ALCOHOLISM CLINICAL & EXPERIMENTAL RESEARCH

A Single Session of Attentional Bias Modification Reduces Alcohol Craving and Implicit Measures of Alcohol Bias in Young Adult Drinkers

Peter Luehring-Jones, Courtney Louis, Tracy A. Dennis-Tiwary, and Joel Erblich

Background: Attentional bias modification (ABM) techniques for reducing problematic alcohol consumption hold promise as highly accessible and cost-effective treatment approaches. A growing body of literature has examined ABM as a potentially efficacious intervention for reducing drinking and drinking-related cognitions in alcohol-dependent individuals as well as those at-risk of developing problem drinking habits.

Methods: This study tested the effectiveness of a single session of visual probe-based ABM training in a cohort of 60 non-treatment-seeking young adult drinkers, with a focus on examining mechanisms underlying training efficacy. Participants were randomly assigned to a single session of active ABM training or a sham training condition in a laboratory setting. Measures of implicit drinking-related cognitions (alcohol Stroop and an Implicit Association Task) and attentional bias (AB; alcohol visual probe) were administered, and subjective alcohol craving was reported in response to in vivo alcohol cues.

Results: Results showed that active ABM training, relative to sham, resulted in significant differences in measures of implicit alcohol-related cognition, alcohol-related AB, and self-reports of alcohol craving. Mediation analysis showed that reductions in craving were fully mediated by ABM-related reductions in alcohol-Stroop interference scores, suggesting a previously undocumented relationship between the 2 measures.

Conclusions: Results document the efficacy of brief ABM to reduce both implicit and explicit processes related to drinking, and highlight the potential intervention-relevance of alcohol-related implicit cognitions in social drinkers.

Key Words: Alcohol, Attentional Bias Modification, Visual Probe, Cue-Induced Craving, Young Adult Drinkers.

THE PROBLEMATIC CONSUMPTION of alcohol affects nearly 16% of the people over age 15 and contributes to 1.5 million worldwide deaths annually (Rehm and Shielf, 2013). Treatments to reduce drinking do exist, particularly in the domains of motivational interviewing and cognitive-behavioral therapies, but significant barriers to access, including cost and the limited availability of trained providers, mean that treatments cannot be offered to all who would benefit from them (Fowler et al., 2016). Moreover, relapse rates remain high, with up to 50% of alcohol-dependent drinkers relapsing within 3 months of concluding treatment (Fadardi and Cox, 2009). Attentional bias (AB), or the tendency for a person to preferentially allocate attention to salient stimuli in the environment, has been identified as a clinical feature of a number of different psychological conditions, including generalized anxiety disorder (e.g., Bar-Haim et al., 2007), substance use disorders (including alcohol use disorders) (e.g., Field and Cox, 2008), and eating disorders (e.g., Aspen et al., 2013). Numerous studies in recent years have investigated the complex relationships between ABs to alcohol, alcohol craving, alcohol consumption, and alcohol-related decision making, and whether those biases can be modified through clinical interventions to meaningfully reduce bias and/or consumption-related decisions (e.g., Eberl et al., 2013; Field and Eastwood, 2005; Field et al., 2007b; McGeary et al., 2014; Schoenmakers et al., 2007; Wiers et al., 2011).

Even with this large body of research, however, attentional bias modification (ABM) techniques to reduce alcohol use have been a topic of significant empirical debate given mixed results and null findings (Christiansen et al., 2015; Cristea et al., 2016; Eberl et al., 2013; Field et al., 2013; Mogoaşe et al., 2014). Complicating this debate is a dearth of evidence identifying specific mechanisms underlying the relationship between AB and alcohol use. Thus, there is no sufficient experimental clinical research based upon which to develop effective and scalable ABM techniques targeting alcohol use. Refining ABM techniques is highly desirable because they

From the Boston University (PL-J), Boston, Massachusetts; Hunter College (CL, TAD-T, JE), The City University of New York, New York City, New York; The Graduate Center (TAD-T, JE), The City University of New York, New York City, New York; and Icahn School of Medicine at Mount Sinai (JE), New York City, New York.

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Reprint requests: Joel Erblich, PhD, MPH, Hunter College Department of Psychology, HN628, The City University of New York, 695 Park Avenue, New York, NY 10065; Tel.: 212-396-6766; E-mail: jerblich@hunter.cuny.edu

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are brief, cost-effective, and highly accessible and thus have the potential to reduce treatment burden and optimize treatment engagement. In this study, we focus on 2 potential mechanisms underlying ABM efficacy: implicit cognitions and explicit craving for alcohol.

On a theoretical level, alcohol-related AB is thought to be a form of implicit cognition reflecting early, automatic orienting processes in the brain that interact with later, more reflective cognitions to influence decision-making and consumption choices (Burton et al., 2012; Dickson et al., 2013; Field et al., 2012; Houben and Wiers, 2009; Stacy and Wiers, 2010). These 2 forms of cognitive processes are conceptualized in modern dual-process theories of alcohol use (e.g., Tiffany, 1990) as belonging to different systems in the brain —implicit and automatic, versus explicit and reflective—that together dynamically impact decisions about drinking (Houben and Wiers, 2009; Stacy and Wiers, 2010). Indeed, recent research has shown that individual differences in the performance of the 2 systems can affect alcohol consumption choices (Burton et al., 2012; Houben and Wiers, 2009; Luehring-Jones et al., 2016; Thush et al., 2008).

Because implicit cognitions are by their nature impervious to modification through reflection alone, recent research has investigated whether they may be manipulated through laboratory interventions that fall under the general heading of attentional (or cognitive) bias modification training programs. These ABM programs include modified visual probe tasks that redirect attention from one type of stimuli to another over the course of numerous trials (Field and Eastwood, 2005; Field et al., 2007b), and the presentation of alcohol-related and neutral images against different colored backgrounds that require the user to identify the color of the background (Fadardi and Cox, 2009). In drinkers, existing literature suggests that AB can be modified by these training programs to either increase or decrease bias (Field et al., 2007a, 2012), with concomitant effects on the absolute consumption of alcohol (Fadardi and Cox, 2009; Field and Eastwood, 2005), a reduction in time spent in an inpatient alcohol treatment program (Schoenmakers et al., 2010), and reductions in craving for alcohol (Field et al., 2009).

