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The effectiveness of cognitive bias modification in reducing substance use in detained juveniles: An RCT

Hans S. van der Baan[a,b,*], dr Annematt L. Collot D'Escury-Koenigs[a], dr Reinout W. Wiers[c,**]

[a] Department of Psychology, University of Amsterdam, PB 15916, 1001 NK, Amsterdam, the Netherlands
[b] Department of Pedagogical Sciences, Utrecht University, PB 15916, 1001 NK, Amsterdam, the Netherlands
[c] Developmental Psychopathology at the Department of Psychology, Universiteit van Amsterdam, Co-Chair Urban Mental Health, Uva.nl/Urban-Mental-Health, PB 15916, 1001 NK, Amsterdam, the Netherlands

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ABSTRACT

Background and objective: Young offenders show high levels of substance use. Treatment programs within detention settings are less effective. Cognitive bias modification (CBM) is a promising supplement to substance use treatment. This study tests the effectiveness of CBM in young offenders to reduce cannabis and alcohol use, and delinquent recidivism.
Method: A randomized controlled trial added CBM to treatment as usual (TAU), among 181 youth in juvenile detention centers. In a factorial design, participants were randomly assigned to either active- or sham-training for two varieties of CBM, targeting attentional-bias (AtB) and approach-bias (ApB) for their most used substance. Substance use was measured with the Alcohol and Cannabis Use Disorder Identification Tests. Delinquent recidivism was measured with the International Self-Report Delinquency (ISRD) survey.
Results: At pretest, participants showed AtB but no ApB for both substances. For alcohol, a decrease was found in AtB in the active-training group. For cannabis, a decrease was found in AtB for both active- and sham-training groups. Regardless of condition, no effects were found on substance use or ISRD scores at follow-up.
Limitations: The sample is judicial, not clinical, as is the setting. TAU and participant goals are not necessarily substance related.
Conclusions: Young offenders show a significant attentional-bias towards substance cues. CBM changed attentional-biases but not substance use. Combining CBM with a motivational intervention is advised. Follow-up research should better integrate CBM with running treatment programs. New developments regarding CBM task design could be used that link training better to treatment.

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Registration

Netherlands Clinical Trial Registry (NTR6458)

Young offenders use more substances than non-offenders, both internationally (Mulvey et al., 2011; Ogunwale et al., 2012; Putniņš, 2001) and in the Netherlands (current study's location; Kepper et al., 2009; Vreugdenhil et al., 2004) and run increased risks of developing substance use disorders (SUDs; see Online Supplement 1 for abbreviations; Kinner et al., 2014; Plattner et al., 2012) SUDs are associated with various negative outcomes and related societal costs, (Chen & Lin, 2009; French et al., 2008; Marshall, 2014) as well as delinquency (Arseneault et al., 2002; Doran et al., 2012). In detention, alcohol and (hard)drug use typically decrease, while cannabis use remains high, with motives like passing time (Cope, 2003) or self-medication (e.g., to mitigate ADHD symptoms; Gudjonsson et al., 2012). Heavy usage in young offenders is a major concern in forensic care, both regarding work inside juvenile detention centers (JDC; Young et al., 2011) and delinquent recidivism (Putniņš, 2003).

Several substance-use interventions have been developed for young

* Corresponding author. Department of Psychology, University of Amsterdam, PB 15916, 1001 NK Amsterdam, the Netherlands.
** Corresponding author. Developmental Psychopathology at the Department of Psychology, Universiteit van Amsterdam; Co-chair Urban Mental Health, Uva.nl/urban-mental-health, PB 15916, 1001 NK, Amsterdam, the Netherlands.
E-mail addresses: h.s.vanderbaan@uva.nl (H.S. van der Baan), A.L.CollotDEscury-Koenigs@uva.nl (A.L. Collot D'Escury-Koenigs), r.wiers@uva.nl (R.W. Wiers).

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offenders, mostly based on cognitive behavior therapy (CBT). However, there is evidence that CBT is less effective when applied inside a JDC (Koehler et al., 2013; Lipsey, 2009). Important factors in adolescent substance-use treatment (e.g., family involvement; Chassin et al., 2009) often cannot be realized. Given the need for effective treatment, there is much to be gained from improving available programs.

One potential improvement is cognitive bias modification (CBM). CBM interventions are relatively simple, targeting cognitive biases involved in the maintenance of substance-use behavior. Cognitive biases are cue processing predilections, which elicit specific reactions. For example, spotting someone attractive will focus attention with accompanying eye-movements. This is called an Attentional Bias (AtB). Similarly, cues may evoke approach tendencies, like reaching towards candy in the supermarket before reconsidering. This bias is called an Approach Bias (ApB; Wiers et al., 2009). AtB and ApB are the most commonly targeted biases in substance-use. Studies have found cognitive biases related to alcohol and cannabis use in adolescents, (Ames et al., 2005; van Hemel-Ruiter et al., 2016; Willem et al., 2013) and implicated them in the development and maintenance of SUDs (Rooke et al., 2008). Heightened attention for substances, and a strong impulse to use them provide a powerful impetus that is difficult to stop.

Several studies have investigated the effects of re-training cognitive biases through CBM, mostly in alcohol and tobacco SUDs. While initial doubt was expressed regarding behavioral outcomes (including clinical effectiveness; Field et al., 2014), reviews show positive effects on targeted biases (Wiers et al., 2013, 2018). Success has been achieved when CBM was auxiliary to existing treatment in clinical populations (review: Wiers et al., 2018; meta-analysis: Boffo et al., 2019). CBM has potential as an add-on to SUD treatment, but research should identify for which populations it is effective (Field et al., 2014; Wiers et al., 2018).

