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Leeman, R.F.; Nogueira, C.; Wiers, R.W.; Cousijn, J.; Serafini, K.; DeMartini, K.S.; Bargh, J.A.; O'Malley, S.S.

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A Test of Multisession Automatic Action Tendency Retraining to Reduce Alcohol Consumption Among Young Adults in the Context of a Human Laboratory Paradigm

Robert F. Leeman, Christine Nogueira, Reinout W. Wiers, Janna Cousijn, Kelly Serafini, Kelly S. DeMartini, John A. Bargh, and Stephanie S. O'Malley

Background: Young adult heavy drinking is an important public health concern. Current interventions have efficacy but with only modest effects, and thus, novel interventions are needed. In prior studies, heavy drinkers, including young adults, have demonstrated stronger automatically triggered approach tendencies to alcohol-related stimuli than lighter drinkers. Automatic action tendency retraining has been developed to correct this tendency and consequently reduce alcohol consumption. This study is the first to test multiple iterations of automatic action tendency retraining, followed by laboratory alcohol self-administration.

Methods: A total of 72 nontreatment-seeking, heavy drinking young adults ages 21 to 25 were randomized to automatic action tendency retraining or a control condition (i.e., "sham training"). Of these, 69 (54% male) completed 4 iterations of retraining or the control condition over 5 days with an alcohol drinking session on Day 5. Self-administration was conducted according to a human laboratory paradigm designed to model individual differences in impaired control (i.e., difficulty adhering to limits on alcohol consumption).

Results: Automatic action tendency retraining was not associated with greater reduction in alcohol approach tendency or less alcohol self-administration than the control condition. The laboratory paradigm was probably sufficiently sensitive to detect an effect of an experimental manipulation given the range of self-administration behavior observed, both in terms of number of alcoholic and nonalcoholic drinks and measures of drinking topography.

Conclusions: Automatic action tendency retraining was ineffective among heavy drinking young adults without motivation to change their drinking. Details of the retraining procedure may have contributed to the lack of a significant effect. Despite null primary findings, the impaired control laboratory paradigm is a valid laboratory-based measure of young adult alcohol consumption that provides the opportunity to observe drinking topography and self-administration of nonalcoholic beverages (i.e., protective behavioral strategies directly related to alcohol use).

Key Words: Automatic Action Tendency Retraining, Cognitive Bias Retraining, Young Adult, Alcohol Self-Administration, Impaired Control Over Alcohol Use.

APPROXIMATELY 40% of young adults in the United States report at least monthly heavy episodic drinking (i.e., 5 drinks or more on an occasion for males; 4 or more for females) (Dawson et al., 2015), with similarly high rates in other countries (Macinko et al., 2015). This level of use is associated with negative consequences including accidental injuries and motor vehicle accidents (Jackson et al., 2005). While most young adults will eventually "mature out" and reduce drinking on their own, a considerable minority persist and encounter clinically significant problems (Jackson et al., 2001). Thus, interventions tailored to heavy drinking young adults are needed.

Evidence supports the efficacy of existing interventions for young adults, but effect sizes are modest (Tanner-Smith and Lipsey, 2015). Large effect-intervention in this population is difficult due to environmental contingencies that support young adult alcohol use (e.g., fewer responsibilities than older adults; Arnett, 2000) and limited motivation to change behavior (Epler et al., 2009). Thus, new interventions that account for these challenges are needed.

Dual process models (Bechara, 2005; Wiers et al., 2007) offer theoretical bases for the development of addictive behaviors and for prioritizing intervention targets. According to these models, addictive behaviors stem from a combination of failed attempts to inhibit impulses and overactive

From the Department of Health Education and Behavior (RFL), University of Florida, Gainesville, Florida; Yale School of Medicine (RFL, CN, KSD, SSO), New Haven, Connecticut; Department of Psychology (RWW, JC), University of Amsterdam, Amsterdam, the Netherlands; Swedish Medical Center (KS), Seattle, Washington; and Department of Psychology (JAB), Yale University, New Haven, Connecticut.

