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CHAPTER 5

THE APPROACH BIAS & FUTURE CANNABIS USE

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ABSTRACT

Repeated drug exposure can lead to an approach bias, i.e., the relatively automatically triggered tendencies to approach rather that avoid drug-related stimuli. This approach-bias has been though to play an important role in the development of addictive behaviors. The main aim of this study was to investigate the approach-bias in heavy cannabis users and to investigate the predictive relationship between an approach bias for cannabis-related materials and levels of cannabis use, craving, and the course of cannabis use. Approach and avoidance action-tendencies towards cannabis and neutral images were assessed with an Approach Avoidance Task (AAT) in 32 heavy cannabis users and 39 non-using controls. During the AAT, participants pulled or pushed a joystick in response to image orientation. To generate additional sense of approach or avoidance, pulling the joystick increased picture size while pushing decreased it. Craving was measured pre- and post-test with the multi-factorial Marijuana Craving Questionnaire (MCQ). Cannabis use frequencies and levels of dependence were measured at baseline and after a six-month follow-up. Heavy cannabis users demonstrated an approach-bias for cannabis images, as compared to controls. The approach-bias predicted changes in cannabis use at six-month follow-up. The pre-test MCQ emotionality and expectancy factor were associated negatively with the approach-bias. No effects were found on levels of cannabis dependence. These results imply that heavy cannabis users with a strong approach-bias for cannabis are more likely to increase their cannabis use. This approach-bias could be used as a predictor of the course of cannabis use to identify individuals at risk for increasing cannabis use.

INTRODUCTION

Cannabis is the most commonly used illegal drug in most countries and treatment demands have strongly increased over the last decades (UNDOC World Drug Report 2009; Degenhardt et al., 2008; Perkonigg et al., 2008). Growing awareness of addictive properties of cannabis is accompanied by growing need for research investigating cannabis abuse and dependence. A key question in research on addiction is why some individuals escalate from recreational use to problematic use, while others do not. From all heavy cannabis users (defined as using cannabis on at least ten occasions per month) an estimated seven to eight percent meets DSM-IV criteria of dependence (UNDOC World Drug Report 2009; Degenhardt et al., 2008; Perkonigg et al., 2008). Identifying predictors of the course of cannabis use is crucial for development of effective prevention strategies.

Inability to control drug use is considered a core aspect of drug dependence (Bechara, 2005; Koob and Volkow, 2010; Robinson and Berridge, 2000; Verdejo-Garcia and Bechara, 2009; Wiers et al., 2007). Despite awareness of harmful consequences, an addicted person compulsively continues to use drugs, with frequent failed attempts to cut down or quit. These addictive behaviors have been hypothesized to arise from an imbalance between an approach oriented motivational system and a regulatory executive system. After repeated drug exposure, the motivational system becomes sensitized towards a drug, which can lead to relatively automatically triggered tendency to approach drug-related stimuli (Wiers et al., 2007; Wiers et al., 2009b). A drug oriented motivational system combined with insufficient executive resources (possibly compromised by drug use) promote escalation of drug use.

Cognitive biases for drug-related cues are thought to be behavioral manifestations of a drug oriented motivational system. An abundance of studies, mainly focusing on alcohol and tobacco use, highlight roles of attentional, approach, and evaluative biases in the development and maintenance of addictive behaviors [(Bradley et al., 2004; Ehrman et al., 2002; Field et al., 2008a; Field et al., 2005; Mogg et al., 2003; Mogg et al., 2005; Ostafin and Palfai, 2006; Palfai and Ostafin, 2003; Waters and Feyerabend, 2000); for review see (Stacy and Wiers, 2010)]. In drug-abusing and -dependent individuals compared to non-dependent individuals, drug-related cues automatically capture attention, evoke approach tendencies, and are evaluated as more positive and arousing in comparison to neutral cues. Recently, evidence has emerged that these processes are also present in heavy cannabis users. Unlike controls, heavy cannabis users are biased in detecting subtle cannabis-related changes in complex scenes (Jones et al., 2002; Jones et al., 2003), implying higher attention to cannabis than neutral cues. Further, in heavy cannabis users, an attentional bias for cannabis-related words is associated with craving, frequency of use, and severity of dependence (Field, 2005; Field et al., 2006). Compared to non-users, heavy cannabis users maintain their gaze longer upon cannabis cues, are faster in approaching cannabis cues, and rate cannabis cues as more pleasant compared to neutral cues (Field et al., 2006). Finally, in

adolescents at risk for drug-abuse, evaluative biases, measured with a word association task and Implicit Association Task (IAT), were found to predict cannabis use (Ames et al., 2007).