In a related literature, a number of studies (e.g., Lindgren et al., 2015; Wiers et al., 2011) have investigated the efficacy of cognitive bias modification (CBM) techniques to modify implicit alcohol-related approach-avoid expectancies (e.g., Palfai and Ostafin, 2003). Research has found that heavy drinkers are faster to use a joystick to "pull" (i.e., approach) computer-presented images of alcohol toward them than they are to "push" (avoid) those same images away (Wiers et al., 2009). Repetitive training tasks have decreased alcohol approach bias in hazardous-drinking students (Wiers et al., 2010) and inpatients in alcohol treatment, who exhibited a 13% reduction in relapse (compared to a control group) 1 year after treatment (Wiers et al., 2011). These CBM results have been replicated (Eberl et al., 2013) and extended (Manning et al., 2016) by showing a 30% reduction in relapse 2 weeks after patients completed a 7-day alcohol detoxification program that included a course of active CBM training compared to controls in a sham training condition. While the outcomes from these studies suggest that ABM and CBM may be promising clinical tools, other authors have cautioned that more experimental evidence is required to clarify research results from studies that have failed to note similar effects (Christiansen et al., 2015; Cristea et al., 2016; Field et al., 2013; Schoenmakers et al., 2007; Wiers et al., 2013).

This study evaluated the efficacy of a modified visual probe task (modeled on the task used by Field and Eastwood, 2005) to reduce alcohol-related implicit cognitions, including ABs to alcohol-related stimuli, in a sample of non-treatment-seeking young adult drinkers. This population of young adult drinkers (including college students) represents an especially important group of individuals early in the trajectory of their lifetime drinking behavior, who may be particularly amenable to brief alcohol consumption interventions such as ABM. Recent research has shown that alcohol-related biases can be measured in adolescents soon after they begin drinking (Peeters et al., 2012, 2013), so that young adult drinkers, even if they have only been drinking for a short time, are likely to have developed biases that can be modified by ABM training. In particular, more evidence about the efficacy of ABM programs in different types of drinkers will help determine whether there are different groups for whom such training may be clinically useful, especially as different studies have offered alternate views about whether treatment-seeking participants respond to ABM programs differently than non-treatment-seeking participants (e.g., Lindgren et al., 2015; McGeary et al., 2014). This approach will allow practitioners to more accurately tailor their treatment offerings and help behavioral interventions move toward a model of precision medicine.

In the laboratory, AB toward alcohol-related stimuli is often measured by a visual probe task, which compares the time required to identify the location of a probe that replaces alcohol-related cues and neutral cues (e.g., Field and Cox, 2008), with faster reaction times to probes that replace alcohol-related cues indicating that those cues capture attention more quickly and are more salient than the neutral cues. Implicit associations about alcohol can be measured by the Implicit Association Task (IAT; Greenwald et al., 1998; Ostafin and Palfai, 2006) and reflect the relative strength of favorable and unfavorable associations about alcohol, with more favorable associations about alcohol related to increased consumption of alcohol and stronger cravings for alcohol (Burton et al., 2012; Jajodia and Earleywine, 2003; Lindgren et al., 2013; Stacy and Wiers, 2010; de Wit, 2008). Separately, implicit alcohol-Stroop interference is assessed through a modified version of the traditional Stroop task (Stroop, 1935) wherein differences in the reaction times required to correctly identify the colors in which alcohol-related and neutral words are presented are believed to index the degree to which each type of word captures attention (Cox et al., 2006; Field et al., 2007a, 2012). Past research has revealed that heavy and dependent drinkers take longer to correctly identify the color of the alcohol-related words than the neutral words (Field et al., 2007a, 2012), which implies that the alcohol-Stroop task, like the IAT, can be used as both a measure of change for implicit cognitions and an index of the generalizability of effects that may derive from ABM training programs.

In an independent literature, alcohol craving has been defined as one of the underlying motivational mechanisms for alcohol seeking and consumption (Franken, 2003), and can serve as potential mechanism for relapse (Papachristou et al., 2014). Under laboratory conditions, exposure to alcohol-related cues have been shown to elicit significant craving responses (Manchery et al., 2017; Rankin et al., 1979) which may be important predictors of drinking decisions (Carter and Tiffany, 1999; Drummond, 2000). Differences in craving following laboratory cue exposures may serve as a valuable index of the real-world effectiveness of ABM training. Consistent with this possibility, Field and Eastwood (2005) and Field and colleagues (2007b) found that participants trained to attend to alcohol-related stimuli reported an increase in subjective craving. In a meta-analysis conducted by Field and colleagues (2009), the authors found a positive correlation between ABs toward alcohol and craving for alcohol. A recent study (Manchery et al., 2017) also found a significant relationship between AB and cue-induced alcohol craving, suggesting that heightened attention to alcohol cues may be associated with increased craving responses to these cues. Taken together, this research raises the possibility that ABM training may be able to reduce cue-induced cravings for alcohol via a reduction in AB toward alcohol.

Hypotheses

In this study, we hypothesized that (i) a computerized, laboratory-based ABM training program based on a modified visual probe task would measurably reduce ABs to alcohol-related stimuli and associated implicit cognitions of young adult drinkers, and (ii) the same bias training would, through its reduction in bias, also reduce cravings elicited by exposure to alcohol cues. The random allocation of participants to either active or sham bias training would provide the necessary comparison groups to evaluate the effect of training type on dependent posttraining measures of bias and craving.

MATERIALS AND METHODS

Participants

Participants were healthy young adult drinkers (n = 60) recruited from a larger pool of participants (N = 123) who had already completed a 2-visit study of alcohol craving at a large, urban university in the Northeastern United States (for partial results of the larger study, see Luehring-Jones et al., 2016; Manchery et al., 2017; Yarmush et al., 2016). The first 60 participants of the larger study were randomized to this study. Forty-five percent (n = 27) of the participants were male, and 55% (n = 33) were female. Reported ethnicity was 28.3% Asian (n = 17), 25% White (n = 15), 23.3% Hispanic (n = 14), and 16.7% Black (n = 10); 6.7% (n = 4) reported other ethnicities. Annual household income varied from <$10,000 (8.3%, n = 5) to more than $100,000 (18.3%, n = 11). Participants had an average age of 21.9 years (SD = 2.2), had started drinking at an average age of 18.5 years (SD = 2.2), and consumed an average of 3.1 drinks per episode (SD = 1.3) during an average of 2.1 drinking episodes per week (SD = 1.2) over the past 90 days. The participants reported an average of 5.3 (SD = 7.3) binge-drinking episodes in the 3 months prior to enrollment in the study and had an average score of 10.1 (SD = 4.6) on the Alcohol Use Disorders Identification Test (AUDIT; Saunders et al., 1993), indicating that some participants had engaged in risky drinking behavior. That said, the mean score on the Obsessive-Compulsive Drinking Scale (OCDS; Anton et al., 1995) was 9.9 (SD = 5.4), well below the average score of 22.5 typically observed in clinical samples (Anton et al., 1995). Table 1 summarizes the demographic information of the participants. None of the participants was seeking treatment for his or her alcohol use or expressed a desire to change his or her drinking habits.