CBM has several characteristics that facilitate implementation within a JDC. It is easily operationalized as computerized tasks and administration does not require specific training or education. CBM studies have shown effects after 4 sessions; (Manning et al., 2021) one week of daily training may suffice. As treatment duration in detention is determined by sentence, rather than treatment protocol, shorter (effective) treatments are preferable.

Studies have found that cognitive biases are stronger when cognitive control is weak, (Peeters et al., 2012; Toplak et al., 2011) whereas good attentional control was reported as a protective factor in adolescent alcohol use (Willem et al., 2013). Automatic cognitive processes may be more important in explaining adolescent than adult behavior, as executive processes are still developing (Krank & Goldstein, 2005). Young offenders show a greater incidence of impulsivity-related problems, indicating weak cognitive control (Carroll et al., 2006). Therefore, CBM might have greater effects in impulsive youth.

Note that much research has been done since this project started and our understanding of CBM's working mechanisms has evolved. Consequently, some of the assumptions, paradigms, and evidence on which this study is based could now be regarded as somewhat outdated. This is addressed further in the discussion.

The current study's aim was to examine the effectiveness of a brief CBM training protocol on top of treatment as usual (TAU) within the JDC, in reducing alcohol and cannabis use. TAU, in this context, can be defined as treatment programs participants receive during their detention. In Dutch JDCs, all youth receive the EQUIP program, (Gibbs et al., 1995) targeting behavioral problems, and continue secondary education. If juvenile courts orders substance use treatment, or a youth requests it, they receive Brains4Use (Jeugdinstituut, 2015).

We targeted AtB with a training-version of the Visual Probe Task (VPT; Bradley et al., 1998) and ApB with a training version of the Approach-Avoid Task (AAT; Wiers et al., 2009). Our primary aim was to examine whether adding CBM to TAU resulted in reduced self-reported substance use at 12-month follow-up. In line with previous research on CBM's clinical effects, (Eberl et al., 2013; Manning et al., 2016, Manning et al., 2021; Schoenmakers et al., 2010; Wiers et al., 2011) we expected to find substance-focused biases at pretest, and a reduction in biases after training in participants who received active-CBM. Active-CBM was also expected to lead to a significant reduction in substance use, compared to sham-CBM. The secondary aim was to examine whether self-reported delinquency at 12-month follow-up was also reduced after active-CBM. Given relations between substance use and offending, (Arseneault et al., 2002; Doran et al., 2012; Young et al., 2011) we expected active-CBM to reduce delinquent behavior compared with sham-CBM. Finally, we explored potential moderators of treatment effects: initial substance use, age, gender, initial biases, motivation, self-control and working memory, and whether substance use treatment (Brains4Use) was received. The goal here was to identify potential subgroups for whom CBM could be differentially effective.

1. Methods

1.1. Trial design

The study was a double-blind RCT with a 2x2 factorial design. Participants were randomly assigned to active- or sham-training versions for both ApB modification (ApBM) and AtB modification (AtBM), resulting in four groups.

1. active-ApBM, active-AtBM;
2. active-ApBM, sham-AtBM;
3. sham-ApBM, active-AtBM;
4. sham-ApBM, sham-AtBM.

This design minimized the number of participants receiving only sham-training (25%), whilst still allowing for comparisons of active with sham-training. Data was collected as part of the SCREEN project, a collaborative study between the University of Amsterdam (UvA) and Vrije Universiteit Amsterdam. Protocols have been approved by an Ethics Committee (UvA, 2013-DP-3165; 2013-DP-3142). The study has been registered in the Netherlands Clinical Trial Registry (NTR6458). The SCREEN project was funded by the Dutch Ministry of Justice and Safety, who had no role in study execution, data collection or analysis, nor in writing this manuscript.

1.2. Experimental tasks used to assess and re-train cognitive biases

We employed two tasks to assess cognitive biases, the AAT to assess ApB and the VPT to assess AtB, for substance-related stimuli. Both tasks had two versions, an assessment- and a training-version. The training-version was either active (aimed at retraining the bias) or sham (i.e., continued assessment).

AAT-assessment: Participants were shown substance pictures, or visually-matched neutral images (soft-drinks for alcohol or office-supplies for cannabis). Participants were instructed to press a keyboard key as quickly as possible that would either move the picture towards or away from them. The required response depended on the picture's shape, not its contents. After an approach response, the picture was enlarged, after a push response, it shrank, creating a sense of approach and avoidance, respectively (Wiers et al., 2009). On a mistake, a large red X appeared on screen. The assessment-version of the AAT consisted of 80 trials where each picture-type (substance or neutral) was approached or avoided equally often (50-50). Trials were presented in two blocks, separated by a short break.

AAT-training: The training-version consisted of a short assessment block (64 trials), followed by training (192 trials). The approach-avoid ratios for the training trials varied between condition (active or sham): in active, all substance pictures were to be pushed away, in sham, half were pushed and half pulled.

VPT-assessment: Participants were shown paired pictures, one substance and one neutral, followed by an arrow appearing at either location. Participants indicated which way the arrow pointed by pressing a key (up or down). If an incorrect response was given, a big red X appeared on screen. The assessment-version of the VPT consisted of 80 trials using substance and neutral stimuli. The arrow appeared at both locations in equal measure (50-50).

VPT-training: The training-version consisted of a short assessment block (64 trials), followed by training (192 trials). The appearance ratio of the arrow was contingent on group. In sham the ratio was again 50-50, in active the ratio was 100-0 for substance stimuli.

See Online Supplement 2 for more technical details regarding these tasks.