The cognitive bias central in this study is an approach bias for cannabis-related stimuli. Tasks previously used to assess an approach bias for substance-related stimuli are the Stimulus Response Compatibility Task (SRC; Bradley et al., 2004; Field et al., 2006; Field et al., 2008a; Field et al., 2005; Mogg et al., 2005), IAT (Ostafin and Palfai, 2006; Palfai, 2006; Palfai and Ostafin, 2003), and Approach Avoidance Task (AAT; Rinck and Becker, 2007; Wiers et al., 2009b; Wiers et al., 2010). These tasks differ on a number of dimensions. First, in both the SRC and IAT, participants are explicitly instructed to categorize target stimuli (e.g., substance-related or neutral) with 'approach' in one block and 'avoid' in another block of the task (in the SRC, but not the IAT, this is accompanied by a symbolic approach or avoidance movement of a manikin). The approach bias is then derived from RT-differences between these two categorizations. In contrast, the AAT measures approach and avoid action tendencies by asking participants to pull or push a joystick in response to a content-irrelevant feature, for example format or orientation of images (Rinck and Becker, 2007; Wiers et al., 2009b; Wiers et al., 2010). The AAT also uses a zooming feature: pulling the joystick increases the picture's size while pushing decreases it, which in itself already generates sense of approach or avoidance, respectively. Combining this zooming feature with actual arm flexion and extension results in more realistic approach and avoid actions, as compared to the SRC and IAT (for a comparison between SRC and AAT see Krieglmeyer and Deutsch, 2010). Further, responding to a feature irrelevant to the content might be more likely to tap into automatic motivational processes (De Houwer, 2003).

Regarding the approach bias in cannabis users, to the best of our knowledge, only one SRC study exists, which showed faster (biased) approach responses to cannabis cues in heavy cannabis users compared to non-users (Field et al., 2006). The aim of the present study was to investigate the approach bias in cannabis users with the AAT, and to investigate the predictive relationship between the approach bias and levels of cannabis use, craving, and the course of cannabis use over six months. We hypothesized that cannabis users would show a stronger approach bias towards cannabis-related images compared to controls. We expected that a stronger approach bias in heavy cannabis users would be related to higher levels of craving and cannabis use and problems. We also expected that heavy cannabis users with larger approach biases would be more likely to increase cannabis use and levels of dependence after six months.

MATERIALS AND METHODS

Participants

Thirty-two heavy cannabis users and forty-one controls aged 18-25 were recruited through advertisements on the Internet and in cannabis outlets (coffee shops). Groups were matched for age, gender, and estimated intelligence (Nelson, 1984; Schmand et al., 1991), see Table 1. Heavy cannabis use was defined as using cannabis 10 or more days last month, at least 240 days last two years, and not seeking treatment or having a history of treatment for cannabis use. Participants in the control group used cannabis on less than 50 lifetime occasions and did not use last year (Pope et al., 2001). Drug and alcohol use was controlled for by excluding participants with an Alcohol Use Disorder Identification Test (AUDIT) score higher than 10 (Saunders et al., 1993), smoking daily more than 20 cigarettes, or using non-cannabinoid drugs on more than 100 occasions (Kouri et al., 1999; Pope et al., 2001). Other exclusion criteria were a history of major medical, physical, or psychiatric disorders, which was assessed with the Mini-International Neuropsychiatric Interview [MINI (Sheehan et al., 1998), Dutch version 5.0.0]. The medical ethics committee of the Academic Medical Centre approved the study and all participants signed informed consent before participation.