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Reprint requests: Robert Leeman, PhD, Department of Health Education and Behavior, College of Health and Human Performance, University of Florida, Box 118210, Gainesville, FL 32611; Tel.: 352-294-1808; Fax: 352-392-1909; E-mail: robert.leeman@ufl.edu

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automatic, appetitive tendencies. Most current interventions (e.g., Dimeff et al., 1999) aim to enhance self-regulation of drinking through effortful means (i.e., actively implementing moderate drinking strategies). However, self-regulation can be compromised at a trait level, over time due to heavy drinking (Bava and Tapert, 2010) and acutely, within drinking sessions (e.g., Marczinski et al., 2005 de Wit et al., 2000), even after small-to-moderate alcohol doses (Weafer and Fillmore, 2008).

In contrast, automatic appetitive tendencies tend to be maintained or enhanced following alcohol consumption. Initial consumption, for example, primes subjective, alcohol-related reward and contributes to subsequent drinking (de Wit, 1996). Behavioral activation, including automatic reactivity to alcohol cues, remains stable at levels of alcohol consumption that impair inhibitory control (e.g., Duka and Townshend, 2004; Gauggel et al., 2010; de Wit et al., 2000). Thus, automatic appetitive tendencies are important intervention targets.

Recent research has addressed the relationship of automatically activated cognitive processes to alcohol use. Using computer-based cognitive tasks, young adults with heavier alcohol use have demonstrated stronger automatic tendencies to approach alcohol-related stimuli than lighter drinkers (e.g., Field et al., 2011; Lindgren et al., 2013; Ostafin et al., 2008; Wiers et al., 2009).

Investigators have attempted to correct automatic approach tendencies toward alcohol by reorienting these computer-based tasks to present alcohol stimuli repeatedly with instructions for participants to make physical avoidance (pushing away) responses with a joystick. Based on theory and prior results (Wiers et al., 2010, 2011), if automatic action tendencies toward alcohol are reduced through repeatedly pushing images of alcohol away, actual alcohol use should be reduced. The effect is based on a phenomenon discovered by Chen and Bargh (1999) in which pushing motions with a lever were related to unfavorable attitudes while pulling motions were associated with favorable attitudes.

An initial experimental laboratory study testing a single iteration of automatic action tendency retraining among hazardous-drinking male students showed evidence of a shift toward avoidance tendencies following retraining (Wiers et al., 2010). In the full sample, there was no significant difference between the retraining and control condition in amount of beer consumed during a subsequent taste test. However, in a post hoc examination of the 55% who were successfully retrained, those receiving the retraining consumed significantly less beer compared to controls. Two recent experimental laboratory studies testing single-iteration retraining among undergraduate drinkers showed evidence of successful retraining completed immediately prior to an alcohol taste test (Di Lemma and Field, 2017; Sharbanee et al., 2014), but only one of these studies reported a direct effect of retraining on alcohol self-administration (Di Lemma and Field, 2017). Initial efforts to reduce approach tendency in social and heavier drinking young adults using 2 iterations of retraining in an experimental laboratory context were not successful (Lindgren et al., 2015). Notably, the samples in the Sharbanee and colleagues (2014) and Lindgren and colleagues (2015) studies did not show clear automatic approach tendencies to alcohol stimuli at baseline, however participants in DiLemma and Field (2017) did. In studies testing 4 (Wiers et al., 2011) and 12 iterations of retraining (Eberl et al., 2013) among adults in inpatient treatment, there was evidence of retraining and differences between retraining and control conditions on likelihood of alcohol relapse 1 year postdischarge. Notably, while retraining in Di Lemma and Field (2017) took place in a single session, it included 1 lengthy retraining (480 trials) followed by two 80-trial booster retrainings shortly after. In summary, initial studies suggest key considerations include the number of retrainings; presence/absence of baseline approach tendency to alcohol stimuli; and whether the study occurs within a treatment or experimental laboratory context with the latter enrolling less severe drinkers.