1.3. Participants

Participants were 449 adolescents detained in seven JDCs in the Netherlands, from both short-stay and long-stay groups (>3 months). Youth were placed after a juvenile court conviction of a felony, or while awaiting trial. Participant recruitment ran from 2014 to 2016. Selection was organized in three phases: 1) open invitation through personal communication at the center; 2) eligibility assessment (T0); and 3) randomization (T1). Exclusion criteria for both eligibility assessments and randomization were: (a) placement in Very Intensive Care or Forensic Observation groups, as participation was too intrusive in these conditions, (b) insufficient mastery of the Dutch language and (c) colorblindness.

1.4. Procedure

Recruitment and data collection were performed by SCREEN researchers, unaffiliated with the Dutch judicial system. Candidate participants were approached after having been detained for at least two weeks. The first two weeks are filled with institutional assessments and acclimatization for the youth. Participants were first recruited for the larger SCREEN project (T0 and follow-up measurements). They were told that we wanted to collect a broad array of information to gain more insight into the youths themselves, and that all youth in the institutions would be approached; they were not singled out. Information about the study was given both verbally and in writing. Youth who consented (and, where necessary, of whom we'd obtained parental consent) were then administered the SCREEN test battery, which included the instruments used for our eligibility assessment. This was scheduled 24 h after the youth agreed to participate (=T0). T0 was administered digitally by SCREEN researchers and took 1.5–2 h. Participants provided demographics, followed by a battery of instruments including the Alcohol Use Disorder Identification Test (AUDIT; Saunders et al., 1993), the Cannabis Use Disorder Identification Test – Revised (CUDIT-R; (Adamson et al., 2010), a self-control questionnaire and a task assessing working memory (for details see Online Supplement 3). The software in which both the questionnaires and tasks were embedded was developed by the University of Amsterdam.

Following T0, eligibility was assessed off-site by the lead researcher, keeping research-staff remained blind to condition. Participants were eligible if they reported either alcohol or cannabis usage during the past year. This low threshold meant third-party observers (e.g., JDC staff) could not infer the timing or extent of usage from participation, ensuring confidentiality. Participants were eligible for alcohol- or cannabis-focused training depending on their highest score (AUDIT or CUDIT-R). After eligibility was determined, on-site staff was told which participants were eligible for which training (alcohol or cannabis). These youth were again approached for participation in the training sessions (T1-T6). They were told that the training was intended to improve self-control over their substance use and that participation (or non-participation) would not affect their sentence or their stay in the JDC. We also explained that the JDC staff would not be informed about the details, that nothing incriminating could be inferred from participation, and that we would not report to the staff what substance they were being trained for. IC was obtained anew. Where necessary, IC was again obtained from parents, but to retain confidentiality parents were told that the training intended to improve self-control, without mentioning the substance-use context.

Fig. 1 shows a CONSORT diagram of the participant flow. Sample characteristics are shown in Table 1.

The training (T1-T6) consisted of baseline assessments of AtB & ApB and motivation (T1), and five training sessions (T2–T6), scheduled between 24 h and one week apart. Assessment and training occurred in a designated room with only the participant and data-collector present. At T1, participants indicated to what extent they wanted to use the substance right now, were motivated for the training, and motivated to change their substance use, followed by two computer tasks to measure AtB and ApB. At this point the software randomized both the order in which the participant would receive the tasks (i.e., AAT first or VPT first), as well as which version of each task they would receive (active or sham). This randomization was stratified across institutions, aiming for a roughly equal distribution between the four experimental groups in each institution.

Later sessions (T2–T6) were the same, except participants now performed training versions of the CBM tasks (active or sham depending on experimental group). Each session took 20–30 min.

All participants were approached for follow-up measurements (T7–T9), approximately 1, 3 and 12 months after their last session. They were contacted as of the allotted date, but as they were often unavailable or unreachable at first attempt, further contact/scheduling attempts were made up to two weeks after. T7–T9 were conducted in the same setting as T0–T6, if the participant was still detained. If no longer detained, participants were contacted by phone or visited at home. The follow-up included questionnaires on substance use and delinquent recidivism, but no cognitive-bias measurements as these were unobtainable over the phone. For privacy reasons, questions regarding sensitive information (e.g., delinquent recidivism) required only 'yes' or 'no' answers. The interview took 10–15 min.

At T0 participants were given a choice of rewards of approximately €5. Rewards varied per JDC and were selected in consultation with the staff, most commonly personal-hygiene products or phone credits. There was no reward for training participation. Rewards for follow-up participation were €5 at T7, €10 at T8, and €15 at T9. If the youth was still detained, rewards were similar as at T0.

IC and permission to access data from institutional files were obtained from the participants and, where required, from a parent or guardian.

2. Materials

Alcohol use: AUDIT (Saunders et al., 1993) assesses potentially hazardous and harmful alcohol use during the past year. Internal consistency was good (α = 0.86).

Cannabis use: The CUDIT-R (Adamson et al., 2010) assesses potentially hazardous and harmful cannabis use during the past year. Internal consistency was good (α = 0.85). The AUDIT and CUDIT-R were used to assess eligibility and as baseline measure to assess long-term outcomes.

Self-Control: The Brief Self-Control Scale (BSCS; Tangney et al., 2004) was used to assess dispositional self-control. Internal consistency was good (α = 0.80).

Working Memory: The Self-Ordered Pointing Task (SOPT; Ross et al., 2007) was used to assess working memory (Colom et al., 2003). The SOPT was included as a potential moderator. Our version used concrete pictures, with instructions to click each picture once. The outcome is the total number of errors (Ross et al., 2007).

Motivation: Participants indicated how motivated they were to change their substance use on a visual analog scale ranging from 0 ("not at all") to 100 ("completely"). Participants answered these questions regarding the substance they were trained for.

