Attention Bias Modification for Negative Affective Attention Bias in Methamphetamine Abstainers

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Abstract

This study examined, via a randomized controlled experiment, the intervention effects of Attention Bias Modification (ABM) on negative emotional attention bias among individuals undergoing methamphetamine withdrawal, and discussed the underlying cognitive mechanisms through cognitive modeling approaches. The results demonstrated that, compared to the control group, the ABM intervention group showed significant improvement in negative emotional attention bias following a single 40-minute intervention. Through analysis using the Drift Diffusion Model (DDM), we argue that this is attributable to the ABM intervention's ability to significantly attenuate participants' attentional enhancement towards negative emotional stimuli, while concurrently accelerating their attentional disengagement from such stimuli to a certain extent.

Full Text

Preamble

Title: Attentional Bias Modification for Negative Emotional Attentional Bias in Methamphetamine Abstainers

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Research Highlights: 1. This study is the first to apply ABM to intervene on negative emotional attentional bias in methamphetamine abstainers. 2. We propose that ABM may break the negative reinforcement pattern in methamphetamine abstainers and reduce relapse risk.

Short Abstract: This study employed a randomized controlled experiment to investigate the effects of Attentional Bias Modification (ABM) intervention on negative emotional attentional bias in methamphetamine abstainers and explored its underlying cognitive mechanisms through cognitive modeling. Results showed that compared with the control group, the ABM intervention group exhibited significant improvement in negative emotional attentional bias after a single 40-minute intervention. Through Drift Diffusion Model (DDM) analysis, we suggest that this is because ABM intervention can significantly weaken participants' attentional enhancement process toward negative emotional stimuli while also accelerating their attentional disengagement process from such stimuli to some extent.

Keywords: methamphetamine abstainers, negative emotional attentional bias, attentional bias modification, drift diffusion model

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Attentional Bias Modification for Attentional Bias Towards Negative Emotional Stimuli on Methamphetamine Abstainers

Abstract

This study investigated the effectiveness of attention bias modification (ABM) in reducing the attentional bias towards negative emotional stimuli on methamphetamine abstainers and explored the underlying mechanisms using the drift diffusion model (DDM). A total of 43 male methamphetamine abstainers were randomly assigned to either an ABM group (n=20) or a control group (n=23). The ABM group received a 40-min training section to shift attention bias away from negative emotional faces, while the control group received placebo training. Results revealed a significant reduction in attentional bias towards negative emotional stimuli on the ABM group, compared with control group. DDM analyses further suggested that ABM intervention could reduce the process of participants' attentional enhancement while quicken the process of attentional disengagement towards negative emotional stimuli. This finding highlights the potential of ABM as a tool to reduce drug addicts' relapse risk by breaking their negative reinforcement behavior patterns.

Key words: methamphetamine abstainers, attentional bias towards negative

emotional stimuli, attentional bias modification, drift-diffusion model

Drug abuse represents one of the major global challenges threatening human survival and development. According to the United Nations' *World Drug Report 2023*, the number of global drug users exceeded an estimated 296 million in 2021, representing a 23% increase over the past decade. Additionally, the number of people with drug addiction has risen sharply to 39.5 million, a staggering 45% increase over ten years. A critical challenge in addressing drug problems is preventing relapse. Relapse refers to the behavior of returning to addiction after maintaining abstinence for a period of time (曾晓青 et al., 2019). Research indicates that in Western countries with good detoxification conditions and methods, the probability of relapse among drug abstainers exceeds 60% within six months, while in developing countries, the relapse rate is generally above 90% (Mao et al., 2024; Jia et al., 2024). Thus, effectively reducing relapse rates among drug addicts is a core challenge in current addiction treatment work, and exploring and implementing an effective intervention method may be key to solving this problem.