Table 1. Participant Characteristics

Measure	Total (N = 60)	Active training (n = 30)	Sham training (n = 30)
Gender			
Female	33 (55%)	16 (53%)	17 (57%)
Male	27 (45%)	14 (47%)	13 (43%)
Age in years	21.9 (2.2)	22.1 (2.4)	21.8 (2.0)
Drinking behavior			
Age of regular drinking	18.5 (2.2)	18.5 (2.1)	18.4 (2.3)
Episodes per week	2.1 (1.2)	1.9 (1.0)	2.3 (1.3)
Drinks per episode	3.1 (1.3)	3.1 (1.4)	3.0 (1.3)
Binge-drinking episodes[a]	5.3 (7.7)	5.3 (8.6)	5.4 (6.8)
AUDIT score	10.1 (4.6)	10.1 (5.0)	10.0 (4.3)
OCDS score	9.9 (5.4)	10.0 (5.6)	9.7 (5.2)

[a]Binge-drinking episodes were the number of episodes during the 3 months prior to enrollment in the study, as revealed by the Timeline Follow-Back Questionnaire interview.

Means (SD) are displayed, except for gender, where n (%) are displayed. No significant group differences were observed in any of the variables in the table.

Potential participants were excluded if they reported consuming fewer than 3 drinks per week, endorsed a past or present psychiatric disorder, reported the current consumption of illegal substances, had a history of cardiovascular disease or current pregnancy, or failed either a urine toxicology screening for illicit drugs or an alcohol breath test (using an Alco-Sensor IV portable breath alcohol analyzer; Intoximeters, Inc., St. Louis, MO).

Overview

The research activities described in this paper were approved by the University-Integrated Institutional Review Board of the City University of New York. Participants gave informed consent prior to engaging in this study, received compensation of $60 in cash for the protocol described in this report, and were fully debriefed upon completion. Participants attended 3 study sessions on different days. During the first session, participants provided urine and breath samples to confirm eligibility, completed background questionnaires, and participated in a baseline cue-induced craving task. During the second session, participants completed measures of alcohol-related implicit biases. Finally, during the third session, participants were randomly assigned to either the active or sham ABM training group and completed a series of computer-based tasks to measure alcohol-related biases immediately before and after the training program.

These tasks included an alcohol visual probe task, alcohol-Stroop task, and alcohol approach-avoid IAT in an order that was counterbalanced between participants. Finally, immediately prior to finishing the third session, participants completed a second cue-induced craving task in the same form as had been administered during the first study session.

Background Questionnaires

The AUDIT (Saunders et al., 1993) is a 10-item questionnaire that collects information about alcohol consumption, dependence, and consequences. Possible scores range between 0 and 40, with scores over 8 suggesting the presence of harmful drinking (Bohn et al., 1995).

The OCDS (Anton et al., 1995) is a 14-item questionnaire in which participants respond on a Likert-like scale from 0 to 4. The scale consists of 2 subscales, obsessions and compulsions, with a possible range of 0 to 28 for each, with higher scores indicating more obsessions and/or compulsions.

The Timeline Follow-Back Questionnaire (TLFB; Sobell and Sobell, 1992) is an assessment designed to aid participants in accurately recalling their past alcohol consumption. For the purposes of this study, the TLFB assessed drinking over the 90 days prior to the participant's first laboratory session and collected data on the number of total drinks, drinking days, and drinks per day during that period.

Cognitive Measures

Implicit Association Task. Participants completed a version of the IAT (Greenwald et al., 1998) developed by Ostafin and Palfai (2006) to measure favorable associations with alcohol-related stimuli. The IAT was presented in Inquisit 4 (Millisecond Software, Seattle, WA) on a PC running Windows 7 (Microsoft, Redmond, WA) and measured the strength of individuals' associations between approach/avoid attribute words (e.g., approach, closer, avoid, leave) and target images of alcohol and water. Participants were instructed to sort alcohol and water images with approach words and avoid words in different blocks of trials. In one block of trials, participants were instructed to classify alcohol-related images with approach words and water-related images with avoid words. In a separate block of trials, the pairings were reversed, and participants matched alcohol-related images to avoid words and water-related images to approach words. Differences in categorization latencies between the 2 sets of blocks were used to assess individual tendencies to associate alcohol with approach or avoid words. Consistent with Greenwald and colleagues (2003), trials with latencies >10,000 ms were to be eliminated and participants for whom more than 10% of trials had latencies <300 ms were to be excluded from analyses. In this sample, however, no such conditions existed, and thus adjustments were not necessary. Latencies on error trials were replaced with the mean latency for the block plus an additional 600 ms error penalty. The IAT was scored using Greenwald and colleagues' (2003) *d*-score algorithm with higher (positive) *d*-scores indicating stronger associations between alcohol and "approach" and lower (negative) scores indicating stronger associations between alcohol and "avoid." Internal consistency was high for all trial blocks, with correlations of 0.591 for the pretraining blocks and 0.680 for the posttraining blocks.

Alcohol-Stroop Task. The alcohol-Stroop task consisted of 2 blocks of 25 alcohol-related (e.g., alcohol: vodka) and 25 neutral (e.g., nature-related: sea) words that were presented in each of 4 different colors (blue, green, red, or yellow), for a total of 200 trials during which the participant had to rapidly indicate the color of the word presented on the screen using a response box. The word list used in this study was derived from the alcohol-Stroop task featured in Field and colleagues (2012) and updated slightly to reflect alcohol-related words more common to an American audience. The order of the stimuli was counterbalanced so that participants completed either the alcohol or neutral block first. Only correct responses were utilized in the calculation of response latencies. AB scores (i.e., Stroop interference scores) were computed by subtracting the average neutral reaction time from the average alcohol reaction time, so that a positive value indicated that participants took longer to identify the color in which alcohol-related words were presented during the task.

Visual Probe Task. AB to alcohol-related stimuli was measured by a visual probe task modeled on the task used by Miller and Fillmore (2010) and was presented in ePrime Professional 2.0 (Psychology Software Tools, Inc., Sharpsburg, PA) on a PC running Windows 7. During the task, participants used a manual response box to identify the location (either left or right) of a visual probe (an "X") that replaced 1 of 2 horizontally opposed images. After completing 12 practice trials (in which all images were drawn from Miller and Fillmore's [2010] library of simple "filler" images of single office objects against a gray background), participants completed an evaluative round of 80 trials, 40 of which paired 1 alcoholic beverage image and 1 filler image, and 40 of which paired 1 nonalcoholic beverage image and 1 filler image. There were 10 images of alcoholic beverages, 10 images of nonalcoholic beverages, and 20 filler images. The task was programmed in such a way so that over the course of the 80 trials, each of the 20 alcoholic and nonalcoholic beverage images was presented 4 times: twice on the left side of the screen and twice on the right side of the screen. In half of those appearances, the probe appeared behind the beverage images; during the other appearances, the probe appeared behind the filler images. This resulted in the presentation of all possible image/probe combinations to each participant.