Delinquency: The International Self-Report Delinquency (ISRD; Enzmann et al., 2010) measures delinquency by asking whether

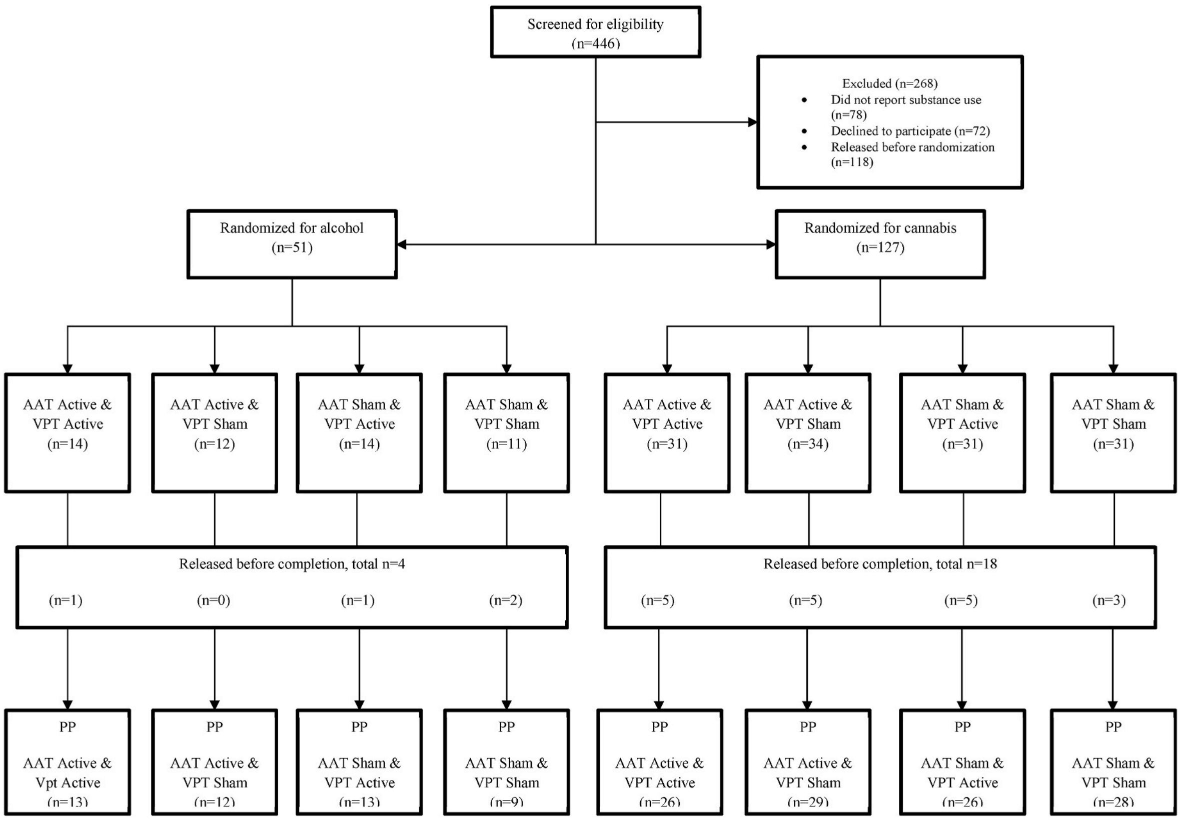

Fig. 1. CONSORT flow diagram.

Table 1
Sample characteristics.

	Alcohol training				Cannabis training			
Groups	AAT Active – VPT Active	AAT Active – VPT Sham	AAT Sham – VPT Active	AAT Sham – VPT Sham	AAT Active – VPT Active	AAT Active – VPT Sham	AAT Sham – VPT Active	AAT Sham – VPT Sham
N	14	12	14	11	31	34	31	31
Gender (% male)	92.90	100	100	100	93.50	88.20	93.50	93.50
Brains4Use	1	2	2	2	4	6	5	9
Age	19.01 (2.62)	19.21 (1.77)	18.56 (1.54)	18.37 (1.69)	18.67 (2.03)	18.50 (1.96)	18.51 (1.82)	18.67 (2.03)
AUDIT	7.36 (7.76)	4.00 (3.02)	8.21 (7.15)	6.09 (4.37)	4.48 (4.24)	5.09 (4.79)	4.61 (4.53)	4.48 (4.24)
CUDIT-R	4.43 (7.72)	1.33 (3.4)	1.21 (4.00)	3.09 (3.83)	11.94 (5.06)	13.18 (6.44)	12.97 (5.54)	14.27 (6.22)
BSCS	43.29 (9.59)	47.42 (6.79)	46.36 (8.57)	45.73 (7.56)	43.13 (8.37)	42.64 (9.03)	44.77 (7.44)	43.13 (8.37)
SOPT	11.36 (3.52)	11.42 (3.94)	9.57 (3.39)	9.45 (4.93)	10.26 (5.89)	11.35 (6.10)	11.00 (5.59)	10.26 (5.89)
Motivation	30.77 (31.18)	42.25 (39.45)	63.15 (41.70)	57.00 (47.48)	47.13 (36.09)	47.16 (36.74)	54.90 (38.10)	47.13 (36.09)

Note. Numbers between brackets = Standard errors. Brains4Use = N participants receiving Brains4Use; AUDIT = Alcohol Use Disorder Identification Test - Revised, range 0–40; CUDIT-R = Cannabis Use Disorder Identification Test, range 0–32; BSCS = Brief Self-Control Scale, range 13–65; SOPT = Self-Ordered Pointing Task, range 0–48; Motivation = Motivation to quit/reduce substance use, range 0–100; Motivation was formulated to be substance specific (alcohol or cannabis).

respondents engaged in several delinquent behaviors. Internal consistency was good (α = 0.84). As the execution of the project and data collection proved very intensive and time-consuming we were unfortunately unable to obtain police records, as proposed in the preregistration.

