 8.29 ± 3.05, $F = -7.263$, $p > 0.05$) between the groups.

Relationship between rumination and drug craving in group with MAUD and HUD

Correlation analyses (Tables 3 and 4) revealed distinct patterns between the groups. In patients with MAUD, the total RRS score and its subscales were positively correlated with OCDUS total score, craving frequency, and interference scores (all $p < 0.01$). Symptom rumination specifically showed a positive association with the OCDUS drug control score ($p < 0.05$). This indicates that patients with MAUD and have higher rumination tendencies may struggle more with controlling cravings and coping with drug-related interference. For patients with HUD, only symptom rumination showed a significant correlation with craving frequency and total OCDUS scores (both $p < 0.05$), while other rumination subtypes (brooding and reflective pondering) were not significantly associated with OCDUS measures (all $p > 0.05$). In terms of clinical characteristics, the correlations between abstinence duration and the total scores of the RRS and OCDUS, as well as the subscale scores, were not significant in either group. The onset age of drug use was associated with RRS reflective pondering ($r = 0.251$, $p < 0.05$) and OCDUS control ($r = -0.324$, $p < 0.01$). Duration of drug use was also associated with RRS reflective pondering ($r = -0.256$, $p < 0.05$). We further performed partial correlation analyses controlling for these clinical characteristics to test the relationship between RRS and OCDUS scores. Results showed that RRS reflective pondering and brooding were still not correlated with OCDUS scores. These findings suggest that patients with HUD may exhibit a more specific link between symptom rumination and craving, compared to the broader associations observed in patients with MAUD.

Regression analysis (Table 5) identified symptom rumination as an independent predictor of OCDUS total score in both group with MAUD (β = 0.324, t = 6.898, $p < 0.001$) and HUD (β = 0.252, t = 2.32, $p < 0.05$). Additionally, in patients with MAUD, monthly drug use (β = 0.147, t = 2.985, $p < 0.01$) and duration of drug use (β = 0.117, t = 2.368, $p < 0.05$) were positively associated with craving, highlighting the impact of drug use severity. In contrast, in patients with HUD, a younger age of drug initiation was negatively associated with OCDUS total score (β = −0.247, t = −2.27, $p < 0.05$), suggesting that earlier drug use may influence craving patterns differently in this group.

Discussion

This is the first large-sample study of the relationship between rumination and drug craving in Chinese patients with MAUD and HUD by extend the

Table 5 Significant variables in multiple stepwise regression of rumination and drug use characteristics to OCDUS total

Groups	Predictors	β	t	p	R^2 change
Patients with MAUD	RRS Symptom Rumination	0.324	6.898	< 0.001	0.11
	Quantity of use per month (milligram/month)	0.147	2.985	0.003	0.14
	Duration of drug use (years)	0.117	2.368	0.018	0.15
Patients with HUD	RRS Symptom Rumination	0.252	2.326	0.023	0.07
	Onset age of drug use (years)	−0.247	−2.279	0.026	0.06

geographical diversity of SUDs research [40]. The results showed that male patients with HUD exhibited greater levels of rumination and experienced greater drug craving compared to male patients with MAUD. Furthermore, drug craving was highly correlated with rumination in patients with MAUD. However, in the case of patients with HUD, the correlation was limited to the frequency of craving and the total score of rumination. Unexpectedly, symptom rumination was the only independent correlate of drug craving in both MA and heroin addiction. Age of drug initiation was associated with heroin craving, whereas factors such as drug dose and duration of drug use were found to be linked to cravings for MA. Our focus on these specific substances is essential, as it highlights the possibility of distinct neurobiological and psychological pathways that uniquely shape the relationship between rumination and craving. This critical aspect has not been examined in previous research. In addition, our findings reveal a consistent association between depressive symptom rumination and craving across both substance types, supporting the previous view that rumination constitutes a generalizable risk factor rather than a marginal or substance-specific factor [20].

In the present study, male patients with HUD had significantly higher levels of both rumination and drug craving than male patients with MAUD, contradicting the results of a previous study which suggested patients with MAUD may experience more severe craving and anxiety during withdrawal compared to patients with HUD [41]. These conflicting results may stem from differences in measurement accuracy [42], limited participant samples, and differences in addiction severity in previous studies [43].