Before each trial, a fixation cross appeared in the center of the screen for 1,000 ms. The fixation cross then disappeared and the 2 images appeared to the left and right of where the cross had been and remained on the screen for 1,000 ms. After a brief interval (1,000 ms), an "X" replaced 1 of the images, after which the participants used a response box to identify whether the X had appeared behind the image on the left or the image on the right.

The mean reaction times required to identify the location of the probe, either behind the alcoholic or nonalcoholic beverage image (the alcohol-congruent or neutral-congruent conditions) or behind the filler image (the alcohol-incongruent or neutral-incongruent conditions), were calculated. Slower alcohol-incongruent and faster alcohol-congruent reaction times indicated greater implicit bias toward alcohol. Overall AB to the alcohol images was computed by subtracting the average alcohol-congruent reaction time from the average alcohol-incongruent reaction time, so that a positive difference score indicated a bias toward the alcohol images and a negative difference score indicated a bias away from the alcohol images. Reaction times from incorrect trials and trials in which participants responded more quickly than 100 ms or more slowly than 1,000 ms were eliminated (Duka and Townshend, 2004; Townshend and Duka, 2001).

ABM Training

The ABM training consisted of a modified version of the visual probe task with neutral and alcohol-related images. The ABM training included 3 blocks of training (approx. 10.5 minutes per block), with a 5-minute break between the first and second blocks and a 10-minute break between the second and third blocks. Each block included 256 trials. During the task, participants were presented with a fixation cross (1,000 ms) followed by an alcohol or neutral image on the left and right of the cross for 500 ms. After image offset and an interval of 1,000 ms, a probe (i.e., either a left or right pointing arrow) was presented on the screen and replaced either the alcohol or neutral image. Participants were instructed to identify which image (either left or right) the arrow had replaced. Participants were randomly assigned to either active or sham training. In the active training condition, the probe replaced the neutral images 100% of the time, and in the sham condition, the probe replaced the neutral image 50% of the time. The participants were not informed of their training assignment.

Cue Exposure Task

The cue exposure task measured craving for alcohol immediately before and after 4 different cues: 90-second in vivo exposures to alcohol (looking at and smelling a glass of one's preferred type of alcohol) and neutral (looking at and smelling a glass of water) cues, and 90-second imaginal exposures to alcohol (imaging yourself at a party and having a drink) and neutral (imagining yourself at a grocery store) situations. Craving was measured using a face-valid 5-item (e.g., craving, urge, desire) self-report measure (0 to 100) used in previous work (Erblich et al., 2009; Yarmush et al., 2016). The order of the cue exposures was counterbalanced to avoid order effects. In addition, to minimize potential carryover effects, participants viewed 90-second nature-related video clips between the cue exposures (Piferi et al., 2000). As indicated above, the cue-induced craving task was administered twice, once during the first "baseline" study visit, and once again during the third study visit, after the ABM training and assessment of posttraining implicit biases.

Table 2. Pre-/Posttraining Descriptive Measures (Raw, Unadjusted Means) of Attentional Bias and Cue-Induced Craving

	Pretraining		Posttraining	
Measure	*M*	SD	*M*	SD
Active Training Group (*n* = 30)				
Stroop Interference Score	7.53	129.15	−14.51	145.46
Implicit Association Task (IAT) *d*-score	−0.47	0.43	−0.38	0.41
Alcohol-incongruent condition	393.04	53.46	385.62	39.15
Craving to in vivo alcohol cues	16.5		9.9	
Craving to in vivo neutral cues	−1.1		−1.0	
Sham Training Group (*n* = 30)				
Stroop Interference Score	−18.31	206.08	53.11	166.47
IAT *d*-score	−0.24	0.40	−0.19	0.41
Alcohol-incongruent condition	394.81	56.43	407.24	54.13
Craving to in vivo alcohol cues	11.1		16.2	
Craving to in vivo neutral cues	−1.5		−3.0	

As indicated in the text, statistical analyses were conducted on posttraining bias and craving, controlling for pretraining, in an omnibus model.

RESULTS

Calculating AB

Many studies that have utilized the visual probe task have assessed bias toward alcohol on the basis of an "overall bias" score calculated as the difference between average reaction times to the alcohol-incongruent and alcohol-congruent conditions versus neutral conditions (Field and Eastwood, 2005; Field et al., 2004, 2005; Noël et al., 2006). The overall bias score therefore is often a composite of 2 difference scores, which can be somewhat unreliable, especially in small samples. Other studies have examined the reaction times to the alcohol-congruent and alcohol-incongruent conditions separately (Field and Powell, 2007; Miller and Fillmore, 2010; Schoenmakers et al., 2008). In the present results, overall bias was not significantly altered by the ABM training program, but reaction times in the alcohol-incongruent condition were significantly reduced between the active and sham training groups. In the results and analyses that follow, only the alcohol-incongruent reactions times, rather than the overall bias score, were used.

Participant Characteristics

Table 2 lists the pre- and posttraining scores obtained from our 3 measures of implicit bias (the alcohol-Stroop, alcohol-incongruent condition of the visual probe, and IAT tasks) and the posttraining cue-induced craving task. Table 3 lists the Pearson correlation coefficients between the outcome variables of interest in the study. Greater AUDIT scores were associated with greater OCDS scores and the number of drinks per drinking episode in our overall sample, whereas greater OCDS scores were separately associated with an increased number of drinking episodes per week and an increased number of drinks per drinking episode.

Among the 3 cognitive variables, none of the pretraining scores were significantly associated with one another. However, both the posttraining visual probe task scores and the posttraining alcohol-Stroop interference scores were associated with greater posttraining IAT scores. Pre- and posttraining visual probe task scores were moderately significantly correlated, as were pre- and posttraining IAT *d*-scores. Greater AUDIT scores were correlated with greater pretraining IAT *d*-scores whereas greater OCDS scores were correlated with greater pre- and posttraining IAT *d*-scores. Finally, an increased number of drinks per drinking episode was related to greater pretraining alcohol-Stroop scores.

Effects of Training on Implicit Alcohol Bias

To address the study hypotheses, we conducted a multivariate analysis of variance (MANOVA) with the 3 posttraining implicit bias measures (alcohol-Stroop interference, bias toward the alcohol-incongruent condition of the visual probe, and IAT *d*-score) as dependent variables, and ABM condition (active training, sham training) as the independent variable. After controlling for pre-ABM implicit bias scores, drinking habits and OCDS scores, findings revealed a significant overall effect of the training, $F(3, 48) = 4.4$, $p = 0.008$, with an effect size (η^2) of 0.22.

