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ABSTRACT

Background: Many experimental studies and theoretical models have tried to explain the multi-faceted formation of drug addiction. In most addiction models, social factors are an important component; however, few empirical studies have investigated the social influences on the safe or risky choices of drug-addicted individuals during the abstinence stage. **Objectives:** To investigate the behavioral patterns of female methamphetamine abstiners under social influence. **Methods:** Thirty-seven female methamphetamine abstiners (average abstinence time: 8.61 ± 4.75 months) and 40 matched controls performed a gambling task in the presence of peers' choices. We applied both model-free and computational model-based analysis to examine how the decision patterns differed with social influence between the two groups. **Results:** 1) the choice data from the two groups showed a social influence effect such that participants made more risky choices when others made risky choices; 2) overall, the female methamphetamine abstiners made more risky choices in the social influence task; and 3) in the computational model parameters, the female methamphetamine abstiners exhibited more nonconforming attitudes (with negative other-conferred utility) with respect to peer influence, whereas controls showed higher conformity to peers. **Conclusion:** Our findings provide the first objective evidence that female methamphetamine abstiners show peer nonconformity. This nonconformist tendency may be a potential behavioral marker to track drug addiction and help to elucidate the mechanisms of decisions made by female methamphetamine abstiners.

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Introduction

Q3 30 Methamphetamine is a highly addictive drug related to the natural biochemical amphetamine (1). Epidemiological data show recent rapid increases in the production, development, and use of methamphetamine worldwide (2), including a notable increase in use in China (3). One key characteristic of substance dependence is its relapsing nature, such that more than 50% of individuals return to disordered drug use within one year (4). Substance use can be conceptualized as a series of stages ranging from initial exposure to experimental use, regular and/or heavy use, substance use-related problems, and diagnosable clinical substance use disorders (5,6). Many studies have shown that substance users exhibit varying degrees of cognitive impairment in terms of attention (7–9), inhibition control (10,11), decision-making (12), and interoception (13). Self-

control is one important predictor of drug use and recovery 45
from addiction and may help buffer individuals from addiction (14–16). Studies have shown that substance users have higher risk preferences in decision-making (17,18), as well as higher time discounts for future benefits (19,20). However, previous studies have primarily focused on individual decisions made by substance users, ignoring perceived social influence. Yet a deep interplay between a user's risk preference and others' influence may also be an important factor in substance users' decisions. 50

A given risk preference is generally considered to be a subjective preference, which should be relatively stable within an individual. However, human behavior, whether risky or not, does not exist in isolation; people tend to adjust their beliefs or decisions through social influence, according to others' opinions, choices, and attitudes in social life (i.e., social conformity) (21–24). Recent 55 60

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research has also shed light on the contagion effect, elucidating behavioral, and neural patterns in modulating risk-seeking/averse behavior (25). Interestingly, in a risky gambling task with or without knowledge of others' decisions, an individual's conformity is typically congruent with his or her personal risk attitude (26). That is, risk-averse individuals tend to conform to others' safe decisions while risk-seeking individuals tend to conform to others' risky decisions. Despite the importance of risk attitude in shaping our lives, little is known about how people's risk preference can be modulated by observing risky behavior in others, especially for supposedly more risk-prone individuals (e.g., substance users).

Although social influence has been largely neglected in the broader substance use literature, peer influence is considered a major cause of adolescent substance use (27). Researchers have asserted substance users' vulnerability to peer influence, which may manifest within a range of stages (e.g., addiction development or abstinence stages). For example, the influence of friends is associated with the initiation of adolescent substance use (28–30). The influence of conformity direction (e.g., toward the risky or safe position) on substance users could be multifaceted and remains unclear. For example, people may choose friends with similar substance use profiles due to an innate need for social acceptance or to avoid social isolation (31,32). However, one recent study showed that people within friendships with higher differences in self-control engaged in significantly more drug use (31). Therefore, people may select their peer influence, which could, in turn, drive more conformity behavior. In clinical applications, it is common to emphasize refusal skills when responding to risky peer pressure (i.e., nonconformity), as substance users may have fewer opportunities to interact with drug-free persons as they engage with the recovery process.