Cannabis use, tobacco use, and craving

Cannabis use and related problems were assessed with the Cannabis Use Disorder Identification Test (CUDIT; Adamson and Sellman, 2003) and a structured diagnostic interview [MINI (Sheehan et al., 1998), Dutch version 5.0.0]. The CUDIT is a screening-instrument for at-risk cannabis use and consists of 10 items on cannabis use-frequencies, symptoms of dependence, and use-related problems (Adamson et al., 2010; Adamson and Sellman, 2003). From the diagnostic interview, DSM-IV criteria-count for cannabis dependence was used for analysis. In addition, history of past and present cannabis use was obtained (e.g., lifetime episodes, duration of heavy use, days per week, weekly use in gram, ways of using). Tobacco use and dependence were measured with the Fagerström Test for Nicotine Dependence (FTND; Heatherton et al., 1991). The short version of the Marijuana Craving Questionnaire (MCQ) was used to assess craving before (pre-test) and after (post-test) test-session (Heishman et al., 2009). The MCQ is reliable for assessing craving in cannabis users not seeking treatment (Heishman et al., 2009; Heishman et al., 2001). Items were rated on a Likert response scale ranging from 1 (strongly disagree) to 7 (strongly agree). It distinguishes four three-item craving factors: compulsivity (inability to control use, e.g., 'I need to smoke marijuana now'), emotionality (relief from withdrawal and negative affect, e.g., 'I would feel less anxious if I smoked marijuana right now'), expectancy (anticipation of positive outcomes, e.g., 'smoking marijuana would make me content'), and purposefulness (planning/intention to use for positive outcomes, e.g., 'smoking marijuana would be pleasant right now'). Craving scores for

each factor were obtained by summing item scales. Pre-test, post-test, and pre-test post-test difference scores were used as independent variables.

Approach Avoidance Task

An adapted AAT (Rinck and Becker, 2007; Wiers et al., 2009b; Wiers et al., 2010) was used to measure biases in automatic action-tendencies towards cannabis (see Figure 1). Participants viewed 20 cannabis-related images and 20 neutral images. Cannabis-related images were close-ups of cannabis, objects for using cannabis, and individuals smoking cannabis. Neutral images were close-ups of individuals and objects visually matched to the cannabis-related images on color and composition. All images were rotated 3° left or right. Image content was irrelevant to the task: participants were instructed to pull or push a joystick in response to rotation direction. Half of participants pushed images rotated left and pulled images rotated right while the other half received opposite instructions. Pulling and pushing the joystick gradually increased and decreased image-size. This zooming feature combined with arm flexion and extension mimics approach and avoid actions (Rinck and Becker, 2007; Wiers et al., 2009b; Wiers et al., 2010). Each image was presented four times, twice in push- and twice in pull-format. The resulting 160 trials were presented in semi-random order (at most three similar rotations and image categories in a row) and preceded by 15 practice trials with grey rectangles.