We followed the significant MANOVA with a series of univariate ANOVAs to better characterize the effect of the training on each dependent measure. As depicted in Fig. 1, the training had a significant effect on alcohol-Stroop scores, $F(1, 50) = 10.1$, $p = 0.003$, partial $\eta^2 = 0.167$; a significant effect on IAT *d*-scores, $F(1, 50) = 4.8$, $p = 0.034$, partial $\eta^2 = 0.089$; and a significant effect on reaction times in the

Table 3. Correlations

Item	1	2	3	4	5	6	7	8	9	10
1. AUDIT score	—	0.674**	0.243	0.579**	−0.011	−0.091	0.182	0.023	0.283*	0.231
2. OCDS score		—	0.453**	0.442**	0.143	0.007	−0.002	0.186	0.373*	0.289*
3. Drinking episodes per week			—	−0.083	0.235	0.022	−0.144	0.042	0.183	0.083
4. Drinks per drinking episode				—	−0.147	−0.119	0.301*	0.056	0.121	0.250
5. Pretraining visual probe score					—	0.585**	−0.052	0.132	0.128	−0.027
6. Posttraining visual probe score						—	−0.085	0.148	0.205	0.278*
7. Pretraining Stroop score							—	−0.113	−0.247	0.148
8. Posttraining Stroop score								—	0.191	0.323*
9. Pretraining IAT *d*-score									—	0.548**
10. Posttraining IAT *d*-score										—

*$p < 0.05$, **$p < 0.01$.
Visual probe scores are reported for the alcohol-incongruent condition only.

Fig. 1. Effects of ABMT on implicit measures of alcohol bias. **p* is significant at 0.05, ***p* is significant at 0.01.

incongruent condition of the alcohol visual probe task, $F(1, 50) = 4.6$, $p = 0.036$, partial $\eta^2 = 0.088$. In each case, participants in the active training condition exhibited less bias toward alcohol-related stimuli, including lower alcohol-Stroop interference scores, greater associations between "alcohol" and "avoid" on the IAT, and faster reaction times in the alcohol-incongruent condition of the visual probe task, than did participants who had received the sham training. Effects of ABM on alcohol-congruent reaction time, however, did not reach significance ($p > 0.10$). Similarly, there were no training effects on either neutral-congruent or neutral-incongruent reaction times (*p*s > 0.24). Finally, while the posttraining IAT *d*-scores of the active training group were significantly lower (i.e., representing a greater association between alcohol and avoid) than the posttraining IAT *d*-scores in the sham training group, overall associations for both groups actually increased slightly, representing a global increase in associations between alcohol and approach across the entire sample. The implications of this finding will be discussed below.

Effects of Training on Cue-Induced Alcohol Craving

To test the effects of training on cue-induced craving, we conducted a repeated-measures ANOVA with cue (neutral, alcohol) and day (pretraining, posttraining) as within-subjects factors, and training (active, sham) as the independent variable, controlling, as above, for drinking habits and OCDS scores. The dependent variable was the change in craving from immediately before to immediately after each exposure. Consistent with the study hypothesis, we observed a significant Training × Cue × Day interaction, $F(1, 51) = 4.4$, $p = 0.042$, $\eta^2 = 0.078$, such that those participants in the active training group exhibited significantly lower craving reactions after exposure to alcohol cues.

Mediational Analyses of ABM Training, Cue-Induced Craving, and Implicit Bias

We next tested the hypothesis that the effects of ABM on cue-induced craving were mediated by reductions in implicit bias. To that end, we calculated indirect effects of training on craving through implicit bias, and we estimated bootstrapped 95% confidence intervals (10,000 samples) for the indirect effect using the SPSS PROCESS macro, as described in Hayes (2013). This process was carried out separately for each of the 3 potential mediators: Stroop interference, alcohol-incongruent visual probe scores, and IAT *d*-scores. Partially consistent with the hypothesis, results revealed a significant indirect effect of training on the reduction in craving, but only through the reduction in Stroop interference scores (see Fig. 2; $b = -0.13$, 95% confidence interval:

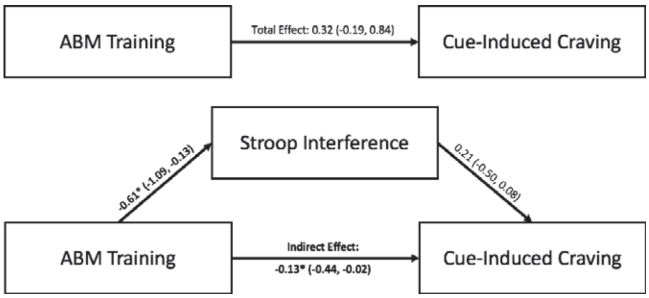

Fig. 2. Stroop interference scores mediated the effects of ABMT on cue-induced craving. $*p < 0.05$

[−0.44, −0.02]). Indirect effects through visual probe scores and IAT *d*-scores, however, were not significant.

DISCUSSION

The results of this study replicate previous work that has demonstrated the efficacy of ABM training in reducing ABs toward alcohol-related stimuli (Eberl et al., 2013; Field and Eastwood, 2005; Field et al., 2007b; McGeary et al., 2014; Schoenmakers et al., 2007, 2010) and extend findings to non-treatment-seeking young adult drinkers, a potential risk group that has been less studied in the literature than drinkers who consume alcohol excessively (e.g., Christiansen et al., 2015). Although our ABM intervention employed a visual probe task, its effects generalized to Stroop interference scores in addition to improvements in the alcohol-incongruent condition of the visual probe task itself. IAT *d*-scores were significantly lower in the active training group after training, but global increases in posttraining IAT *d*-scores across both groups suggest that the finding of a significant difference might have been due to initial variation in *d*-scores between the groups rather than to the ABM training (see Table 2). Additionally, findings demonstrate that ABM training reduces cravings elicited by exposure to alcohol cues, an outcome with particular clinical relevance given its potential role in problem drinking. Importantly, we found an indirect effect of ABM training on craving reductions through the reduction in alcohol-Stroop interference scores. This indirect effect suggests that there may be an underlying cognitive mechanism common to both cue-induced craving and the Stroop interference effect that is subject to manipulation by laboratory-based ABM training and that ABM exerts its effects on cue-induced craving by altering implicit cognitions related to alcohol. Whereas previous research similarly documents that ABs toward alcohol-related stimuli can be manipulated by a single session of a visual probe-based ABM training program (Fadardi and Cox, 2009; Field and Eastwood, 2005; Field et al., 2007b; Schoenmakers et al., 2007), the present study investigated these effects in a sample of young adult drinkers who were neither treatment-seeking nor alcohol-dependent and thus represent an important target group for early, brief interventions such as ABM.