This study incorporated 2 enhancements to prior automatic approach tendency retraining studies among young adult drinkers: repeated retraining sessions in close succession and use of an ecologically valid alcohol self-administration paradigm. First, we used the same number of retrainings (4) as in the initial Wiers and colleagues (2011) study that demonstrated successful automatic action tendency retraining with accompanying decrease in likelihood of relapse in a clinical sample. Second, following retraining or control, participants could self-administer alcohol in a bar setting as part of a paradigm designed to model individual differences in impaired control over alcohol use (i.e., difficulty adhering to limits on alcohol consumption) (Leeman et al., 2013). Impaired control is an important construct to the development of problem drinking (Heather et al., 1993; Leeman et al., 2007) relevant to young drinkers (Leeman et al., 2009, 2012; Patock-Peckham and Morgan-Lopez, 2006). This paradigm includes gender-based moderate drinking guidelines and probabilistic reductions in payment based on task performance (Leeman et al., 2013). Prior laboratory paradigms have incorporated the idea of pay contingencies for task performance following alcohol self-administration (Christiansen et al., 2012). An initial proof of concept study showed that alcohol self-administration was significantly lower when these components were included and that individual differences in alcohol self-administration were observable (Leeman et al., 2013). Prior studies utilized a laboratory taste test approach, which has been found to have construct validity (Jones et al., 2016), but is typically brief (as short as 10 minutes; Di Lemma and Field, 2017) and departs from real world conditions.

MATERIALS AND METHODS

Participants

Young adults (21 to 25 years) were recruited with Web-based advertising and flyer postings near college campuses and other public areas. Advertisements stated we were seeking individuals 21 to

25 years old who drink alcohol at least twice per week (although actual inclusion criteria were more specific) and meet other requirements for a study not involving medication. Maximum compensation up to $325 was described.

Inclusion required at least 4 heavy drinking days, 10 any-drinking days and 1 day with estimated blood alcohol concentration (eBAC) ≥0.10% during the prior 30 days. Exclusion criteria were seeking treatment or having been in treatment for substance misuse in the past 12 months; current DSM-IV dependence on substances (including nicotine) other than alcohol (American Psychiatric Association, 1994); past history of medically assisted detoxification or current withdrawal; 2 breath alcohol concentration (BrAC) readings >0.00% at study appointments; urine drug screening indicating cocaine, amphetamine, methamphetamine, opiate, methadone, phencyclidine, barbiturate, or benzodiazepine use; a recent prescription for or current psychotropic drug use; disliking beer; severe psychiatric or medical conditions; body mass index <18.5 or >35; pregnancy, nursing, or lack of reliable birth control for women. This study was approved by the Yale School of Medicine Human Investigation Committee.

Procedures

Potential participants received an overview of the study via Web page or verbal telephone script. Those interested screened initially by telephone or Web survey. Those who appeared eligible were invited to attend an in-person screening (Fig. 1).

The in-person screening began with verification of identity and age; breathalyzer reading using a handheld Alcohol-Sensor III (Intoximeter Inc., St. Louis, MO); and then informed consent. A BrAC of 0.00% was required to provide consent. Subsequent steps were urine drug and pregnancy testing; weight measurement on a calibrated scale; timeline followback (TLFB) interview (Sobell and Sobell, 2003) to obtain past-30-day alcohol and cigarette use; Structured Clinical Interview for DSM-IV-TR Axis-1 Disorders (First et al., 2002) to diagnose alcohol and drug dependence; Clinical Institute Withdrawal Assessment for Alcohol Revised (Sullivan et al., 1989); Columbia Suicide Interview (Posner et al., 2011); medical interview including medical history, current medication use, history of psychiatric diagnosis and treatment, symptom inventory, and menstrual cycle information from women. A battery of 4 cognitive/psychomotor tasks was also administered. Participants were informed that they must perform normatively on each task to participate in the study. Participants completed a baseline alcohol approach avoidance task (AAT; Wiers et al., 2009), followed by online questionnaires.

Eligible, enrolled participants were scheduled with 1 or 2 other participants they were unlikely to know (i.e., did not attend the same college/university or reside near each other) for an alcohol drinking session 5 to 7 days later. This permitted scheduling of brief appointments on 4 of 5 days leading up to the alcohol drinking session with the session occurring on Day 5. Participants were randomized to complete a modified, retraining version of the AAT or control ("sham") training at each appointment (i.e., continued assessment). The randomization scheme ensured at least 1 person in each alcohol drinking session was randomized to each study condition. Efforts were made to include both genders in each session.

On appointment Day 5/alcohol drinking session, participants were instructed to not consume alcohol and to eat lunch but nothing after 1 PM. Following retraining or control, urine drug and pregnancy tests for women were repeated at approximately 3 PM. Participants were then transported to a local bar for the alcohol drinking session.