Attentional Bias Modification (ABM) is an intervention method that uses cognitive training to alter the automatic attentional bias toward negative social stimuli in psychopathological populations, thereby improving their susceptibility to social stress and psychopathological symptoms (MacLeod, 2023). This technique has been widely applied in interventions for mental disorders such as anxiety, depression, and post-traumatic stress disorder (PTSD) (MacLeod, 2023; McNally, 2019). ABM interventions primarily target attentional biases toward two types of stimuli: appetitive stimuli (e.g., social stimuli for social phobia patients (Chen et al., 2015)) and negative emotional stimuli (e.g., sad, disgusted stimuli for depressed patients (Holas et al., 2020)). These studies demonstrate that ABM can effectively modify patients' attentional biases toward these stimuli, thereby improving symptoms and mental health status, showing broad application prospects.

In recent years, ABM has begun to be applied in substance addiction intervention research, yielding certain effectiveness (alcohol addiction: den Uyl et al., 2017; methamphetamine addiction: Dean et al., 2019; nicotine addiction: Robinson et al., 2022; alcohol and cannabis addiction: Heitmann et al., 2021; van der Baan et al., 2024). However, existing research has primarily focused on attentional biases toward addiction-related stimuli formed by addicts due to their impulsive characteristics; consequently, these interventions have generally targeted appetitive cue stimuli (e.g., cannabis images) rather than negative emotional stimuli. Nevertheless, according to the negative reinforcement affective processing model of addiction, avoiding negative emotions is the core motivation driving individuals to use drugs and relapse (Baker et al., 2004; 朱海燕, 沈模卫, & 张锋, 2006). According to this model's perspective, when facing stress or negative emotions, addicts are more inclined to use drugs to escape and alleviate these negative feelings, thereby forming a negative reinforcement mechanism that prompts them to repeatedly use drugs.

Research indicates that drug abstainers are more likely to develop attentional biases toward negative emotional stimuli (曾宁宁, 张萌, & 李新宇, 2017), a characteristic that strengthens the negative reinforcement mechanism of drug use, leading them to be more prone to relapse when encountering negative experiences. Therefore, applying ABM to intervene on drug addicts' attentional bias toward negative emotions holds promise for breaking this negative reinforcement mechanism and thereby reducing their probability of relapse.

Although ABM intervention research has shown initial success, investigations into its mechanisms remain scarce (MacLeod, 2023). In recent years, cognitive modeling approaches represented by the Drift-Diffusion Model (DDM) have been gradually applied to explore the mechanisms of mental disorder interventions and pathology (Price et al., 2019; Hales et al., 2023; Zhang et al., 2023).

DDM describes individuals' decision-making response process, where information is continuously accumulated until a decision threshold is reached (Ratcliff & McKoon, 2008). Existing research indicates that changes in various DDM parameters can reflect different cognitive processes; for example, t0 reflects the attentional enhancement process toward threatening stimuli (Price et al., 2019; Zhang et al., 2023), while v reflects the attentional disengagement process from threatening stimuli (Zhang et al., 2023). DDM can help us more precisely quantify underlying psychological processes and provide a new perspective for understanding the cognitive mechanisms of ABM intervention.

According to the *2023 China Drug Situation Report* released by the China National Narcotics Control Commission, methamphetamine abusers account for as high as 57.59% of major drug abusers. Therefore, this study will use the dot-probe task, the most commonly used paradigm for reflecting individual attentional bias (McNally, 2019), to explore the intervention effects of ABM based on negative emotional stimuli on negative emotional attentional bias in methamphetamine abstainers and examine its underlying cognitive mechanisms through DDM analysis.

2.1 Participants

This study recruited 60 male methamphetamine abstainers from a compulsory isolation drug rehabilitation center in Zhejiang Province, who were randomly assigned to either an ABM intervention group or a control intervention group. All participants had completed physiological detoxification, had no history of psychiatric disorders, and had normal or corrected-to-normal vision.

Data from 43 participants were ultimately included in the analysis (see Table 1 for details). This study was approved by the Medical Ethics Committee of the Department of Psychology and Behavioral Sciences at Zhejiang University, and all participants volunteered to take part in the experiment.