On the other hand, substance users are more likely to experience social rejection, and individuals who are socially isolated from their peers are more likely to try drugs (33,34). Recently, one study demonstrated that socially excluded people were unmotivated to process social influential information (35). In this respect, substance users may be unconcerned with the opinions of unrelated outside parties, exhibiting less susceptibility to social influence. Furthermore, as substance users are hypothesized to be more accepting of risk in their decisions, they may show more conformity toward risky peers, triggering more risky behaviors. Therefore, it remains unclear how substance users respond to risky or safe social influence. Combining conformity and economic decision-making paradigms may allow us to disentangle the processes of users' personal risk preference and influence selection to better understand the effects of social influence on substance users' behavior.

The gender factor should be considered as well, as disordered substance use has traditionally been considered a primarily male issue, and many substance use studies have been conducted with a preponderance of male subjects. However, male and female substance users' experiences vary greatly, particularly in the different stages of addiction. For example, during the acquisition phase, females may experience more pleasurable responses to drugs than men (36). Females also tend to progress more rapidly than males from initial experience to addiction (37–39). During the abstinence stage, females exhibit more unpleasant withdrawal symptoms than males (40,41). Females may also be more sensitive to stress or drug-related cues, which may lead to greater potential for relapse (42). Understanding the unique mechanisms mediating the path to addiction in females is important for improving prevention and enhancing treatment in female substance users. To address this, we will study an exclusively female sample.

With regard to the gender factor in social conformity, although social psychology textbooks typically assert that females are more easily conformed than males, there is no consistent empirical support for a sex difference in conformity. For instance, Eagly et al. found that of 61 group pressure conformity studies, 38 reported no difference, 21 studies found females to be significantly more conforming, and 2 found males significantly more conforming. Of 22 studies not involving group pressure, 19 reported no difference, 2 studies reported significantly greater conformity among females, and 1 reported significantly greater conformity among males (43). Similarly, another study found females' conformity significantly greater than that of males only with surveillance (44). Although there are inconsistent results regarding gender difference in social conformity, our research interests are not on gender difference, but specifically on females' behavioral pattern in a social influential task.

In light of pioneering studies investigating the development of social skills as a way to counter social influences promoting smoking (45,46), we will investigate how female methamphetamine users in abstinence behave under social influence, and try to explain the mechanism's influence on addiction. Although there is a large body of research on social influence and addiction formation, few studies link it to a social conformity paradigm to investigate the effect of social influence during the addiction abstinence stage. To address this gap, we will examine how female methamphetamine abstainers make decisions with or without information about others' choices, using an experimental setup in which participants make a series of choices in gambling alone and after viewing others' choices.

Methods

Participants

170 Initially, we recruited 90 inpatients from an addiction
rehabilitation center in Hebei Province, China, to take
part in eligibility screening for the current study. Among
the recruited inpatients, 53 participants were excluded
because they did not meet selection criteria (described
175 below). Thirty-seven females were selected as the female
methamphetamine abstiners (aged between 18 and 35
years, $M = 26.05$ years, $SD = 5.84$ years, drug experience
between 6 and 72 months, abstinence duration between
2 and 21 months) according to the selection criteria. All
180 inpatients were required to undergo a 24-month com-
pulsory detoxification program during which they were
isolated from the outside world and were unable to
access any drugs or alcohol.

The female methamphetamine abstiners had to satisfy
185 all the following criteria to be eligible for the study (1):
a positive urine test for methamphetamine before their
drug abstinence, with abstinence confirmed by the addic-
tion rehabilitation center (2); meeting the diagnostic cri-
teria for a history of methamphetamine use disorder, no
190 specifier of being in early or sustained recovery, without
any other substance use disorders (e.g., cocaine, heroin,
marijuana, alcohol) assessed with the Structured Clinical
Interview for the Diagnostic and Statistical Manual, fifth
edition (DSM-V) disorders (47); (3) no documented men-
tal diseases or brain injuries; and (4) no use of any psycho-
tropic medication within two weeks of the study
195 enrollment. Forty female healthy controls (aged between
19 and 33 years, $M = 27.63$, $SD = 3.67$) were recruited from
the same geographic area. They matched the female
200 methamphetamine abstiners in terms of age and educa-
tion but had no history of drug use (see Table 1). Using
a questionnaire of our own design, participants reported
their drug use time, abstinence time, cumulative drug
dosage, quantity of cigarettes consumed, and alcohol

usage per day for the month prior to beginning their 205
mandatory treatment. In addition, participants were
asked to complete the Sensation Seeking Scale–Version
V (SSS-V) (48) and the Barratt Impulsiveness Scale–
Version 11 (BIS-11) (49). All participants were right- 210
handed, with normal or corrected to normal visual acuity.
Each participant received 40 RMB as payment. This study
was carried out in accordance with the recommendations
of the Declaration of Helsinki. The protocol was approved
by the Institutional Review Board of the Institute of
Psychology of the Chinese Academy of Science. Informed 215
consent was signed by all participants.