Alcohol drinking sessions were conducted using a human laboratory paradigm designed to model individual differences in impaired control over alcohol use (Fig. 2; Leeman et al., 2013). Participants arrived at the bar around 4 PM. Upon arrival, BrAC was repeated to confirm a 0.00% reading. Participants completed self-reports and the same 4 cognitive/psychomotor tasks. Study activities occurred off to 1 side of the bar, which was open for business. Interaction between patrons and study participants was minimal.

Following initial self-reports and cognitive/psychomotor tasks, participants could consume beers ad libitum for 3 hours. Participants were aware they would complete the same 4 cognitive/psychomotor tasks following ad libitum drinking, and that for each task, they did not perform comparably to initial screening, and they would draw from a hat for a pay reduction of $0, $6, or $12 at a follow-up appointment 1 to 3 days postsession. Thus, total possible pay reduction was $0 to $48. Participants were provided the following guidance: "To avoid having to draw for possible pay reductions, we offer a guideline that you consume no more than 3 beers (2 for women) in the course of the 3-hour alcohol drinking period." Participants were advised they were not required to abide by the guideline but doing so would improve their chances of completing the tasks successfully and avoiding pay reductions.

Ad libitum drinking began at 5 PM. For the next 3 hours, participants could request 12-ounce beers or nonalcoholic beverages (i.e., soda, juice, or water) ad libitum from a research assistant, who obtained drinks from the bartender. Study staff asked participants if they would like an initial drink but all subsequent ordering was initiated by participants only. Three beer options were offered, each of which was 5% alcohol by volume and approximately 150 calories. Participants could switch between brands but were required to complete 1 drink (alcoholic or nonalcoholic) before ordering their next. A nearby supervisor monitored and recorded each drink ordered including type of beverage, time ordered, received, first sip, and last sip. Beer consumption was monitored for safety using personalized eBAC charts, based on sex and weight. No participant was permitted to order a beer that would lead to eBAC > 0.10%.

Ad libitum drinking ended at 8 PM, at which time participants filled out self-reports, gave a BrAC reading, and undertook the 4 cognitive/psychomotor tasks. After these activities, participants were provided food and cigarette smoking was allowed. Participants were retained at the bar until at least midnight and until their BAC levels declined to ≤0.02%.

At a follow-up interview, participants completed an alcohol AAT to compare automatic action tendency in the retraining compared to the control condition. Pay reduction drawings occurred for participants whose cognitive/psychomotor task performance after drinking was not equivalent to the screening appointment.

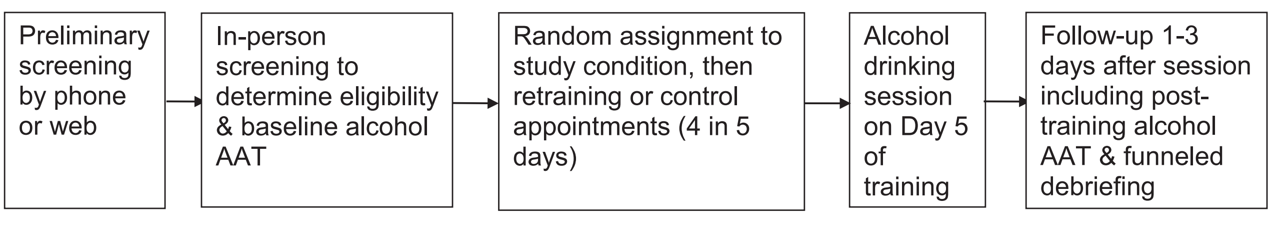

Fig. 1. Timeline of study procedures.