2.2 Experimental Design

This study employed a mixed 2 (participant type: ABM intervention group, control intervention group) × 2 (test phase: pre-test, post-test) design, where participant type was a between-subjects variable (ABM intervention group received ABM intervention, control intervention group received control intervention) and test phase was a within-subjects variable. Dependent variables included attentional bias index, emotional experience scores, craving scores, and cognitive modeling-related parameters.

2.3.1 Self-Report Questionnaires

A self-compiled questionnaire was used to collect participants' demographic information, including age, education level, and duration of drug use. The Self-Rating Depression Scale (SDS, Zung, 1965) and Self-Rating Anxiety Scale (SAS, Zung, 1971) were administered to assess participants' emotional states.

2.3.2 Negative Emotional Attentional Bias Measurement Procedure

This study used an adapted dot-probe paradigm (McNally, 2019) to measure participants' negative emotional attentional bias. The experimental procedure was programmed using E-Prime 3.0. Experimental materials were selected from the MacArthur Face Stimulus Set, and permission for use was obtained from the set's creator, Professor Nim Tottenham. The materials included one neutral, one disgust, and one fear face image for each of 10 male and 10 female models. All selected images had good facial expression discriminability to ensure participants could easily perceive the facial expressions. Additionally, to avoid familiarity effects, face images used in practice trials were not repeated in formal trials.

The trial procedure is illustrated in Figure 1 [Figure 1: see original paper]. Each trial began with a 500ms fixation point at the center of the screen, followed by two face images appearing simultaneously on the left and right sides of the screen center for 500ms. One image was a neutral face, and the other was a negative emotional face. After a random blank interval of 100-300ms, a probe appeared randomly on one side of the screen for 150ms. Participants were required to judge the orientation of the probe after it disappeared and make a key press response on the blank screen. Response time and accuracy were recorded. Trials in which the probe appeared on the same side as the negative face were congruent trials; otherwise, they were incongruent trials. The two trial types were presented randomly with equal frequency (50% each), comprising 20 practice trials and 320 formal trials.

This study used the attentional bias index to reflect participants' attentional bias toward negative emotional stimuli. The index was calculated by subtracting the mean reaction time of correct congruent trials from that of correct incongruent

trials. An attentional bias index greater than 0 indicated an attentional bias toward negative emotional stimuli, whereas a value less than 0 indicated bias toward neutral stimuli. The absolute value of the attentional bias index reflected the magnitude of attentional bias.

2.3.3 Negative Emotional Attentional Bias Modification (ABM) Intervention Procedure

The ABM intervention used the same experimental procedure and materials as the negative emotional attentional bias measurement procedure, with the crucial difference that all probe stimuli appeared on the side of the neutral face images. The logic of ABM intervention is that through repeated presentation of the pairing between probe stimuli and neutral faces, participants would unconsciously prioritize attentional orientation toward neutral faces after extensive training to achieve better performance, thereby achieving the effect of modifying negative emotional attentional bias. In the control intervention condition, probe distribution frequency was consistent with the attentional bias measurement procedure. Both training procedures consisted of 640 trials.

2.3.4 Emotional Experience and Craving Measurement

This study used seven Visual Analogue Scale (VAS) items to reflect participants' emotional experience and craving at different time points. The first six items required participants to select a number from 1 to 7 to indicate their current level of emotional experience, with higher numbers indicating more negative emotional experience. The seventh item required participants to select a number from 1 to 10 to indicate their current craving for drugs, with higher numbers indicating stronger craving. All items were programmed using E-Prime 3.0 and presented at the center of the computer screen, with response options displayed at the bottom.