Experimental procedures

The main task was adapted from Chung et al. (26).
Participants were asked to make economic choices between 220
a pair of two pies, in which one was riskier than the other
(with higher payoff variance than another pie), although
the probability of the two options within one pie was the
same. For example, in pie 1, participants have a 30% prob-
ability to receive 26.3 RMB and 70% to receive 25.2 RMB,
whereas in pie 2, participants have a 30% probability to 225
receive 66.3 RMB and 70% to receive 5.2 RMB. In this pair,
pie 2 was the riskier choice, since the probability was
controlled and the disparity between payoff was much
greater. In the main task, participants were asked to make
such decisions under two conditions (1): Solo condition, in 230
which the participants made their decision alone; or (2)
Info condition, in which the participant would first see the
decisions of two anonymous “others,” then make their own
decision (see Figure 1). The Solo and Info trials were
235 sequential in the current study, and the Solo block was
always presented before the Info block. Participants were
told that all decisions presented for their review in Info
trials were selected from data on previous participants’
choices in Solo trials. There were only eight trials in the
Solo block, to make this phase seem like a practice block 240
and to make participants trust the Info condition’s

Table 1.

Sample characteristics (mean ± SD)	Controls (n = 40)	female methamphetamine abstiners (n = 37)	<i>t</i>	<i>p</i> Values
Age (years)	27.63 ± 3.67	26.29 ± 5.72	1.22	0.23
Education (years)	9.07 ± 0.53	8.9 ± 2.3	0.48	0.64
Drug experience (months)	-	19.39 ± 14.1		
Abstinence time (months)	-	8.61 ± 4.75		
Methamphetamine use, lifetime (g)	0	312.47 ± 522.72		
Number of cigarettes per day	0	8.68 ± 8.86		
Alcohol use per day (g)	0	36 ± 77.3		
BIS-11	65.03 ± 10.42	65.86 ± 10.36	-0.35	0.73
Cognitive impulsiveness	16.63 ± 3.41	16.46 ± 2.78	0.23	0.82
Motor impulsiveness	20.75 ± 4.14	22.51 ± 4.05	-1.86	.07
Non-planning impulsiveness	27.9 ± 5.23	26.89 ± 5.71	0.8	0.43
SSS-V	11.45 ± 5.46	16.23 ± 4.77	-4.01	<0.001
Disinhibition	2.03 ± 1.76	3.86 ± 2.38	-3.82	<0.001
Experience seeking	3.33 ± 2.13	4.29 ± 1.78	-2.1	0.04
Thrill and adventure seeking	3.75 ± 2.86	5.74 ± 2.37	-3.27	0.002
Boredom susceptibility	2.35 ± 1.42	2.31 ± 1.51	0.11	0.82

Note. BIS-11, Barratt Impulsiveness Scale, Version 11; SSS-V, Sensation Seeking Scale Form V.