Figure 1 Schematic representation of the Approach Avoidance Task

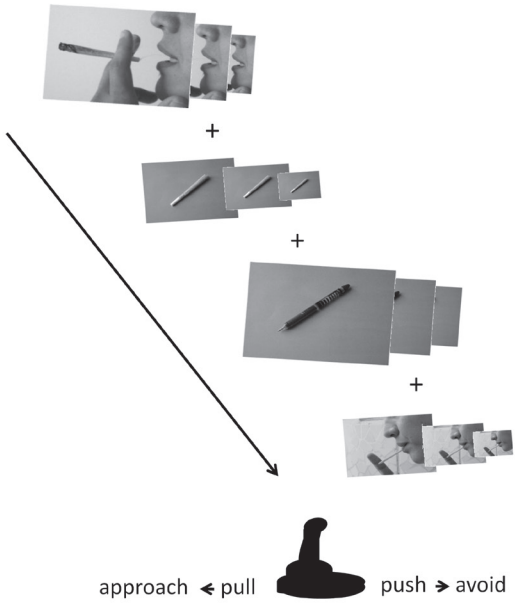

Table 1 Sample characteristics at baseline and six-month follow-up

	Heavy cannabis users		Controls	
	Baseline	Six-month follow-up	Baseline	Six-month follow-up
N (% female)	32 (34)	30 (33)	41 (37)	41 (37)
Age	21.2 (2.4)	21.7 (2.4)	22.0 (2.5)	22.5 (2.5)
Verbal IQ (Dutch Reading Test)	104.1 (5.5)	--	105.2 (6.8)	--
Alcohol use related problems (AUDIT)	6.2 (3.3)	5.6 (3.2)	4.9 (3.0)	4.8 (3.2)
Cigarette smoking (%)	69	63	17**	20**
Cigarette dependence (FTND)	2.8 (2.4)	2.9 (2.5)	.5 (1.1)	.6 (1.2)
Cannabis use lifetime (# joints)	1607.1 (1438.9)	1622.5 (1349.1)	4.4 (9.1)	5.0 (10.0)
Cannabis use related problems (CUDIT)	12.4 (5.8)	9.5 (6.6)*	0 (0)	.2 (.5)
Cannabis dependence (DSM-IV crit-count)	2.3 (1.6)	1.5 (1.5)*	0 (0)	0 (0)
Duration heavy cannabis use (year)	2.5 (1.9)	2.9 (1.9)	--	--
Cannabis use days/week	4.9 (1.5)	4.9 (2.1)	--	--
Cannabis use gram/week	3.0 (2.2)	3.2 (3.0)	--	--
Craving (baseline)	Pre-test	Post-test	Pre-test	Post-test
MCQ Compulsivity	6.6 (4.1)	7.9 (4.3)	3.0 (.3)	3.1 (.3)
MCQ Emotionality	5.9 (3.8)	7.0 (3.9)	3.2 (.6)	3.3 (1.2)
MCQ Expectancy	9.3 (3.9)	10.0 (3.4)	3.3 (.8)	3.3 (.9)
MCQ Purposefulness	8.9 (3.9)	12.5 (5.1)#	3.1 (.3)	3.2 (.1)

Means (SD). *$p < .05$ for baseline follow-up comparison, **$p < .001$ for group comparison, #$p < .001$ for pre-test post-test comparison. SD: standard deviation. MCQ: Marijuana Craving Questionnaire. AUDIT: Alcohol Use Disorder Identification Test. CUDIT: Cannabis Use Disorder Identification Test.

Procedure

Test-sessions took place during the late afternoon and at the beginning of the evening. All participants were asked to refrain from alcohol and drug use 24 hours prior to testing. Each session started and ended with filling out the MCQ. After completing other questionnaires, administering cannabis use history and the diagnostic interview, participants performed the AAT. Six months later participants were contacted for a telephone interview on present drug use and related problems.

Data preparation and statistical analysis

To correct for outliers, RTs below 200 ms, above 2000 ms, and more than 3 standard deviations (SD) above and below the mean were removed for each participant. Error trials were removed. The bias score was calculated by subtracting median approach RT from median avoid RT for each image category. The subtraction resulted in a bias score for cannabis images and neutral images for each participant. As in previous AAT publications, median RTs were used because they are less sensitive to outliers than means (MacLeod et al., 2002; Rinck and Becker, 2007; Wiers et al., 2009b; Wiers et al., 2010). A positive score indicated relative faster approach compared to avoid RTs whereas a negative score indicated relative faster avoid compared to approach RTs for a given image category. A positive or negative bias score will be referred to further as an approach bias or avoid-bias. To validate the AAT, Cronbach's alpha was calculated for the cannabis and neutral condition with the separate bias scores for each image. Internal reliability of the cannabis bias score (Cronbach's α = .68) and neutral bias score (Cronbach's α = .61) was acceptable. To compare groups, AAT bias scores were analyzed using standard analysis of variance (ANOVA). One sample t-tests were used to test if bias scores significantly deviated from zero within each group. Pearson's correlations and sequential multiple regression analyses were used to investigate associations between AAT bias scores, craving, measures of cannabis use and related problems at baseline and six-month follow-up, and tobacco smoking. To control for general biases in approach and avoid action-tendencies, partial correlations and regression analysis were conducted with neutral bias score as covariate.

RESULTS

Sample characteristics

Baseline: One control was discarded as outlier because bias scores were above 6 SD from mean (group comparison was still significant including this participant). Due to technical error, data from another control was lost. The remaining 71 participants performed 95 % correct (range = 78 - 100) with no differences between groups. The groups did not differ in age (t_{71} = 1.30, p = .20), gender (X^2 = .00, p = 1.00), IQ (t_{71} = .76, p = .48), and alcohol use (t_{71} = 1.36, p = .18), but there were more tobacco smokers among heavy cannabis users (X^2 = 22.26, p < .001; see Table 1). Overall median RTs did not differ between groups (t_{69} = .88, p = .38). In heavy cannabis users, post-test craving was higher for the MCQ purposefulness factor (t_{31} = 5.3, p < .001; see Table 1).