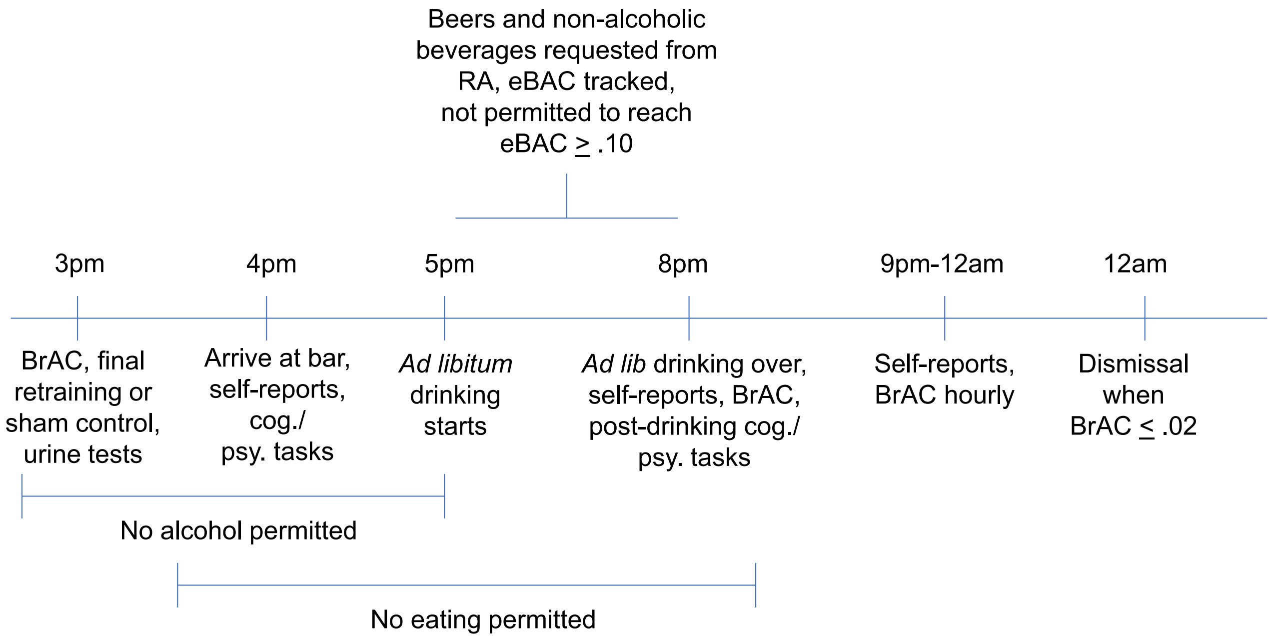

Fig. 2. Timeline of participation on the day of an alcohol drinking session. BrAC: breath alcohol concentration; eBAC: estimated blood alcohol concentration; RA: research assistant; cog./psy.: cognitive/psychomotor.

Participants were engaged in a funneled debriefing and personalized, brief, feedback-based motivational interview on alcohol use of approximately 30 minutes. No participants guessed the true purpose of the retraining/control task appointments.

Alcohol Approach Avoidance Task, Retraining, and Control Task

All forms of the AAT were completed on a Dell Latitude E6400-series laptop computer (Dell Technologies, Round Rock, TX) using a Logitech Attack 3 joystick (Logitech International, S.A., Lausanne, Switzerland). The screen was opened to a 90-degree angle, and the joystick positioning was consistent. Participants were instructed to push or pull the joystick as quickly as possible based on whether it was tilted slightly (3 degrees) to the left or right and then return the joystick to its original position. Images were of alcohol or matched images of nonalcoholic beverages of similar visual orientation with a mixture of images depicting a single beverage, multiple beverages, beverages with a full person, and beverages with a body part (e.g., hand holding it). Before the study, all images were rated via Web survey. Sixty alcohol and 60 matched nonalcohol images were selected with high ratings for realism, pleasantness, and normalness. Selected alcohol images also had high ratings indicating they made respondents think of drinking alcohol whereas nonalcoholic images had low ratings. In this version of the AAT, 50% of alcohol and 50% of nonalcoholic trials required the participant to push the joystick. The pushing and pulling experience was enhanced by movement of the image on screen. The image retreated and grew smaller when pushed and came forward and enlarged when pulled.

Each AAT iteration included 20 of the 60 alcohol images and 20 matched nonalcohol images. The versions of the AAT completed at the in-person screen and the follow-up appointment were made up of 160 trials with the same alcohol and matched nonalcohol images. Participants randomized to retraining completed 4 iterations of a version of the task in which they pushed images using the joystick on 90% of alcohol image trials. Conversely, participants pulled on 90% of nonalcoholic image trials. In the control condition, participants pushed alcoholic and nonalcoholic images on 50% of trials. Each retraining or control task iteration had 400 trials. Participants were not made aware of the possibility of retraining and instead believed they were completing similar versions of the task repeatedly to enable the investigators to test task performance consistency. Staff interacting with participants were blind to study condition.

Before calculating approach bias, trials with reaction time (RT) <200 ms or >2,000 ms were eliminated. Separate mean RTs were calculated for trials with approach and avoid instructions for each participant, with RT to approach trials subtracted from RT to avoid trials. Thus, positive numbers indicate approach bias. Separate calculations were made for alcohol and nonalcohol trials.