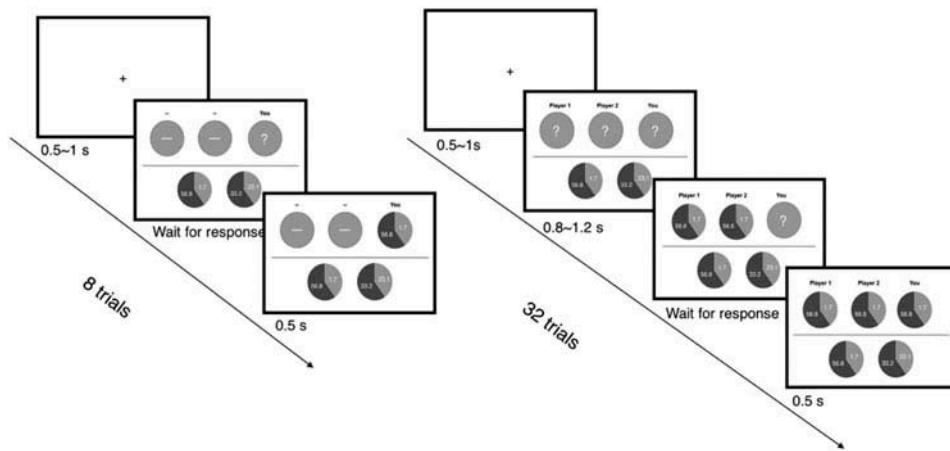


Figure 1. Task timeline for Solo and Info trials.

Each trial started with a “New Round” screen. Participants made a series of choices between two gambles, one of which was obviously riskier than the other. The decisions were made (a) alone (“Solo” trials) or (b) with information provided about other players’ selections (“Info” trials). At the start of each trial, a new pair of gambles was presented. For each pair, the safer (“safe”) gamble had lower payoff variance, while the riskier (“risky”) gamble had greater payoff variance. In Info trials, the decisions of two other individuals were displayed prior to the participant’s cue to enter a choice. Info and Solo trials were intermixed and drawn without replacement from a uniform distribution.

manipulation. After completing the Solo block, participants underwent three types of trials in the Info block: (i) “Info_safe” trials in which both of the two others choose the safe decisions, (ii) “Info_risky” trials in which both others choose the riskier decisions, and (iii) “Info_mix” trials in which the two others’ decisions were mixed (one safer and one riskier). As all female methamphetamine abstainers were given limited time for the experiment, in total, each participant had 32 Info trials in total randomly selected from 96 trials (4 lottery menus \times 6 payoff probabilities (40%, 50%, 60%, 70%, 80%, 90%) \times 3 trial types (Info_safe; Info_risk; Info_mix).

Before the experiment, all participants were told that no player’s choices affected the payoff of any other player, and all participants were paid at the end of the study.

Risky choice percentages analysis

Although the Solo block trial number is limited in the Solo block, we first computed the risky choice percentage in the Solo block and performed a two-sample t -test to measure whether the female methamphetamine abstainers and controls showed significant risk preference when they made decisions in isolation. For the Info block, we further calculated the overall percentage of risky choice in different types of Info trials (risky choice in mixed trials, risky choice in risky trials, and risky choice in safe trials). Afterward, we performed a mixed group (female methamphetamine abstainers vs. controls) \times trial type (safe vs. risky vs. mixed) analysis of covariance (ANCOVA) on the risky choice percentage with individual factors as covariables.

Other-conferred utility (OCU) model-based analysis

Utility theory suggests that participants’ subjective valuation (utility) of an uncertain option during decision-making tasks, which is evaluated using a basic two-parameter model including risk preference (ρ) and sensitivity (μ), relates to the perceived difference between the utilities of the paired options. However, an individual’s perceived utility for a given option might increase or decrease as a result of social influence. Adopting the work of Chung et al. (26), we applied the other-conferred utility (OCU) computational model to investigate how female methamphetamine abstainers and controls incorporate information from others during economic decision-making (Info trials). In the OCU model, an additional other-conferred utility is estimated as a constant addition of utility to the (safe or risky) gamble chosen by others.

$$U_{safe} = p(V_{hs})^\rho + (1 - p)(V_{ls})^\rho + OCU[\delta(\text{safe}, \text{safe})]$$

$$U_{risky} = p(V_{hr})^\rho + (1 - p)(V_{lr})^\rho + OCU[\delta(\text{risky}, \text{risky})]$$

$$P_{safe} = \frac{1}{1 + e^{-\mu(U_{safe} - U_{risky})}}$$

where p is the probability of earning the higher payoff, which is from 40% to 90% in this study. V_{hs} and V_{ls} are the value of high payoff and low payoff in the safe option, respectively, whereas V_{hr} and V_{lr} are the value in the riskier option. P_{safe} is the probability of choosing the safe option, guided by a sigmoid function. Notably, the estimated risk preference coefficient (ρ) indicates whether a participant is risk-neutral ($\rho = 1$), risk-seeking ($\rho > 1$) or risk-averse ($0 < \rho < 1$). The other-conferred utility indicates the change

of utility when both peers choose the same option, implying the level of social conformity. Specifically, other-conferred utility is added into the safe option when both peers choose the safe option ($\delta(\text{safe}, \text{safe}) = 1$), while other-conferred utility is added to the risky option when both peers choose the risky option ($\delta(\text{risky}, \text{risky}) = 1$).