Six-month follow-up: A 97 % follow-up rate was achieved after 6 months (two non-responders among the heavy cannabis users). Within heavy cannabis users, Little's Missing Completely At

Random (MCAR; Little, 1988) test with all study variables indicated that the two non-responders were missing at random (X^2 = 20.3, *df* = 20, *p* = .44). Average DSM-IV criteria-count (t_{29} = 2.3, *p* = .026) and CUDIT-scores (t_{29} = 2.2, *p* = .035) decreased in heavy cannabis users (see Table 1). Cannabis use frequencies and measures of alcohol and tobacco use did not change in both heavy cannabis users and controls (see Table 1).

AAT bias scores in heavy cannabis users and controls

Group comparison: Differences in AAT bias scores were first analyzed with a mixed ANOVA with group as between-subject factor and image type as within-subject factor with two levels (cannabis and neutral images). Homogeneity of variance assumption was not violated (*p* > .12). There was no main effect of image type ($F_{1,69}$ = .09 , *p* = .77). The interaction between image type and group was significant ($F_{1,69}$ = 4 .53 , *p* = .037, η^2 = .062). In line with our hypothesis, heavy cannabis users had larger cannabis bias scores than controls (t_{69} = 2.33, *p* = .023, *d* = .55), whereas neutral bias scores did not differ between groups (t_{69} = .12, *p* = .91). Figure 2 shows mean bias score per image type for each group. Heavy cannabis users were faster in approaching compared to avoiding cannabis images because the cannabis bias score was larger than zero (t_{31} = 2.64, *p* = .013, *d* = .47). This cannabis bias score reflected an approach bias: approach RTs for cannabis (mean = 803.7, SD = 80.1) were faster than for neutral images (mean = 827.5, SD = 79.7; t_{31} = 3.61, *p* < .001, *d* = .64), whereas avoid RTs for cannabis (mean = 831.4, SD = 72.5) and neutral images (mean = 837.3, SD =7 5.1) did not differ (t_{31} = .63, *p* = .54). None of the other bias scores deviated from zero (*p* > .28).

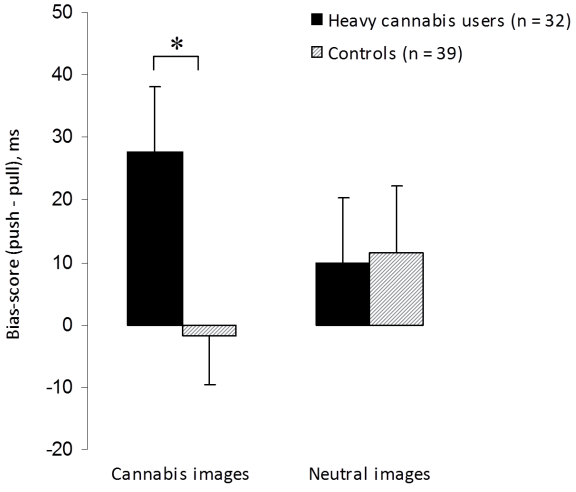

Figure 2 Mean AAT bias score for cannabis and neutral images in heavy cannabis users and controls (ms with standard error bars). A positive score indicates faster RTs on pull (approach) trials compared to push (avoid) trials. Heavy cannabis users have an approach bias towards cannabis-related images and their bias score significantly differs from controls (* *p* < .05).

Correlations: In contrast to our hypothesis, the approach bias correlated negatively with craving in heavy cannabis users: higher approach bias was related to lower pre-test scores on the MCQ emotionality (R = -.36, p = .049) and expectancy factor (R = -.36, p = .049), but not the compulsivity (R = .08, p = .68) and purposefulness factor (R = -.24, p = .20). The approach bias correlated positively with weekly cannabis use at six-month follow-up: higher approach bias was related to higher levels of cannabis use (in gram, R = .42, p = .023). The approach bias did not correlate with post-test craving, baseline cannabis use, baseline and six-month follow-up measures of cannabis use-related problems and tobacco smoking.