2.1. Data analysis

Two data sets were created, an Intention-To-Treat (ITT) set and a Per Protocol (PP) set. The ITT data included all participants who were randomized. The PP data included all participants who had completed at least 1 training session. The main analyses outlined below were conducted with ITT data first, then repeated for PP data. Moderation analyses were only done with PP data. Analyses examined the alcohol- and cannabis-trained groups separately, unless stated otherwise. Given the relatively small sample sizes, significance is reported as of $p < .10$ unless stated otherwise. It is often difficult to achieve large sample-sizes for clinical studies with young offenders, making this type of study rare. Yet the importance of effective treatment, and the potential benefit thereof to the youth themselves and society, can hardly be overstated. As CBM training carries low costs and practically no risks, we feel this lower significance threshold is justified (Palesch, 2014).

Desired sample sizes were derived from the literature at the time. Assuming a medium effect on substance use reduction, (Schoenmakers et al., 2010) we aimed for 50 participants per group, per substance. This would give us enough power (0.80), even with 25% dropout (Cohen, 1992). A post-hoc power analysis was conducted on the PP participants with GPower (Faul et al., 2007). Our PP data consisted of 109 cannabis participants, and 47 alcohol participants. To detect a medium effect within and between four groups using ANOVA with $\alpha = 0.10$, our PP data for the cannabis participants had power =.99. Our PP data for the alcohol participants had power = .76, which is slightly below the .80 threshold. Note that our original effect size expectations are likely no longer valid, as new research has emerged since. This is addressed further in the discussion.

Bias scores: The presence of biases at T0 was evaluated with one-sample T-tests (difference from 0). Change-over-time was evaluated with a mixed factorial ANOVA with Time as within-subject factor (comparing scores at T0 with T6) and Group as between-subjects factor (alcohol or cannabis, and training or sham, creating 4 groups). Changes were further explored with paired-sample T-tests. These analyses examined VPT-scores (AtB), AAT-scores for substance stimuli (substance-ApB), and AAT sores for control stimuli (control-ApB). Note that participants in the ITT data who were not included in the PP data, have only provided baseline bias scores (they dropped out after T1). Change-over-time for bias scores is thus only presented for the PP data.

Clinical effects: We analyzed the prediction of substance use at T9 with a hierarchical multiple regression. In step 1 we enter background variables (use at T0, age, gender and biases), in step 2 training factors (AAT group, VPT group, # of sessions, and the interaction term AATgroup*VPTgroup).

Recidivism: A between-subjects ANOVA was used to evaluate group differences (training vs. sham) in delinquent recidivism at T9.

Moderation: Given the numerous variables involved, and the relatively small participant groups, a base model was first established, followed by separate tests for each moderation effect. To establish the base model, a hierarchical regression analysis was conducted with established predictors (prior use, age, gender, motivation, working memory, self-control, biases and Brains4Use enrollment) in step 1, adding training factors in step 2. The base model was compiled by retaining those predictors where $p < .30$. Separate analyses were then run for each potential moderator, adding the main effect of the moderator in step 1 or 2 (if it wasn't retained in the base model) and an interaction term with group, once for AAT and once for VPT.

3. Results

3.1. Biases at T1 ITT

One-sample T-tests showed a small difference from 0 for VPT-scores for alcohol stimuli at T1 (M = 9.46, SD = 32.00, t(48) = 2.07, $p = .04$), and a moderate difference for cannabis stimuli at T1 (M = 15.97, SD = 33.08, t(123) = 5.38, $p < .001$). AAT-scores for alcohol stimuli at T1 did not differ significantly from 0 (M = 2.67, SD = 105.06, t(47) = 0.18, $p =$ .86), nor did AAT-scores for cannabis stimuli at T1 (M = −3.46, SD = 123.73, t(122) = −0.31, $p = .76$). AAT-scores for control stimuli at T1 also did not differ significantly from 0, neither for alcohol (M = −0.65, SD = 100.21, t(48) = −0.05, $p = .97$), nor for cannabis (M = 4.30, SD = 120.39, t(122) = 0.40, $p = .69$). Hence, attentional bias was confirmed for both substances at pretest, but not approach bias.

3.2. Training effects ITT

Table 3 shows mean AUDIT and CUDIT-R scores at T0 and T9. Regression statistics predicting AUDIT-scores at T9 for the alcohol participants and regression statistics predicting CUDIT-R scores at T9 for the cannabis participants can be found in Online Supplements 4 and 5, respectively. For alcohol, only the first model containing basic predictors explained a significant proportion of the variance in AUDIT-scores at T9, $R^2 = 0.34$, $F(6, 26) = 2.23$, $p = .07$. Of those predictors, only AUDIT-scores at T0 predicted AUDIT scores at T9, $\beta = 0.35$, $t(26) = 1.79$, $p = .08$. For cannabis, no model significantly explained variance, and only CUDIT-R scores at T0 predicted CUDIT-R scores at T9, $\beta = 0.20$, $t(72) = 1.68$, $p = .098$. We found no effects of CBM on either alcohol or cannabis use a year later.

3.3. Delinquent recidivism ITT

Table 4 shows mean ISRD scores at T9. A one-way, between-subjects ANOVA showed no significant effect of CBM-group for the alcohol participants ($F(3, 28) = 1.02$, $p = .40$), nor for the cannabis participants ($F(3, 81) = 0.10$, $p = .96$). We found that actively-trained participants did not show less delinquent recidivism compared to sham-trained participants.