Our primary hypothesis was that in the female methamphetamine abstainers and controls, others' choices of a risky (or safe) option would confer different trends of shifted utility for the risky and safe options, with the shift being quantified by other-conferred utility. We, therefore, performed one-way ANCOVA on ρ and OCU to compare the group differences in risk preference and social influence effect between the two groups with individual factors as covariables. We also provided the one-way ANCOVA on results of the sensitivity (μ) between groups.

Results

Risky choice percentage among two groups

In the Solo trials, there was no group difference in the risky choice percentage, $t_{75} = 0.62$, $p = .54$. In the Info trials, using measures of drug experience, abstinence time, cigarettes usage and alcohol usage as covariables, the group (female methamphetamine abstainers vs. controls) \times trial type (safe vs. risky vs. mixed) repeated measures ANCOVA revealed a main effect of trial type ($F_{2, 142} = 7.3$, $p < .001$, $\eta_p^2 = 0.09$). Further comparisons indicated significant differences across the three Info trial types (Info_risk > Info_mixed > Info_safe), suggesting that others' choices shift subjects' choices, such that participants made the most risky choices in the Info_risk condition ($M = 0.62$, $SE = 0.04$) and the least risky choices in the Info_safe condition ($M = 0.38$, $SE = 0.04$), all $p_s < 0.05$. However, there was no significant group difference regarding the risky choice percentage ($F_{1, 71} = 3.69$, $p = .06$) nor was there an interaction between group and trial type ($F_{2, 142} = 0.59$, $p = .57$) found (see Figure 2).

However, the Info_mixed condition may have limited the effect, as the observed pattern showed that the female methamphetamine abstainers made more risky choices in Info_safe trials (see Figure 2). To further explore this, we performed an additional group (female methamphetamine abstainers vs. controls) \times trial type (safe vs. risky) repeated measures ANCOVA test without Info_mixed data, using measures of drug experience, abstinence time, cigarette usage, and alcohol usage as covariables. ANCOVA analysis revealed a main effect of trial type ($F_{1, 71} = 9.96$, $p < .01$, $\eta_p^2 = 0.12$) and a main effect of group ($F_{1, 71} = 4.19$, $p < .05$, $\eta_p^2 = 0.06$), with the female methamphetamine abstainers ($M = 0.64$, $SE = 0.07$)

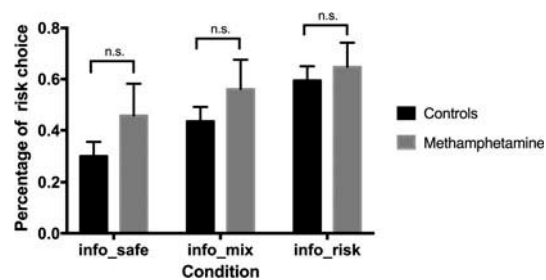


Figure 2. Risky choice percentage in information trials for female methamphetamine abstainers and controls.

Using measures of drug experience, abstinence time, cigarette usage, and alcohol usage as covariables, the group (female methamphetamine abstainers vs. controls) \times trial type (safe vs. risky vs. mixed) repeated analysis of covariance (ANCOVA) analysis revealed a main effect of trial type ($F_{2, 142} = 7.3$, $p < .001$, $\eta_p^2 = 0.09$, Info_risk > Info_mixed > Info_safe). A further group \times trial type repeated measures ANCOVA test without Info_mixed data revealed a main effect of trial type ($F_{1, 71} = 9.96$, $p < .01$, $\eta_p^2 = 0.12$), and a main effect of group ($F_{1, 71} = 4.19$, $p < .05$, $\eta_p^2 = 0.06$), with the female methamphetamine abstainers showing more risky choices than the controls. (Info_safe: trials in which both of the two others chose the safe decisions; Info_risk: trials in which both of the two others chose the riskier decisions; Info_mix: trials in which the two others' decisions were mixed [one safer and one riskier]).

showing more risky choices than the controls ($M = 0.37$, $SE = 0.07$). There was no interaction effect between group and trial type ($F_{1, 71} = 0.78$, $p = .38$).