Table 2 Hierarchical multiple regression analysis for variables predicting weekly cannabis use (in grams) at six-month follow-up in heavy cannabis users (n = 30)

	B	SE B	*β*
Step 1: Change R^2 = .63**			
Weekly cannabis use baseline	1.05	.28	.61**
CUDIT	-.07	.10	-.14
DSM-IV criteria-count	.57	.33	.32
MCQ Compulsivity	.46	.23	.55
MCQ Emotionality	-.29	.21	-.32
MCQ Expectancy	.03	.23	.03
MCQ Purposefulness	-.06	.16	-.08
AAT neutral bias score	.00	.01	.03
Step 2: Change R^2 = .13*			
Weekly cannabis use baseline	1.09	.23	.63**
CUDIT	-.01	.09	-.01
DSM-IV criteria-count	.43	.27	.24
MCQ Compulsivity	.21	.20	.25
MCQ Emotionality	.02	.20	-.04
MCQ Expectancy	.01	.17	.01
MCQ Purposefulness	-.04	.14	-.05
AAT neutral bias score	-.01	.01	-.23
AAT cannabis bias score	.03	.01	.53*

*p < .01 and **p < .001. Final model R^2 = .76**, adjusted R^2 = .65. SE: standard error. MCQ: Marijuana Craving Questionnaire. CUDIT: Cannabis Use Disorder Identification Test.

Predictors of cannabis use at six-month follow-up in heavy cannabis users

To assess the predictive relationship between approach bias and changes in weekly cannabis use after six months (in grams) in heavy users, hierarchical multiple regression was performed. To control for other variables, baseline weekly cannabis use (in grams), CUDIT score, DSM-IV criteria-count, craving factors (pre-post-test average), and neutral bias score were entered first, after which the approach bias was entered. Preliminary analyses indicated no violation of the assumption of normality, linearity, multicollinearity, and homoscedasticity (maximum Cook's distance = .63, maximum standardized residual = 2.0). The total variance explained by the final model was 76 % ($F_{9,20}$ = 7.00, p < .001). The control variables explained 63 % of the variance in cannabis use six months later. Baseline weekly cannabis use (p < .001) was a significant predictor in the first step (compulsive craving was marginally significant, p = .053). The approach bias explained an additional 13 % of the variance in cannabis use six months later (F change$_{1, 20}$ = 10.65, p = .004). Participants with a stronger bias to approach cannabis used more cannabis at six-month follow-up. Besides the approach bias, only baseline weekly cannabis use was a significant predictor in the final model. In contrast to our hypothesis, no predictive relations were found between the approach bias and changes in measures of cannabis-related problems and dependence (CUDIT score, DSM-IV criteria count) after six months.

DISCUSSION

This study showed that heavy cannabis users, but not controls, have an approach bias specifically for cannabis-related images (not for neutral images), as measured with the AAT (Rinck and Becker, 2007; Wiers et al., 2009b; Wiers et al., 2010). In line with our hypothesis, the approach bias predicted changes in cannabis use six months later in heavy cannabis users: stronger approach biases were related to increases in weekly cannabis use. In contrast to our hypothesis, the approach bias was negatively related to craving for relief from negative affect and anticipation of positive outcome (i.e., MCQ emotionality and expectancy factor). No associations were found between the approach bias and measures of cannabis-related problems and dependence.

The approach bias found here in heavy cannabis users supports the idea that an approach bias for substance-related stimuli is a common phenomenon in cannabis users as well as in alcohol users and tobacco smokers (Bradley et al., 2004; Field et al., 2008a; Mogg et al., 2005; Ostafin and Palfai, 2006; Palfai and Ostafin, 2003; Wiers et al., 2009b). The most important finding is that the approach bias predicted changes in cannabis use after six months. Heavy cannabis users with stronger approach biases were more likely to increase weekly cannabis use while lower approach (or even avoid) biases were related to decreases in use. To our knowledge, this study is the first to find a prospective predictive relation between an approach bias and course of drug use. This predictive relationship may have clinical implications. Even after prolonged drug use, some heavy

using individuals develop abuse and dependence while others do not. The approach bias could be a predictor of the course of drug use. It might be used for identifying individuals especially at risk for increasing cannabis use for targeted interventions. An advantage of using implicit measures like the AAT is that they do not rely on self-report. Insight into severity of drug dependence and self-awareness might be compromised in dependent individuals, thereby influencing reliability of self-reports (Goldstein et al., 2009b). A second clinical implication could be using a modified AAT to retrain heavy cannabis users to avoid cannabis. Recent studies showed that approach action tendencies in heavy alcohol drinkers and alcohol-dependent patients can be modified (Wiers et al., 2011; Wiers et al., 2010). Successful training to avoid alcohol was related to decreased subsequent alcohol use and improved treatment outcome. Future research is needed to verify this in heavy cannabis users and clinical cannabis users, as has recently been shown for alcohol dependent patients (Wiers et al., 2011).