These results provide an additional perspective on other findings related to young adult drinkers in the experimental literature. In a recent study, Lindgren and colleagues (2015) found that a training paradigm designed to reduce implicit alcohol approach tendencies in a non-treatment-seeking sample of undergraduate social and risky drinkers did not reduce implicit alcohol associations or drinking outcomes. In a second study, McGeary and colleagues (2014) reported that an online dot-probe-based attentional training program did result in significant reductions in alcohol consumption in a group of non-treatment-seeking but heavy-drinking undergraduate students. The participants in the present study included some undergraduates and some heavier/risker drinkers (as measured by AUDIT scores and engagement in binge-drinking episodes), but also nonstudents and lighter drinkers, so that the results described herein may recommend visual probe-based interventions over other training approaches that attempt to alter alcohol approach and avoidance tendencies.

The alcohol visual probe and alcohol-Stroop tasks are the tasks most-often encountered in the ABM training literature (e.g., Christiansen et al., 2015), and while not without methodological challenges (Ataya et al., 2012; Cox et al., 2006), remain the standard tasks used to assess outcomes in ABM training studies. The alcohol IAT was included as a third cognitive assessment task in order to examine whether the ABM training was capable of altering implicit attitudes toward alcohol-related stimuli, which a growing body of evidence has found to be predictive of alcohol consumption, poorly controlled drinking, and other important factors related to alcohol use (Lindgren et al., 2014; Ostafin et al., 2008, 2014; Reich et al., 2010; Roefs et al., 2011). The inclusion of these 3 measures of implicit alcohol-related cognition allowed us to better conceptualize the range of effects that ABM training can exert and model relationships between alcohol-related cognitions and behaviors that have not been previously observed.

To our knowledge, this is the first study to demonstrate that ABM training can significantly reduce cravings for alcohol induced by exposure to in vivo alcohol cues. den Uyl and colleagues (2016) noted a significant reduction in cue-induced craving to alcohol-related pictures (rather than in vivo cues) for hazardous-drinking participants who received transcranial direct current stimulation (tDCS) in addition to a CBM program, but the authors attributed the reduction in cue-induced craving to the effects of the tDCS and noted that overall craving did not decrease in their participants. Wiers and colleagues (2015) observed significant reductions in both craving and amygdala activity in response to visual alcohol cues in alcohol-dependent patients following several sessions of active CBM: their findings suggest that the amygdala may be the neurological locus of the changes in cue-induced craving observed in the present study.

Our observation that reductions in cue-induced craving after ABM training were mediated by reductions in alcohol-Stroop interference scores is a similarly novel finding within the AB literature. Only 1 study (Fadardi and Cox, 2009) noted a decrease in alcohol-Stroop interference scores following ABM training in hazardous drinkers. The mediation effect of the alcohol-Stroop interference scores on cue-induced craving suggests that both craving and the alcohol-Stroop task may share a common cognitive mechanism that is amenable to change via ABM training techniques. Finally, it is worth noting that of the 3 cognitive variables examined in this study (the alcohol-Stroop task, the IAT, and the visual probe task), the alcohol-Stroop task exhibited the largest effect from pre- to posttraining measurement. The relatively small overall effects of ABM on IAT and visual probe scores may have made it difficult in this sample to identify significant indirect effects.

Additionally, there is evidence that Stroop interference scores reflect a measure of delayed disengagement rather than the initial orienting of attention (Field and Cox, 2008; Field et al., 2009). Keeping this in mind, the mediated effect of ABM training on cue-induced craving via the Stroop may indicate that the ABM intervention reduced the extent to which alcohol-related stimuli were able to sustain the participants' attention, which in turn led to reductions in cravings following exposure to alcohol cues. When combined with the results of the visual probe task, which measures the strength of the participants' initial attentional orientation, the results suggest that the ABM training program was able to target both the initial orienting of attention and later delayed disengagement. Future research should investigate the role of initial attention allocation and sustained attention on craving outcomes.

The study has several noteworthy limitations. First, the sample was relatively small, and thus, results should be interpreted with appropriate caution. Along these lines, the modest sample size may have contributed to the pretraining variability observed in the study. A larger sample may have yielded more stable pretraining levels of AB, potentially yielding stronger overall effects. Replication on a larger sample would also permit the exploration of key effect moderators, including drinking habits, with a particular focus on drinkers who are selected for increased risk of developing alcohol use disorders. Replication of the current effects in high-risk samples would provide further evidence of the clinical utility of ABM. Finally, to reduce habituation, we employed filler images in the visual probe task (Miller and Fillmore, 2010). It is possible that direct comparisons between alcohol and neutral stimuli as a measure of bias would have yielded stronger results.

Research into the efficacy of ABM training programs has expanded greatly over the past decade. Initial enthusiasm, however, has been tempered by numerous studies with inconclusive or contradictory findings, and recent articles, including a review (Christiansen et al., 2015) and meta-analyses (Cristea et al., 2016; Mogoaşe et al., 2014), have advised researchers and clinicians to demand more data before reaching firm conclusions about the utility of these attentional retraining techniques. The results presented in this paper offer evidence that ABM training can be effective at reducing alcohol-related biases and cue-induced craving in a group of young adult drinkers, but additional research will be required to gauge the effectiveness of this type of training over time and in the many different situations in which craving may occur. Ultimately, the assessment of the clinical relevance of ABM will rest on larger prospective studies that link ABM training with downstream reductions in alcohol ABs, other implicit cognitions, cravings, and drinking behavior.

AUTHOR CONTRIBUTIONS

PL-J, TAD-T, and JE designed the study. JE conducted all statistical analyses and associated interpretations of data. PL-J and CL drafted the manuscript. All authors contributed to the editing of the manuscript and approved the final version of the manuscript prior to submission.

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CONFLICTS OF INTEREST

The authors report no conflicts of interest.

REFERENCES

Anton RF, Moak DH, Latham P (1995) The Obsessive Compulsive Drinking Scale: a self-rated instrument for the quantification of thoughts about alcohol and drinking behavior. Alcohol Clin Exp Res 19:92–99.

Aspen V, Darcy AM, Lock J (2013) A review of attention biases in women with eating disorders. Cogn Emot 27:820–838.

Ataya AF, Adams S, Mullings E, Cooper RM, Attwood AS, Munafò MR (2012) Internal reliability of measures of substance-related cognitive bias. Drug Alcohol Depend 121:148–151.

Bar-Haim Y, Lamy D, Pergamin L, Bakermans-Kranenburg MJ, van IJzendoorn MH (2007) Threat-related attentional bias in anxious and nonanxious individuals: a meta-analytic study. Psychol Bull 133:1–24.

Bohn MJ, Babor TF, Kranzler HR (1995) The Alcohol Use Disorders Identification Test (AUDIT): validation of a screening instrument for use in medical settings. J Stud Alcohol 56:423–432.