Computation model results

Based on the OCU model analysis, we tested the group difference in model parameters directly. Using measures of drug experience, abstinence time, cigarette usage, and alcohol usage as covariables, the one-way ANCOVA first showed that the two groups did not display a difference in the risk preference parameter (ρ), $F_{1, 71} = 0.39$, $p = .53$. There was no significant group difference in sensitivity (μ), $F_{1, 71} = 2.28$, $p = .14$. However, the OCU values showed significant group difference, $F_{1, 71} = 4.85$, $p < .05$, $\eta_p^2 = 0.06$, indicating higher OCU for the control group ($M = 8.54$, $SD = 25.62$) than the female methamphetamine abstainers ($M = -10.56$, $SD = 27.03$). The positive OCU value in the control group and negative OCU value in the female methamphetamine abstainers further confirmed the presence of the conformity behavior in controls and nonconformity in the female methamphetamine abstainers (see Figure 3).

To further confirm the nonconformity behavior in the female methamphetamine abstainers, we performed a one-tail t -test to see whether the female methamphetamine abstainers had an OCU value significantly lower than 0. Indeed, the t -test results showed that the OCU of the female methamphetamine abstainers was significantly lower than 0, $t_{37} = -2.38$, $p = .02$.

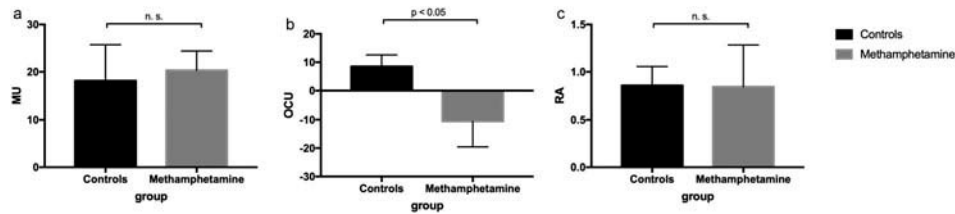


Figure 3. (A) The sensitivity (?) to the difference between the utilities of the paired options for controls and female methamphetamine abstainers displays no difference ($F_{1,71} = 2.28$, $p = .14$). (B) The other-conferred utility (OCU) values of female methamphetamine abstainers were significantly lower than that of controls ($F_{1,71} = 4.85$, $p < .05$). (C) The risk preference parameter (?) between controls and female methamphetamine abstainers displays no difference ($F_{1,71} = 0.39$, $p = .53$).

As impulsivity/sensation-seeking personality traits have been associated with different patterns of decision-making (50), we next explored the associations between the model parameters and impulsivity/sensation-seeking measures. Only the correlations between OCU and sensation-seeking were significant, $r = -0.26$, $p < 0.05$ (see Figure 4).

Discussion

The current study is driven by two opposite hypotheses. According to the social learning theory of drug addiction, people observe how others behave and then reproduce the behavior they witness. Thus, observing other people engaging in addictive behavior can lead to the development of drug addiction. Following this hypothesis, the female methamphetamine abstainers may be more likely to be influenced by others' choices and show higher conformity to others, especially with respect to risky choices. However, substance addiction is considered a socially deviant behavior, which is typically associated with social nonconformity (51). As conformity occurs when one's opinion or behavior is inconsistent with that of the majority, it may be

considered a social skill in conflict resolution (52). Based on this hypothesis, the female methamphetamine abstainers isolated in a compulsory detoxification center may also show loss of sensitivity to social influence. In the present study, we tested these two suppositions by combining a social conformity task and a risky economic game.

First, we did not find group difference in risk preference between the substance users and controls in the Solo trials. That is, the female methamphetamine abstainers did not show a predilection for more risky choices in the Solo trials when uninfluenced by social inputs. For the Info trials, the model-free results showed a marginally significant group difference, in that the female methamphetamine abstainers made more risky choices. However, the other-conferred utility model-based analysis (ρ), which took into account the risk (variance), probability, and others' choices, showed that there was no group difference in risk preference. It may be argued that the female methamphetamine abstainers are generally more risk-seeking, as drug use is a risky behavior, and various studies have proposed that drug use is associated with increased risky decisions by users (53–55).