Measures

Alcohol and Cigarette Use. The TLFB (Sobell and Sobell, 2003) utilizes a calendar with memory prompts that facilitate recall of substance use each day during a specified period (30 days in this study). Reliability and validity of estimates over 30 days from the TLFB have been verified (Carey, 1997). TLFB reports were used to yield estimates of frequency of any and heavy drinking and drinks per drinking day.

Alcohol Abuse and Dependence. The SCID (First et al., 2002) was used to diagnose lifetime and current DSM-IV alcohol and drug abuse and dependence. We report alcohol diagnoses and lifetime alcohol symptom counts across abuse and dependence ($\alpha = 0.70$).

Impaired Control. Part 2 of the Heather and colleagues (1993) Impaired Control Scale (ICS) is a reliable ($\alpha = 0.85$), valid 10-item measure capturing frequency of difficulty controlling alcohol use, including unsuccessful attempts to limit, cut down and stop drinking. A 3-month time frame was utilized. Items were rated on a 0 (never) to 4 (always) scale and then summed with high scores indicating more difficulty controlling alcohol use.

Negative Alcohol Consequences. The Young Adult Alcohol Consequences Questionnaire (YAACQ; Read et al., 2006) is a reliable, valid 48-item scale with a 3-month time frame in this study. Items were rated yes/no as to their occurrence and summed to yield a total score of 48 ($\alpha = 0.87$).

Alcohol History. Participants reported the *age when they started drinking*, not counting small sips or tastes. *Family history of alcohol problems* items were based on the Addiction Severity Index (McLellan et al., 1992). Participants were asked if any relatives "had a significant problem with alcohol or drugs, one that either led to treatment or should have led to treatment." Those reporting an alcohol problem history for 1 or both biological parents were considered family history positive.

Protective Behavioral Strategy Use. A modified version of the Protective Strategies Questionnaire (PSQ; DeMartini et al., 2013; Palmer, 2004) was used to measure frequency of use of 11 alcohol-related protective behavioral strategies (PBS) on a 7-point scale. Based on prior analyses, 4 items could be classified as measuring manner of drinking directly (Direct PBS; e.g., alternating alcoholic with nonalcohol drinks). Means were calculated for the Direct PBS items ($\alpha = 0.71$) and the full measure ($\alpha = 0.75$).

Cognitive/Psychomotor Tasks. Four tasks sensitive to alcohol's impairing effects (Brandt, 1991; Brumback et al., 2007; Chait and Perry, 1994) were administered at screening and during alcohol drinking sessions before and after ad libitum drinking. The Digit Symbol Substitution Test of the WAIS-R (Wechsler, 1981) is a perceptual-motor processing task in which participants complete as many items as possible in 90 seconds. Scores comprise the number of correct responses. The Grooved Pegboard (Lafayette Instruments, Lafayette, IN) is a fine motor speed and coordination test in which participants retrieve, rotate, and insert small pegs in slotted holes randomly orientated on a board as quickly as possible with their nondominant hand. In the Time Production task, participants indicated when they believed 30, 60, and 120 seconds had lapsed. Lastl, in the Hopkins Verbal Learning Test (Brandt, 1991), participants are presented verbally a list of words and asked to repeat as many as possible right after the staff member finishes reading the list. Participants completed the tasks in this order each time.

Analyses

Normal probability plots and distributions were reviewed for continuous variables. We then evaluated whether there were differences in baseline self-report variables by study condition and examined bivariate correlations among all variables. Analyses were conducted using IBM SPSS Statistics for Windows, Version 24.0 (IBM Corp., Armonk, NY). In addition to determining whether significant changes in automatic action tendency were associated with retraining, we compared the retraining and control conditions on peak eBAC during alcohol self-administration, which was the planned primary outcome and number of alcoholic drinks self-administered, the planned secondary outcome. Peak eBAC was calculated because no BrAC readings were taken during the ad libitum-drinking period. An eBAC was calculated for the time when each beer was completed using the following formula: ([number of drinks/2] * [constant of 9 for women and 7.5 for men/weight]) – (number of hours $\times$ 0.016) (Matthews and Miller, 1979). While not a prespecified outcome, peak actual BrAC following self-administration allowed us to verify results involving eBAC. Our hypotheses were that participants randomized to retraining would reach lower eBACs and self-administer fewer beers. Predetermined exploratory outcomes concerned possible differences in drinking topography: average duration of beer consumption for the first 3 beers along with duration of interdrink intervals between the first and second and between the second and third beer. We examined 1 additional exploratory outcome: number of nonalcoholic drinks voluntarily self-administered. Nonalcoholic beverages consumed after participants reached maximum allowable eBAC were not included. Drinking topography and nonalcoholic drink consumption variables allow for an understanding of steps participants may have taken to moderate their drinking.