Our findings revealed that all subtypes of rumination in patients with MAUD were associated with drug craving, consistent with prior research demonstrating a reciprocal relationship between rumination and substance use [20, 36]. Continued substance use induces neural adaptations in the striatum and cortical dopaminergic projections, impairing executive functioning and, in particular, reducing the ability to regulate negative emotions and control drug cravings [44]. Compared to healthy controls, patients with MAUD have structurally abnormal brains with diminished activation of inhibitory control regions, including the dorsolateral prefrontal cortex (DLPFC), anterior cingulate cortex, and putamen grey matter [45, 46]. Increased drug-related rumination due to a lack of flexible metacognitive control may lead to compulsive MA craving and relapse despite adverse consequences [47, 48].

Significantly, only the score of depressive symptom rumination was positively correlated with the total score of OCDUS in both male groups with MAUD and HUD. Symptom rumination is a subtype of depression-related rumination characterized by repetitive negative thoughts about depressive mood and distressing symptoms [32]. Our findings align with research on the biopsychosocial model of SUD, emphasizing the need for a comprehensive perspective to understand the interplay between craving, rumination, and their contribute to development of substance use [49]. Biologically, the neurotoxic effects of illicit drugs such as MA cause alterations in neurotransmitter functioning [50], which leads to increased sensitivity of the stress system and triggers attentional biases [51]. These neurobiological changes lead to an increased focus on negative emotions [52], which evolves into automatic cognitive processes of depressive rumination, further exacerbating depressive symptoms [53]. Psychologically, individuals with comorbid mood disorders and substance use disorders demonstrate heightened reward sensitivity [54, 55] and are more likely to be attracted to the reinforcing properties of substances as a means of escape [48] or to self-medicate their uncontrollable distress and cravings [56]. Socially, environmental factors, including peer influence and family dynamics, play a critical role in the amplification of craving, further compounding the risk of SUDs [57]. Eventually, depressive symptom rumination becomes a habitual pattern of maladaptive thinking that turns into a vicious emotion-cognition-behavior cycle.

From a neurocognitive perspective, there is a significant degree of overlap in the specific brain regions activated by depressive symptom rumination and addiction in male patients with MAUD and HUD. It has been demonstrated that there may be mutual underlying neurophysiological mechanisms. Previous studies have noted that persistent activation of the amygdala, ineffectiveness of the DLPFC, and aberrant activity in the default mode network [58] strongly contribute to drug-seeking [59, 60] and these factors have also been positively correlated with levels of depressive rumination in patients with MDD [61]. Therefore, patients with MAUD and HUD need more psychotherapies that target depressive symptom rumination and mood dysregulation, such as Rumination Focused Cognitive Behavioral Therapy [62] and mindfulness-based interventions, rather than focusing solely on withdrawal reactions. Moreover, rumination assessments and comorbid mental health conditions, such as depression and anxiety, should be incorporated into standard clinical screenings for patients with SUD [28].

The most striking finding was that symptom rumination was the only rumination subtype associated with OCDUS total score patients with HUD. Consistent with our study, reflective pondering was not associated with heroin intake in a cross-sectional study [19]. However,

this previous study revealed a significant association between brooding and more severe drug use [19], which contrasts with our results, suggesting that craving for psychostimulants and opioids may act through different rumination mechanisms. According to a runway model study of drug self-administration in animals, cocaine induces approach-avoidance conflict behavior, while heroin induces pure approach behavior [63], suggesting a partial dissociation of brain circuits involved in the regulation of psychostimulants and opioids [10]. Furthermore, based on our findings that drug craving in male patients with HUD was only associated with depressive rumination, we hypothesize that there is a partial dissociation between the neural circuits involved in the rumination subtype and craving for psychostimulants and opioids. This observation aligns with evidence from other studies suggesting that distinct neural mechanisms may underlie different subtypes of rumination [64]. Adaptive rumination was found to be linked to enhanced activity in the prefrontal cortex, whereas maladaptive rumination was associated with reduced activity. In the present study, the average duration of long-term drug use among male patients with HUD was more than ten years, which is significantly higher than in other relevant studies, leading to cumulative toxic effects on brain and cognitive functions [65]. Individuals with chronic heroin use experience have severe brain atrophy and neural damage to the pallidum [66], which plays a crucial role in the transition from motivation to action [67]. We hypothesize that the possible consequences of sustained damage to specific neural systems that support rumination mental activity (e.g., partial inactivation or absence of rumination circuits) may lead to a weak link between brooding and craving in chronic male patients with HUD. However, additional investigation is needed to provide a more comprehensive understanding of relationship between these neurological abnormalities and the development of cognitive impairment.