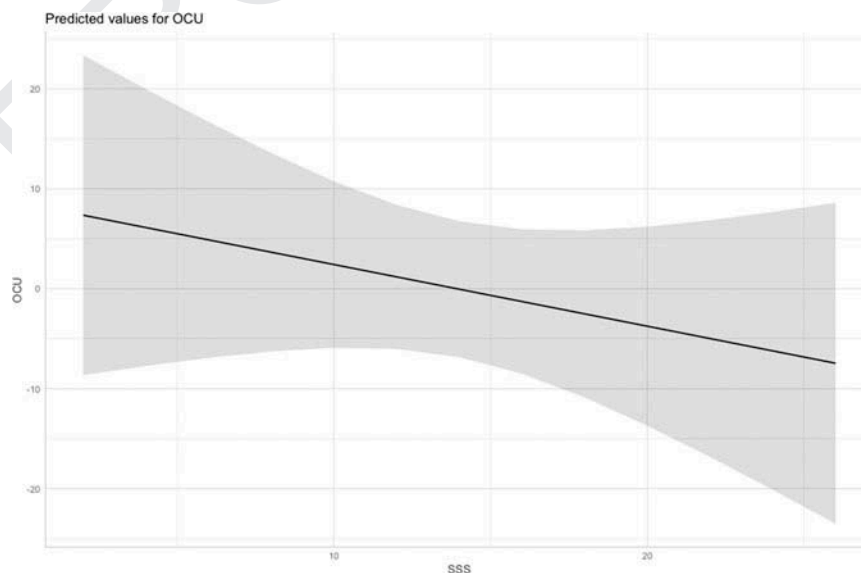


Figure 4. Correlation between other-conferred utility (OCU) and self-reported sensation-seeking score (SSS), $r = -0.26$, $p < .05$.

420 However, our finding is partially consistent with our
 previous study related to female methamphetamine abstain-
 425 ers in a treatment center, in which we found no between-
 group difference in risky choices in a simple gambling task
 (56). We believe that the relatively few trials observed (n =
 16 for Solo trials) may lead to this null difference in making
 risky decisions. Considering that research supports
 a gender difference in risky choices, such that a meta-
 analysis of 150 risk-taking studies showed that males take
 430 more risks than females in 14 out of 16 task types (57), the
 female-only sample in this study may skew the lack of
 significant risk preference among the female methamphete-
 mine abstainers. Another important consideration relates
 to the compulsory addiction rehabilitation center environ-
 ment. Results that have indicated in-treatment drug use
 435 patients demonstrate greater impulsivity or tolerance for
 risky behavior (55,58). However, individuals in compulsory
 addiction rehabilitation centers such as the female
 methamphetamine abstainers in our study, are under strict
 control and withdrawal treatment, which often focuses on
 440 reducing risk-taking behaviors. It is also important to note
 here that female methamphetamine abstainers in this com-
 pulsory addiction rehabilitation center have no access to
 monetary reward, which may also affect their motivation
 and risky choices in the economic task (59).

445 Our observed overall shifts in risky or safe choices
 toward others' choices in the control group are consis-
 tent with previous studies of normal individuals, which
 show various influences of group information on risk
 attitudes and other behaviors (60,61). As the other-
 450 conferred utility model parameters separated factors
 including probability, higher value in the payoff, and
 others' choices, the computation of OCU shows the
 degree of participants' behavioral assimilation to the
 choices of others. The positive OCU value among control
 455 participants replicates participants' choices under
 social influence by demonstrating that individual deci-
 sions change in the direction of others' choices (26),
 suggesting that control participants follow information
 on others' choices when making decisions. This confirms
 460 the explanation of how others' safe or risky decisions
 affects one's own decision-making among control parti-
 cipants (24,25). Surprisingly, among substance users, we
 found that the OCU value was negative, meaning female
 methamphetamine abstainers are less sensitive to social
 465 influence and may even behave in a specifically noncon-
 formist or counter-conforming manner under social
 influence. As indicated in the descriptive data for the
 Info trials (Figure 2), female methamphetamine abstain-
 470 ers made more risky choices when informed of others'
 safe choices whereas control participants followed both
 the risky and safe choices of peers. Such key difference
 between the female methamphetamine abstainers and

controls may show substance users' development of dif-
 ferent sensitivities to types of peer influence. That is, the
 female methamphetamine abstainers appear to be moti- 475
 vated to move toward more risky behavior when the
 majority chooses to be safe.