3.4. Establishing PP data

For PP analyses, we excluded participants who were randomized but received no training. A binominal logistic regression was applied to predict dropout from our baseline predictors. As the number of dropouts was low (14), we combined dropouts from the alcohol and cannabis training. Online shows the results of the dropout analysis. We found that participants with higher AUDIT scores were 10% more likely to drop out, while participants with higher CUDIT-R scores were 14% less likely. This was not unexpected, as alcohol is much harder to obtain in detention than cannabis. Subsequently, considering baseline substance use was measured over the year prior to T0, higher alcohol-scores were to be expected in recently detained youth. Since most leave the detention centers within two months, new arrivals have a greater chance of dropping out compared to those serving a heavier sentence. We also found that participants with a greater approach bias for control stimuli were 1% more likely to drop out.

3.5. Biases at T1 and change over time PP

One-sample T-tests showed a small difference from 0 for VPT-scores for alcohol stimuli at T1 (M = 10.92, SD = 34.22, t(45) = 2.16, $p = .04$), and a moderate difference for cannabis stimuli at T1 (M = 15.75, SD = 31.59, t(108) = 5.21, $p < .0$). AAT-scores for alcohol stimuli at T1 did not differ significantly from 0 (M = 0.21, SD = 107.45, t(44) = 0.01, $p =$ .99), nor did AAT-scores for cannabis stimuli at T1 (M = −0.34, SD = 126.48, t(108) = −0.03, $p = .98$). AAT-scores for control stimuli at T1 also did not differ significantly from 0, neither for alcohol (M = 2.42, SD = 100.75, t(44) = 0.16, $p = .87$), nor for cannabis (M = −0.70, SD = 116.18, t(108) = −0.06, $p = .95$). Hence, attentional bias was confirmed for both substances at pretest, but not approach bias.

A mixed ANOVA showed an effect of time for AAT-scores for substance stimuli (F(1, 117 = 3.29, $p = .07$) and for VPT-scores (F(1, 118) = 14.29, $p < .001$, but not for AAT-scores for control stimuli (F(1, 117) = 0.95, $p = .33$). Finally, the interaction of Time*Group was not significant in any of the analyses. Hence, attentional bias for substances changed over time, but did so for both the active- and sham-training groups. More details were obtained with paired samples T-tests (see Table 2).

The alcohol-active group showed a medium decrease in attentional bias (t(21) = 2.42, $p = .02$), but not the sham group (t(15) = 1.29, $p =$ .22), confirming our hypothesis. Approach bias for the alcohol participants did not change significantly. The cannabis-active group showed a small decrease in attentional bias (t(44) = 2.06, $p = .04$, but the cannabis-sham group also showed a small decrease (t(38) = 2.33, $p =$ .02. Furthermore, the cannabis-sham group showed a small increase in approach bias (t(37) = −2.36, $p = .02$), again counter expectations.

3.6. Training effects PP

Table 3 shows mean AUDIT and CUDIT-R scores at T0 and T9. Regression statistics predicting AUDIT scores at T9 for the alcohol participants and regression statistics predicting CUDIT-R scores at T9 for the cannabis participants can be found in Online Supplements 7 and 8.

Table 2
Bias scores over time.

Substance	Group	Task	T1	T5/6	Cohen's d
Alcohol	Active	AAT Substance	−4.37 (85.49)	−1.16 (102.15)	−.03
		AAT Control	−3.87 (101.64)	−18.71 (108.78)	0.11
		VPT	11.82 (26.48)	−5.66 (25.01)	.52*
	Sham	AAT Substance	14.87 (130.56)	41.60 (112.68)	−.25
		AAT Control	13.82 (106.13)	12.82 (100.26)	.01
		VPT	10.66 (38.14)	−8.69 (33.86)	.32
Cannabis	Active	AAT Substance	−11.08 (104.24)	8.54 (92.63)	−.13
		AAT Control	24.26 (107.50)	9.84 (85.01)	.11
		VPT	16.41 (28.60)	3.46 (25.39)	.31*
	Sham	AAT Substance	−5.41 (71.49)	33.68 (85.48)	.38*
		AAT Control	2.72 (105.20)	−15.14 (104.36)	.13
		VPT	8.99 (29.10))	−8.37 (38.82)	.37*

Note. Columns 'T1' and 'T5/6' list average response times in milliseconds; numbers between brackets = SD; AAT = Approach-Avoid Task; VPT = Visual Probe Task; *$p < .05$.

For alcohol, again only the first model explained a proportion of the variance in AUDIT scores at T9, $R^2 = 0.36$, $F(6, 23) = 2.12$, $p = .09$, similar to the ITT data, but no significant individual predictors. For cannabis, again neither model explained any variance. CUDIT-R scores at T0 predicted CUDIT-R scores at T9 ($\beta = 0.26$, $t(62) = 2.04$, $p = .046$, as did the number of sessions completed ($\beta = -0.30$, $t(58) = -2.31$, $p = .02$). Contrary to expectations, no effects of CBM were found on either substance a year later, although cannabis users did show a reduction of use after training, irrespective of group.

3.7. Delinquent recidivism PP

Table 4 shows mean ISRD scores at T9. Same as the ITT data, there was no significant effect of CBM-group for the alcohol participants ($F(3, 25) = 0.76$, $p = .52$), nor for the cannabis participants ($F(3, 67) = 0.30$, $p = .83$).

3.8. Moderation

For the alcohol participants, Online Supplements 9 and 10 show the statistics for the base model, and Online Supplements 11 through 26 the moderation analyses. For cannabis, Online Supplements 27 and 28 show the base model, and 29 through 47 the moderations.