Burton CM, Pedersen SL, McCarthy DM (2012) Impulsivity moderates the relationship between implicit associations about alcohol and alcohol use. Psychol Addict Behav 26:766–772.

Carter BL, Tiffany ST (1999) Meta-analysis of cue-reactivity in addiction research. Addiction 94:327–340.

Christiansen P, Schoenmakers TM, Field M (2015) Less than meets the eye: reappraising the clinical relevance of attentional bias in addiction. Addict Behav 44:43–50.

Cox WM, Fadardi JS, Pothos EM (2006) The addiction-Stroop test: theoretical considerations and procedural recommendations. Psychol Bull 132:443–476.

Cristea IA, Kok RN, Cuijpers P (2016) The effectiveness of cognitive bias modification interventions for substance addictions: a meta-analysis. PLoS One 11:e0162226.

Dickson JM, Gately C, Field M (2013) Alcohol dependent patients have weak negative rather than strong positive implicit alcohol associations. Psychopharmacology 228:603–610.

Drummond DC (2000) What does cue-reactivity have to offer clinical research? Addiction 95(Suppl 2):S129–S144.

Duka T, Townshend JM (2004) The priming effect of alcohol pre-load on attentional bias to alcohol-related stimuli. Psychopharmacology 176:353–361.

Eberl C, Wiers RW, Pawelczack S, Rinck M, Becker ES, Lindenmeyer J (2013) Approach bias modification in alcohol dependence: do clinical effects replicate and for whom does it work best? Dev Cogn Neurosci 4:38–51.

Erblich J, Montgomery GH, Bovbjerg DH (2009) Script-guided imagery of social drinking induces both alcohol and cigarette craving in a sample of nicotine-dependent smokers. Addict Behav 34:164–170.

Fadardi JS, Cox WM (2009) Reversing the sequence: reducing alcohol consumption by overcoming alcohol attentional bias. Drug Alcohol Depend 101:137–145.

Field M, Christiansen P, Cole J, Goudie A (2007a) Delay discounting and the alcohol Stroop in heavy drinking adolescents. Addiction 102:579–586.

Field M, Cox WM (2008) Attentional bias in addictive behaviors: a review of its development, causes, and consequences. Drug Alcohol Depend 97:1–20.

Field M, Duka T, Eastwood B, Child R, Santarcangelo M, Gayton M (2007b) Experimental manipulation of attentional biases in heavy drinkers: Do the effects generalise? Psychopharmacology 192:593–608.

Field M, Eastwood B (2005) Experimental manipulation of attentional bias increases the motivation to drink alcohol. Psychopharmacology 183:350–357.

Field M, Marhe R, Franken IHA (2013) The clinical relevance of attentional bias in substance use disorders. CNS Spectr 19:225–230.

Field M, Mogg K, Bradley BP (2005) Craving and cognitive biases for alcohol cues in social drinkers. Alcohol Alcohol 40:504–510.

Field M, Mogg K, Mann B, Bennett GA, Bradley BP (2012) Attentional biases in abstinent alcoholics and their association with craving. Psychol Addict Behav 27:71–80.

Field M, Mogg K, Zetteler J, Bradley BP (2004) Attentional biases for alcohol cues in heavy and light social drinkers: the roles of initial orienting and maintained attention. Psychopharmacology 176:88–93.

Field M, Munafò MR, Franken IHA (2009) A meta-analytic investigation of the relationship between attentional bias and subjective craving in substance abuse. Psychol Bull 135:589–607.

Field M, Powell H (2007) Stress increases attentional bias for alcohol cues in social drinkers who drink to cope. Alcohol Alcohol 42:560–566.

Fowler LA, Holt SL, Joshi D (2016) Mobile technology-based interventions for adult users of alcohol: a systematic review of the literature. Addict Behav 62:25–34.

Franken IHA (2003) Drug craving and addiction: integrating psychological and neuropsychopharmacological approaches. Prog Neuropsychopharmacol Biol Psychiatry 27:563–579.

Greenwald AG, McGhee DE, Schwartz JLK (1998) Measuring individual differences in implicit cognition: the implicit association test. J Pers Soc Psychol 74:1464–1480.

Greenwald AG, Nosek BA, Banaji MR (2003) Understanding and using the Implicit Association Test: I. An improved scoring algorithm. J Pers Soc Psychol 85:197–216.

Hayes AF (2013) Introduction to Mediation, Moderation, and Conditional Process Analysis: A Regression-Based Approach, Methodology in the Social Sciences. The Guildford Press, New York, NY.

Houben K, Wiers RW (2009) Response inhibition moderates the relationship between implicit associations and drinking behavior. Alcohol Clin Exp Res 33:626–633.

Jajodia A, Earleywine M (2003) Measuring alcohol expectancies with the implicit association test. Psychol Addict Behav 17:126–133.

Lindgren KP, Foster DW, Westgate EC, Neighbors C (2013) Implicit drinking identity: drinker+me associations predict college student drinking consistently. Addict Behav 38:2163–2166.

Lindgren KP, Neighbors C, Westgate E, Salemink E (2014) Self-control and implicit drinking identity as predictors of alcohol consumption, problems, and cravings. J Stud Alcohol Drugs 75:290–298.

Lindgren KP, Wiers RW, Teachman BA, Gasser ML, Westgate EC, Cousijn J, Enkema MC, Neighbors C (2015) Attempted training of alcohol approach and drinking identity associations in US undergraduate drinkers: null results from two studies. PLoS One 10:e0134642.

Luehring-Jones P, Dennis-Tiwary TA, Murphy JG, Dennhardt A, Lindgren KP, Yarmush DE, Erblich J (2016) Favorable associations with alcohol and impaired self-regulation: a behavioral economic analysis. Drug Alcohol Depend 163:172–178.

Manchery L, Yarmush DE, Luehring-Jones P, Erblich J (2017) Attentional bias to alcohol stimuli predicts elevated cue-induced craving in young adult social drinkers. Addict Behav 70:14–17.

Manning V, Staiger PK, Hall K, Garfield JBB, Flaks G, Leung D, Hughes LK, Lum JAG, Lubman DI, Verdejo-Garcia A (2016) Cognitive bias modification training during inpatient alcohol detoxification reduces early relapse: a randomized controlled trial. Alcohol Clin Exp Res 40:2011–2019.

McGeary JE, Meadows SP, Amir N, Gibb BE (2014) Computer-delivered, home-based, attentional retraining reduces drinking behavior in heavy drinkers. Psychol Addict Behav 28:559–562.

Miller MA, Fillmore MT (2010) The effect of image complexity on attentional bias towards alcohol-related images in adult drinkers. Addiction 105:883–890.