2.3.5 Drift Diffusion Model (DDM) Parameters for Negative Emotional Attentional Bias

The fast-dm-30.2 software (Voss, 2015) (https://www.psychologie.uni-heidelberg.de/projekt/fast-dm/) was used to conduct DDM modeling on the pre- and post-test negative emotional attentional bias measurement data from both groups to further reveal the cognitive processes associated with ABM intervention. The parameter settings for fast-dm command files in this study were consistent with previous research (Voss et al., 2015; Price et al., 2019).

This study focused primarily on the t0 parameter, which reflects the attentional enhancement process toward negative stimuli (Price et al., 2019; Zhang et al., 2023), and the v parameter, which reflects the attentional disengagement process from negative stimuli (Zhang et al., 2023). If ABM intervention weakens the attentional enhancement process toward negative emotions, a decrease in

Δt0 would be observed; if ABM intervention accelerates the attentional disengagement process from negative emotions, an increase in Δv would be observed (Zhang et al., 2023). The calculation formulas for Δt0 and Δv are as follows (Price et al., 2019; Zhang et al., 2023):

Δt0 = t0 of incongruent trials - t0 of congruent trials
Δv = v of incongruent trials - v of congruent trials

Before the experiment began, participants completed self-report questionnaires to control for potential confounding effects of demographic factors and pre-training emotional states on the results. Subsequently, participants underwent negative emotional attentional bias measurement. After a brief rest, participants were randomly assigned to either the ABM intervention group or the control intervention group to receive the corresponding training. Following the intervention, participants completed the negative emotional attentional bias measurement again. Additionally, to assess changes in participants' emotional experience and craving levels, VAS measurements were administered before and after each negative emotional attentional bias measurement.

All experimental materials and data from this study have been uploaded to the Psychological Science Data Bank (https://www.scidb.cn/psych).

3.1 Outlier Removal

Before formal analysis, outliers in the data were removed according to the following criteria: (1) overall response accuracy less than 80%; (2) error trials; (3) trials with extremely short reaction times (<150ms) or excessively long reaction times (>2000ms); and (4) trials with reaction times beyond $±$2 standard deviations from the mean reaction time (Iacoviello et al., 2014). A total of 43 participants were included in the final analysis, comprising 20 in the ABM intervention group and 23 in the control intervention group. Demographic information for the valid participants is presented in Table 1 .

Note: Values in parentheses represent standard deviations. SDS = Self-Rating Depression Scale, SAS = Self-Rating Anxiety Scale.

3.2 Intervention Effects of Negative Emotional Attentional Bias Modification

The negative emotional attentional bias indices for both groups before and after training are shown in Figure 2 [Figure 2: see original paper]. A mixed ANOVA on the attentional bias index with 2(participant type) × 2(test phase) revealed that neither the main effect of participant type ($F(1,41)=2.39$, $p=0.13$, $p^2=0.06$, $BF10=0.53$) nor test phase ($F(1,41)=1.84$, $p=0.18$, $p^2=0.04$, $BF10=0.50$) was significant, but the interaction between the two factors was marginally significant ($F(1,41)=3.47$, $p=0.07$, $p^2=0.08$, $BF10=0.46$). Simple effects analysis found no significant difference in attentional bias indices between the ABM intervention and control groups at pre-test ($F(1,41)=0.13$, $p=0.72$,

p^2<0.01, BF10=0.24), but a significant difference at post-test (F(1,41)=4.85, p=0.03, p^2=0.11, BF10=3.87). This indicates that compared with the control intervention group, participants who underwent a single ABM intervention showed significantly reduced attentional bias toward negative emotions.

Analyses of emotional experience scores and craving scores revealed no differences between the two groups (ps > .05); detailed analyses are provided in the supplementary materials.