In contrast to our hypothesis, no associations were found between approach bias and changes in measures of cannabis dependence. This could be due to methodological issues. Inherent to the sample, cannabis-related problems were relatively low and a six-month follow-up might have been too short to detect changes in measures of dependence. An alternative explanation is that cognitive biases like the approach bias mainly play a role in the course of drug use in *earlier* stages of addiction. The approach bias may predict who will use more but not who will progress to problematic drug use. This appears to disagree with the incentive sensitization theory of addiction (Robinson and Berridge, 2000) and seems more in line with theories where incentive sensitization is mainly important during escalation of drug use and less when subsequent compulsive drug use progresses (Di Chiara, 2000; Everitt and Robbins, 2005). To test this hypothesis, associations between approach bias and prospective cannabis use needs to be assessed in larger samples of dependent, heavy, and sporadic cannabis users compared to non-using controls.

Also in contrast to our hypothesis, the approach bias was negatively associated with pre-test levels of craving for relief from negative affect and craving for anticipation of positive outcome. Post-test craving was not associated with the approach bias. Compulsive craving predicted cannabis use after six months: higher craving was related to increased use. However, the effect disappeared when the approach bias was entered in the regression model. Most theories predict a bidirectional positive association between approach biases and craving (Robinson and Berridge, 2003; Verdejo-Garcia and Bechara, 2009; Wiers et al., 2007). A recent meta-analysis showed weak positive relations between craving and attentional bias for alcohol (Field et al., 2009). In cannabis users a positive relation between post-test craving and attentional bias has been reported (Field et al., 2004), although, no relations between post-test craving, attentional bias, and approach bias were found in a different study (Field et al., 2006). Clearly, more research is needed to assess relations between cognitive biases and craving. Further, the MCQ can reliably

differentiate between craving factors (Heishman et al., 2009) but a theoretical framework should be developed further, something beyond the scope of this article. However, our findings emphasize relevance of measuring both pre- and post-test craving and using factorial decomposition of self-reported craving.

Finally, some limitations must be taken into account. First, there were more tobacco smokers among heavy cannabis users compared to controls and almost all cannabis users smoked cannabis cigarettes combined with tobacco [most common use-form in the Netherlands (Bennett, 2008)]. Tobacco might increase effects of cannabis (McPartland et al., 2008), and resemblance between tobacco and cannabis cigarettes possibly activates approach actions towards tobacco in tobacco users. Neither in heavy cannabis users nor in controls was tobacco use associated with the approach bias. However, our sample prevents discrimination between cannabis and tobacco effects. Secondly, in the course towards dependence, increased sensitivity to general rewards might precede incentive salience of drugs over natural rewards (Koob and Volkow, 2010). Indeed, it has been reported that heavy drinking male carriers of the OPRM1 G-allele had an approach bias for both alcohol and other appetitive stimuli (Wiers et al., 2009b). However, with the present design it cannot be determined if the approach bias in heavy cannabis users generalizes to other rewarding stimuli. Thirdly, the results should be interpreted bearing in mind that the approach bias reflects the relative difference between approaching and avoiding cannabis images. Although the group comparison suggests that strong approach tendencies for cannabis, rather than weak avoidance tendencies for cannabis, predict changes in prospective cannabis use in heavy users, the present findings with a relative measure are not conclusive regarding this issue. Alternatively, the interplay or conflict between approach and avoid tendencies may predict changes in cannabis use. This is an important question that needs to be addressed in future research. Fourthly, the AAT is a relative new measure and its temporal stability is unknown. Finally, the absence of a relation between approach bias and baseline levels of cannabis use might suggest a limitation in the construct validity of the task.

In conclusion, heavy cannabis-smoking young adults automatically activate approach action tendencies in response to cannabis-related stimuli (approach bias), and the extent to which they do so, predicts further escalation of their use.

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