Mogoaşe C, David D, Koster EHW (2014) Clinical efficacy of attentional bias modification procedures: an updated meta-analysis. J Clin Psychol 70:1133–1157.

Noël X, Colmant M, Van Der Linden M, Bechara A, Bullens Q, Hanak C, Verbanck P (2006) Time course of attention for alcohol cues in abstinent alcoholic patients: the role of initial orienting. Alcohol Clin Exp Res 30:1871–1877.

Ostafin BD, Kassman KT, de Jong PJ, van Hemel-Ruiter ME (2014) Predicting dyscontrolled drinking with implicit and explicit measures of alcohol attitude. Drug Alcohol Depend 141:149–152.

Ostafin BD, Marlatt GA, Greenwald AG (2008) Drinking without thinking: an implicit measure of alcohol motivation predicts failure to control alcohol use. Behav Res Ther 46:1210–1219.

Ostafin BD, Palfai TP (2006) Compelled to consume: the Implicit Association Test and automatic alcohol motivation. Psychol Addict Behav 20:322–327.

Palfai TP, Ostafin BD (2003) Alcohol-related motivational tendencies in hazardous drinkers: assessing implicit response tendencies using the modified-IAT. Behav Res Ther 41:1149–1162.

Papachristou H, Nederkoorn C, Giesen JCAH, Jansen A (2014) Cue reactivity during treatment, and not impulsivity, predicts an initial lapse after treatment in alcohol use disorders. Addict Behav 39:737–739.

Peeters M, Monshouwer K, van de Schoot RAGJ, Janssen T, Vollebergh WAM, Wiers RW (2013) Automatic processes and the drinking behavior in early adolescence: a prospective study. Alcohol Clin Exp Res 37:1737–1744.

Peeters M, Wiers RW, Monshouwer K, van de Schoot R, Janssen T, Vollebergh WAM (2012) Automatic processes in at-risk adolescents: the role of alcohol-approach tendencies and response inhibition in drinking behavior. Addiction 107:1939–1946.

Piferi RL, Kline KA, Younger J, Lawler KA (2000) An alternative approach for achieving cardiovascular baseline: viewing an aquatic video. Int J Psychophysiol 37:207–217.

Rankin H, Hodgson R, Stockwell T (1979) The concept of craving and its measurement. Behav Res Ther 17:389–396.

Rehm J, Shielf KD (2013) Alcohol and morbidity: global alcohol-attributable deaths from cancer, liver cirrhosis, and injury in 2010. Alcohol Res 35:174–183.

Reich RR, Below MC, Goldman MS (2010) Explicit and implicit measures of expectancy and related alcohol cognitions: a meta-analytic comparison. Psychol Addict Behav 24:13–25.

Roefs A, Huijding J, Smulders FTY, MacLeod CM, de Jong PJ, Wiers RW, Jansen ATM (2011) Implicit measures of association in psychopathology research. Psychol Bull 137:149–193.

Saunders JB, Aasland OG, Babor TF, de la Fuente JR, Grant M (1993) Development of the Alcohol Use Disorders Identification Test (AUDIT): WHO collaborative project on early detection of persons with harmful alcohol consumption–II. Addiction 88:791–804.

Schoenmakers T, de Bruin M, Lux IFM, Goertz AG, Van Kerkhof DHAT, Wiers RW (2010) Clinical effectiveness of attentional bias modification training in abstinent alcoholic patients. Drug Alcohol Depend 109:30–36.

Schoenmakers T, Wiers RW, Field M (2008) Effects of a low dose of alcohol on cognitive biases and craving in heavy drinkers. Psychopharmacology 197:169–178.

Schoenmakers T, Wiers RW, Jones BT, Bruce G, Jansen ATM (2007) Attentional re-training decreases attentional bias in heavy drinkers without generalization. Addiction 102:399–405.

Sobell LC, Sobell MB (1992) Timeline follow-back: a technique for assessing self-reported alcohol consumption, in *Measuring Alcohol Consumption: Psychosocial and Biochemical Methods* (Litten RZ, Allen JP eds), pp 41–72. Humana Press, Totowa, NJ.

Stacy AW, Wiers RW (2010) Implicit cognition and addiction: a tool for explaining paradoxical behavior. Annu Rev Clin Psychol 6:551–575.

Stroop JR (1935) Studies of interference in serial verbal reaction. J Exp Psychol 18:643–662.

Thush C, Wiers RW, Ames SL, Grenard JL, Sussman S, Stacy AW (2008) Interactions between implicit and explicit cognition and working memory capacity in the prediction of alcohol use in at-risk adolescents. Drug Alcohol Depend 94:116–124.

Tiffany ST (1990) A cognitive model of drug urges and drug-use behavior: role of automatic and nonautomatic processes. Psychol Rev 97:147–168.

Townshend JM, Duka T (2001) Attentional bias associated with alcohol cues: differences between heavy and occasional social drinkers. Psychopharmacology 157:67–74.

den Uyl TE, Gladwin TE, Wiers RW (2016) Electrophysiological and behavioral effects of combined transcranial direct current stimulation and alcohol approach bias retraining in hazardous drinkers. Alcohol Clin Exp Res 40:2124–2133.

Wiers RW, Eberl C, Rinck M, Becker ES, Lindenmeyer J (2011) Retraining automatic action tendencies changes alcoholic patients' approach bias for alcohol and improves treatment outcome. Psychol Sci 22:490–497.

Wiers RW, Gladwin TE, Hofmann W, Salemink E, Ridderinkhof KR (2013) Cognitive bias modification and cognitive control training in addiction and related psychopathology: mechanisms, clinical perspectives, and ways forward. Clin Psychol Sci 1:192–212.

Wiers RW, Rinck M, Dictus M, van den Wildenberg E (2009) Relatively strong automatic appetitive action-tendencies in male carriers of the OPRM1 G-allele. Genes Brain Behav 8:101–106.

Wiers RW, Rinck M, Kordts R, Houben K, Strack F (2010) Retraining automatic action-tendencies to approach alcohol in hazardous drinkers. Addiction 105:279–287.

Wiers CE, Stelzel C, Gladwin TE, Park SQ, Pawelczack S, Gawron CK, Stuke H, Heinz A, Wiers RW, Rinck M, Lindenmeyer J, Walter H, Bermpohl F (2015) Effects of cognitive bias modification training on neural alcohol cue reactivity in alcohol dependence. Am J Psychiatry 172:335–343.

de Wit H (2008) Impulsivity as a determinant and consequence of drug use: a review of underlying processes: impulsivity and drug use. Addict Biol 14:22–31.

Yarmush DE, Manchery L, Luehring-Jones P, Erblich J (2016) Gender and impulsivity: effects on cue-induced alcohol craving. Alcohol Clin Exp Res 40:1052–1057.