3.2 DDM Analysis Results of Negative Emotional Attentional Bias Modification Intervention

The Δt0 values for both groups at pre- and post-test are shown in Figure 3 [Figure 3: see original paper]. A mixed ANOVA on Δt0 with 2(participant type) × 2(test phase) revealed significant main effects of participant type (F(1,41)=4.07, p=0.05, p^2=0.09, BF10=1.15) and test phase (F(1,41)=5.89, p=0.02, p^2=0.13, BF10=2.37), and a significant interaction between the two factors (F(1,41)=4.22, p=0.05, p^2=0.09, BF10=4.76). Simple effects analysis found no significant difference in Δt0 between the ABM intervention and control groups at pre-test (F(1,41)=0.06, p=0.81, p^2<0.01, BF10=0.36), but a significant difference at post-test (F(1,41)=8.46, p=0.006, p^2=0.17, BF10=14.92). This indicates that compared with the control intervention group, the ABM intervention group showed significantly weakened attentional enhancement toward negative emotional stimuli after a single ABM intervention.

The Δv values for both groups at pre- and post-test are shown in Figure 4 [Figure 4: see original paper]. A mixed ANOVA on the attentional bias index Δv with 2(participant type) × 2(test phase) revealed no significant main effect of participant type (F(1,41)=1.77, p=0.19, p^2=0.04, BF10=0.49), a significant main effect of test phase (F(1,41)=4.14, p=0.05, p^2=0.09, BF10=1.29), and a marginally significant interaction between participant type and test phase (F(1,41)=2.92, p=0.095, p^2=0.07, BF10=0.78). Simple effects analysis found no significant difference in Δv between the ABM intervention and control groups at pre-test (F(1,41)=0.05, p=0.83, p^2<0.01, BF10=0.26), but a marginally significant difference at post-test (F(1,41)=3.49, p=0.07, p^2=0.08, BF10=2.25). This indicates that compared with the control intervention group, the ABM intervention group showed accelerated attentional disengagement from negative emotional stimuli to some extent after a single ABM intervention.

This study employed an adapted dot-probe paradigm (McNally, 2019) to conduct negative emotional attentional bias modification (ABM) intervention on methamphetamine abstainers, aiming to explore the intervention effects of ABM and its underlying cognitive mechanisms. The results indicate that a single 40-minute ABM intervention can effectively improve negative emotional attentional bias in methamphetamine abstainers. Furthermore, this study used cognitive modeling methods (DDM, Voss et al., 2015) to analyze the negative emotional attentional bias measurement data before and after intervention. The findings

revealed that after a single 40-minute ABM intervention, methamphetamine abstainers' attentional enhancement process toward negative emotional stimuli (Zhang et al., 2023) was significantly weakened, and their attentional disengagement process from negative emotional stimuli (Zhang et al., 2023) was also accelerated to some extent. Additionally, Price et al. (2019) found that fMRI contrast values in brain regions involved in emotion and attention regulation (incongruent minus congruent trial responses) were negatively correlated with Δt0 (Price et al., 2019), meaning that when Δt0 decreases, participants' emotion and attention regulation abilities increase. This may also suggest that the ABM intervention used in this study simultaneously enhanced methamphetamine abstainers' emotion and attention regulation abilities.

In summary, a single ABM intervention can effectively improve methamphetamine abstainers' attentional bias toward negative emotional stimuli, demonstrating broad application prospects as a potential intervention approach to break negative reinforcement patterns and reduce relapse risk. However, this study only conducted one 40-minute intervention, making it impossible to determine its long-term effects on methamphetamine abstainers. Moreover, changing attentional bias to improve emotional experience and reduce craving may be a gradual, cumulative process (Wolz et al., 2020). Therefore, future research should implement longer-term ABM interventions for methamphetamine abstainers and examine their effects on emotional experience and craving over extended periods to more comprehensively evaluate their applied value.

The main conclusions of this study are: 1. A single ABM intervention can effectively improve methamphetamine abstainers' attentional bias toward negative emotional stimuli; 2. Based on cognitive modeling (DDM) analysis, ABM intervention may achieve its cognitive intervention effects by directly weakening methamphetamine abstainers' attentional enhancement process toward negative emotional stimuli while simultaneously accelerating their attentional disengagement process from such stimuli.

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Note: Figure translations are in progress. See original paper for figures.