For alcohol, the interaction with Brains4Use was significant for both the AAT-training group ($\beta = 0.45$, $t(21) = 2.19$, $p = .04$) and the VPT-training ($\beta = 0.35$, $t(21) = 1.90$, $p = .07$). Unexpectedly, participants who received Brains4Use during detention (N = 4), showed higher alcohol use at T9 when they received active AAT-training (N = 2) or VPT-training (N = 1). The interactions are plotted in Online Supplements 48 and 49 respectively. We also found a significant interaction for VPT-training with working memory ($\beta = 0.45$, $t(21) = 2.10$, $p = .048$), indicating that participants who received active VPT-training (N = 16) drank more at T9 if they scored relatively poorly on working memory, whereas participants with a sham VPT (N = 13) did not (Online Supplement 50).

For cannabis we found a significant interaction between the approach bias for neutral stimuli and AAT-training ($\beta = 0.29$, $t(62) = 2.04$, $p = .046$). Participants who received active AAT-training (N = 34) showed more cannabis use at T9, if they had a high approach bias for the neutral stimuli at T1, whereas participants with a sham AAT (N = 36) showed less (Online Supplement 51).

4. Discussion

This study examined the effectiveness of CBM as add-on to TAU in reducing alcohol and cannabis use in detained juveniles. We hypothesized that substance-focused biases would be present at pre-test, which was found for AtB for both substances, but not for ApB. We further hypothesized that these biases would be reduced after active training.

Table 4
Mean ISRD at T9.

Group	Alcohol	Cannabis
ITT		
2x Active	1.78 (2.22)	1.33 (1.93)
AAT Active	.71 (1.11)	1.67 (3.37)
VPT Active	1.11 (2.62)	1.25 (2.47)
Sham	.14 (.38)	1.37 (2.98)
PP		
2x Active	2.13 (2.23)	1.47 (1.91)
AAT Active	1.29 (1.11)	2.28 (3.46)
VPT Active	1.38 (2.77)	2.15 (2.43)
Sham	.50 (.84)	2.13 (3.05)

Note. Numbers between brackets = Standard deviation; ISRD = International Self-Report Delinquency.

Table 3
Substance use at T0 and T9.

	T0				T9			
	ITT							
Groups	AAT Active – VPT Active	AAT Active – VPT Sham	AAT Sham – VPT Active	AAT Sham – VPT Sham	AAT Active – VPT Active	AAT Active – VPT Sham	AAT Sham – VPT Active	AAT Sham – VPT Sham
AUDIT	7.36 (7.76)	4.00 (3.02)	8.21 (7.15)	6.09 (4.37)	5.22 (5.76)	5.29 (3.04)	5.00 (5.34)	4.00 (4.76)
CUDIT-R	11.94 (5.06)	13.18 (6.44)	12.97 (5.54)	14.27 (6.22)	12.95 (7.27)	11.19 (8.85)	8.26 (6.32)	9.74 (7.24)
				PP				
Groups	AAT Active – VPT Active	AAT Active – VPT Sham	AAT Sham – VPT Active	AAT Sham – VPT Sham	AAT Active – VPT Active	AAT Active – VPT Sham	AAT Sham – VPT Active	AAT Sham – VPT Sham
AUDIT	7.85 (7.85)	4.00 (3.02)	6.33 (2.23)	7.33 (3.78)	5.88 (5.79)	5.29 (3.04)	4.75 (5.65)	4.67 (4.84)
CUDIT-R	12.58 (4.65)	13.90 (6.62)	12.81 (5.59)	13.64 (6.31)	12.44 (7.47)	10.11 (9.10)	8.15 (6.55)	10.75 (6.96)

Note. Numbers between brackets = Standard Deviation. AUDIT = Alcohol Use Disorder Identification Test - Revised, range 0–40; CUDIT-R = Cannabis Use Disorder Identification Test - Revised, range 0–32; AUDIT data presented only for the alcohol-trained participants; CUDIT-R data presented only for the cannabis-trained participants.

This was partially confirmed; AtB decreased after active alcohol AtBM, but cannabis AtB decreased after both active and sham AtBM. As for the effectiveness of ApBM, contrary to our hypotheses, no training effects were found for either substance. Finally, no effects were found on substance use or recidivism. We discuss these findings from the evolving perspective on CBM since the start of this study, 10 years ago.

While AtBs for both substances were found at pretest, no ApBs were found. It's possible that the relative complexity of the AAT's required responses (view stimulus, note angle, recall rule regarding translation of angle into required key to press, press correct key) vs. the VPT (if the arrow points up, press up, if down, press down) could explain this. There is some evidence that irrelevant-feature tasks reduce reliability when measuring cognitive biases (Field et al., 2011). We nevertheless chose this format because the assessment-version of the task can be changed to the training-version without changing the instructions (Wiers et al., 2011). This allows the assessment-version and the training-version to be virtually identical barring the proportion of active stimuli approached vs. avoided, thus reducing the chances of participants realizing which condition they are in, when comparing their experiences with other participants (not unimaginable, considering they're detained together). At the time, research suggested that CBM worked best when participants were unaware of training contingencies, (Grafton et al., 2014) although more recent studies suggest otherwise (Van Dessel et al., 2015, 2020). Note further that our tasks were operated via the keyboard, whilst for the AAT a joystick generally shows stronger effects (Kahveci et al., 2020). Finally, cannabis AtB decreased regardless of group. This was unexpected, but recent literature shows that cognitive biases can be influenced by sham-training (Wiers et al., 2018). Participants in either group were exposed to equal numbers of cannabis-related stimuli but could not immediately respond with use-behavior. The decrease may be due to participants in both groups 'learning' to disregard cannabis stimuli to avoid the frustration of appetitive arousal when it cannot be sated.