The nonconformity observed in female methampheta-
 mine abstainers here may also echo previous neuroimaging
 studies. Chung et al. found that the ventromedial prefrontal 480
 cortex encodes the added utility conferred by others'
 choices and predicts the likelihood of conforming to
 those choices. In particular, when participants conformed
 their behavior in opposition to their innate attitudes
 toward risky choices, activation in the anterior insula and 485
 dorsal anterior cingulate cortex increased (26). These find-
 ings point to the functional roles of the insula, dorsal
 anterior cingulate cortex, and ventromedial prefrontal cor-
 tex in linking individual risk preferences with perceptions
 of social influence and conformity (or not). Such insula, 490
 anterior cingulate cortex, and prefrontal cortex hypoacti-
 vations are often linked to disrupted cognitive control and
 decision-making in methamphetamine users (62-64). We
 recommend future neuroimaging investigation on this
 topic, as the dysfunction of the insula, anterior cingulate 495
 cortex, and prefrontal cortex may account for the noncon-
 forming tendency shown in female methamphetamine
 abstainers in the current study.

Another interesting result is the negative correlation
 between the sensation-seeking score and other-conferred 500
 utility, which suggests that the higher one's sensation-
 seeking, the more that individual tends to nonconforming
 behavior. Previous results showed that sensation-seeking
 and impulsivity are correlated with risk for antisocial
 behavior and addiction (65,66). This may indirectly indi- 505
 cate that OCU can reflect individuals' tendency toward
 nonconformity and may predict addiction behavior.

Most previous studies on social conformity with
 respect to drug users assessed an individual's preference
 using questionnaires, which found peer networks to be 510
 the strongest determinants of both initiation and main-
 tenance of drug use (28-30,67). However, prior research
 exploring the relationship between peer social network
 positions and smoking found that socially isolated indi- 515
 viduals were more likely to have experimented with
 cigarettes than were group members or liaisons (68,69).
 Furthermore, research using an interactive computerized
 ball-toss game found that the healthy controls demon-
 strated significant activation in the insula underlying
 social exclusion, whereas marijuana users did not (70). 520
 As conformity acts as a type of social conflict resolution,
 substance users' apparent unconcern about social con-
 text or signals may imply that these individuals are likely
 to show an overall nonconformist attitude. In the cur-
 525 rent study, using a laboratory paradigm for social

conformity, we provide the first experimental evidence that female methamphetamine abstainers under treatment show more nonconformist behavior in a risky gambling task, adding support for the association between nonconformity and addiction.

Study limitations

Several potential research implications emerge from the current study. The first limitation of the current study is that only female methamphetamine abstainers were included, and future researchers should be cautious when generalizing the results to male methamphetamine abstainers. Second, compared to the controls, the female methamphetamine abstainers we recruited from a compulsory addiction rehabilitation center are living in an extreme environment in which they are undergoing both strict treatment and social isolation. Third, to preclude the possible confounding effects of the use of other drugs, female methamphetamine abstainers were eliminated from the sample if any other substance use disorders were disclosed during screening. This manipulation may also limit the generalizability of our results: the participating individuals may not be representative of the typical female methamphetamine abstainer, as about half of female methamphetamine abstainers we interviewed in our screening sessions also used other drugs. Due to these limitations, the findings from the current study should not be generalized to males, older individuals, individuals who do not seek treatment or have sought treatment voluntarily. Further studies are needed to confirm the current findings in other populations.

Conclusions

Our findings revealed that when they make decisions in isolation, female methamphetamine abstainers show no tendency to make more risky choices while abstinent and under treatment. Instead, individuals with disordered methamphetamine use were more likely to make nonconforming decisions. The other-conferred utility computational model further confirmed these results, as well as the nonconformity trait in female methamphetamine abstainers. These findings add experimental evidence to the social influence effect during the abstinence stage of methamphetamine addiction and help to elucidate the mechanisms of decisions made by individuals engaged in disordered methamphetamine use.

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