In addition, the study found that age at initiation of drug use was inversely associated with heroin craving, suggesting that an earlier age at initiation of drug use may be a risk factor for developing severe drug craving in male patients with HUD. Prior studies have shown that individuals who begin using drugs in adolescence or early adolescence have a higher probability of developing dependence and overall psychosocial problems compared to those who begin using drugs in adulthood [68]. Our observation of higher divorce and attempted suicide rates among patients with HUD is consistent with previous epidemiological studies, which have demonstrated that early drug initiation often leads to increased family, social, and legal difficulties that further intensify the craving for drugs [69]. Furthermore, the developing brain is more susceptible to impairments in synaptic plasticity, inhibitory functioning, and sensitization, leading to a persistent effect on specific aspects of addiction, such as craving, withdrawal, and relapse [69, 70]. Taken together, the earlier the age of addiction, the more severe the neurological damage and the more difficult the recovery. Our findings underscore the importance of early intervention programs and RCBF treatment aimed at adolescent patients with HUD to prevent the development of maladaptive rumination and craving patterns that contribute to addiction.

Limitation and future research directions

There are several limitations to this study. First off, the cross-sectional design prevented the establishment of a causal correlation between rumination and craving in both groups. Second, self-report data on alcohol/drug use behaviors introduce potential recall bias and subjectivity. Third, our sample included only Chinese males from a drug rehabilitation center, which limits the generalizability of our findings to females or other cultural contexts. Fourth, the data on the percentage of patients receiving opioid maintenance treatment (and the type of such treatment) were not collected, although maintenance treatment may have some impact on rumination and craving [71]. Finally, due to objective constraints, we were only able to recruit 81 patients with HUD, approximately one-fifth of the number of patients with MAUD, which may introduce potential selection bias. The post-hoc power analysis indicated that with the sample size of 81, the minimum detectable correlation coefficient was $r = 0.305$. It suggested that the sample size of patients with HUD maybe too small to observe a correlation between RRS and OCDUS scores. Future studies need to use larger sample sizes to assess more subtle associations.

Our study provides preliminary insights into the relationship between rumination and craving in patients with MAUD and HUD, and several avenues for future research exist. First, replication studies with larger and more diverse samples are needed to confirm the generalizability of these findings. Second, longitudinal investigations are crucial to better understand the causal relationships between rumination and craving over time. Such studies could track individuals through different stages of addiction and recovery to identify whether rumination acts as a predictor of relapse or treatment outcomes. Finally, the examination of comorbidities, such as psychiatric conditions like anxiety and depression, would provide a more comprehensive understanding of the mechanisms driving SUDs. Since rumination is closely linked to mood disorders, future research should explore how these comorbidities influence the rumination-craving relationship.

Conclusion

In summary, our findings suggest that male patients with HUD experience more severe rumination and craving during drug withdrawal than male patients with MAUD. Symptom rumination may be a potential risk factor for craving induction in both groups, suggesting that mood management and cognitive interventions targeting depressive rumination may be a generalized treatment for reducing craving in patients with MAUD and HUD. In addition, all rumination subtypes were highly correlated with craving for MA, suggesting that treatments to reduce rumination may also help reduce MA craving. However, future longitudinal studies of clinical assessment and rumination interventions to help control drug craving are warranted to confirm our findings.

Abbreviations

MA	Methamphetamine
MAUD	Methamphetamine use disorder
HUD	Heroin use disorder
SUD	Substance use disorder
OCDUS	Obsessive Compulsive Drug Use Scale
RRS	Ruminative Responses Scale
DLPFC	Dorsolateral prefrontal cortex

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Authors' contributions

Conceptualization, D.W.; methodology, D.W. and X.Z.; formal analysis, Y.M., D.L.; investigation, Y.M., D.L., J.C. and Y.T.; resources, L.J. and X.W.; data curation, J.C. and Y.T; writing—original draft preparation, Y.M. and D.L.; writing—review and editing, D.W. and X.Z.; supervision, L.J. and X.W.; project administration, D.W.; funding acquisition, X.Z. All authors have read and agreed to the published version of the manuscript.

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Data availability

The data that support the findings of this study are not openly available due to reasons of sensitivity and are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate

This study was approved by the Ethics Committee of the Institute of Psychology, Chinese Academy of Sciences and complied with the Declaration of Helsinki on informed consent and confidentiality. All participants in this study voluntarily agreed to participate and signed informed consent forms.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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