The task paradigms used can now, at the time of publication, be regarded as somewhat outdated. Specifically, theses paradigms have shown efficacy as an add-on to abstinence-oriented treatment of alcohol use disorders, (Eberl et al., 2013; Manning et al., 2022; Rinck et al., 2018; Salemink et al., 2022; Wiers et al., 2011) but not in online studies, (Wiers et al., 2015) or in healthy volunteers (Lindgren et al., 2015; Wiers et al., 2018, 2020; Wiers et al., 2020). Recent studies have further investigated CBM's active mechanisms and the conditions under which effects are found (Grafton et al., 2014; Van Dessel et al., 2015, 2020). Dominant theorizing about the processes involved in CBM effects has shifted from automatic action-evaluative associations to a recursive inferential model with an increased focus on client agency and salience (Van Dessel et al., 2019; Wiers et al., 2020). Repeatedly disengaging from the substance is unlikely to effect behavioral adaptation unless the participant can meaningfully link disengagement with positive outcomes, e.g., achieving personal goals. Based on these new insights we would have tested a new variety of training (Wiers et al., 2020). However, at the time our task choices were reasonable and expected to be functional based on then-current scientific evidence.

The lack of clinical effects of CBM is disappointing, but again we can find an explanation in recent research. It's become increasingly clear that CBM has no effects as a stand-alone treatment but may increase the effectiveness of other therapy (Wiers et al., 2018). The large majority of our participants were not in treatment for substance use and for them CBM was a stand-alone treatment. Furthermore, the training targeted behavior that they might not experience as problematic. They may have had little reason to reduce their substance use, particularly at one-year follow-up when most were no longer detained (70% of detained Dutch youth are released within three months). Without motivation to change behavior, no effects can be expected. Recent studies into CBM and addiction treatment argue that behavior is inherently goal-directed and highlight the importance of incorporating clients' goals in achieving positive outcomes (Wiers et al., 2020).

Some participants underwent substance use treatment, and the interaction between Brains4Use and active alcohol training was somewhat worrying. Youth enrolled in Brains4Use showed *more* alcohol use at follow-up when they received active-, rather than sham-training. As Brains4Use is focused on recognizing usage-inducive situations, it's possible that reducing attention to substance cues detracted from treatment. However, the number of youths in the alcohol training that received Brains4Use was very low (N = 4), making it difficult to generalize these findings. Furthermore, no information was available regarding the substance(s) the youths were treated for. It is possible that none of the alcohol-trained youth received alcohol treatment. Therefore, no reliable conclusions can be drawn from these results, but large RCTs with alcohol-dependent patients have shown positive add-on effects (Eberl et al., 2013; Manning et al., 2016, 2020; Wiers et al., 2018).

We also found an interaction for the alcohol training between working memory and VPT-group. Youth with lower working memory showed higher alcohol use, which is in line with a moderating effect of working memory on use. Curiously, this effect was only present in the active VPT group, not in the sham group. Again though, the number of participants was low (N = 29), so this finding may not be reliable. For the cannabis training, only one significant interaction was found, related to the ApB for neutral stimuli. However, given the issues raised earlier regarding AAT data, this finding is unlikely to be relevant for clinical practice.

When this study started, CBM addiction studies had only been performed within clinical, abstinence-oriented treatment settings or in student volunteers. As youth detention centers in the Netherlands are treatment settings where abstinence is imposed, it seemed reasonable to expect comparable effect-sizes. However, recent studies have shown that in non-abstaining volunteers, effects are much smaller, if existing at all (van Deursen, 2019; Wiers et al., 2015, 2018). In hindsight, our participants are much closer to non-abstaining volunteers than to clinical abstinence-oriented patients; our participants (presumably) don't have abstinence as a goal. They have not sought out treatment and do not have treatment motivations related to substances, as one might expect in clinical populations.

CBM effects are therefore likely to be small, if any. Our original power analysis was too optimistic as it was based on effects found in clinical samples. This means our study may not have been adequately powered to detect a small effect, and our results should be evaluated accordingly. Any effects that have been found should also be considered critically due to the relatively low number of inclusions, and relatively low average usage levels. It should also be noted that, contrary to standard RCTs, the TAU in this study did not necessarily relate to substance use. Nevertheless, there are still several strengths to the current study. Our CBM reduced substance AtBs, suggesting that it could support behavioral change if the participant wants to change. It is the first RCT investigating CBM effectiveness for detained youth. The study included most Dutch JDCs, increasing generalizability, and examined effects after a relatively long follow-up period (a year). Finally, the study has been executed with great independence from the judicial system. This makes the self-report data more reliable, as participants could be shown that we had no connections with the police, or anyone involved in their case.

It's become increasingly clear that CBM is not a catch-all solution, which this study corroborates. Despite relatively heavy cannabis use in our population, CBM alone did not result in change. Future research could focus on CBM as auxiliary treatment, in detained participants who receive treatment for substance use issues next to their court-mandated treatment. Additionally, those developing CBM should incorporate current views on task-design into their studies, such as using feature-relevant tasks and participant-salient alternatives, rather than universally neutral cues, and highlight the consequences of use vs. personally-relevant alternatives (Wiers et al., 2020). This new variety of cognitive training should preferably be tested in an integrated form with treatment for substance use.

CRediT authorship contribution statement

Hans S. van der Baan: Conceptualization, Data curation, Formal analysis, Methodology, Project administration, Writing – original draft, Writing – review & editing. **dr Annematt L. Collot D'Escury-Koenigs:** Conceptualization, Methodology, Supervision, Writing – review & editing. **dr Reinout W. Wiers:** Conceptualization, Funding acquisition, Methodology, Project administration, Resources, Supervision, Writing – review & editing.

Declaration of competing interest

The authors whose names are listed on the title page belonging to the manuscript with the title: "The effectiveness of Cognitive Bias Modification in reducing substance use in detained juveniles: An RCT" certify that they have NO affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

Data availability

Data will be made available on request.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jbtep.2023.101916.

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