A repeated-measures general linear model was used to compare changes in automatic action tendency toward alcohol from pre- to postretraining between the retraining and control conditions. To account for a possible relationship between magnitude of baseline drinking and automatic action tendency, a decision was made a priori to enter baseline drinks per drinking day as a covariate. Mixed-design analysis of variance (ANOVA) was used for differences by study condition on the primary, secondary, and exploratory outcomes. Study condition and gender were entered as fixed effects with session (i.e., small group of 2 to 3 participants in which alcohol self-administration occurred) as a random effect. Drinks per drinking day was included as a covariate to represent effects of baseline drinking for all models except for eBAC in which frequency of heavy drinking was entered instead given that the calculation of both heavy drinking days and eBAC differs based on gender. Alpha was set at 0.05 for the primary and secondary outcomes and at 0.01 for others.

We estimated effect size and calculated power a priori although this was challenging given a lack of comparable prior studies (i.e., no prior studies implementing multiple retrainings followed by alcohol self-administration in young adults). An earlier retraining study conducted among young adults by Wiers and colleagues (2010) found a difference in beer consumption of about 0.5 standard drinks of the 3 offered in a taste test paradigm among those who were retrained successfully. We expected a difference between retraining and control of closer to 1 full beer due to our implementation of multiple retrainings and a longer self-administration period than in Wiers and colleagues (2010). Mean peak eBAC in the impaired control paradigm in our initial study (Leeman et al., 2013) was 0.06% (SD = 0.028%), which we expected to be equivalent to the control condition in the proposed study. A hypothetical 160-lb male who would drink to this average eBAC of 0.06% in the control condition would reach a peak eBAC of 0.036% if he consumed the proposed 1 drink less in a 3-hour period. Thus, we used eBAC = 0.036% as our estimate for the retraining condition, allowing a 33% larger SD than in the control condition to account for added variability due to retraining, yielding a Cohen's d of 0.73. An n of 32 in each condition would enable detection of an effect of this size at an alpha of 0.05 with 80% power using a 2-sided test. An initial sample size of 72 was proposed to allow for a final projected sample of 64 (32 per condition) completing an alcohol drinking session, allowing 10% attrition during retraining.

RESULTS

Description of Sample

The proposed sample of 72 began retraining/control appointments; however, 3 did not go on to complete an alcohol drinking session: 1 each because of scheduling difficulties; positive urine drug test on the session day; and no longer attending appointments. This was a lower attrition rate than anticipated, leaving a sample of 69 (35 retraining, 34 control), 68 of whom completed all 4 retraining/control iterations with 1 participant missing 1 appointment. The sample had an approximately even split by gender and was primarily White. Just over half reported being a student. About 30% were family history positive and about 25% smoked cigarettes at least weekly. The sample drank frequently, including frequent heavy drinking days. Participants used protective strategies to moderate drinking and avoid consequences

Table 1. Sample Characteristics Overall and by Study Condition

Variable	Retraining condition (n = 35)	Control condition (n = 34)	Overall (N = 69)
Percent male	57.1%	50%	53.6%
Race/ethnicity,%			
White	74.3	79.4	76.8
Hispanic	8.6	8.8	8.7
Asian	8.6	2.9	5.8
African American	5.7	2.9	4.3
Other or chose not to answer	2.9	5.9	4.3
Student status, %			
Nonstudent	42.9	44.1	43.5
Undergraduate	42.9	29.4	36.2
Graduate	14.3	26.5	20.3
At least 1 biological parent with an alcohol problem	32.4%	26.5%	29.4%
Current at least weekly smoker	25.7%	23.5%	24.6%
Alcohol abuse diagnosis (lifetime/current)	62.9/31.4%	50%/32.4%	56.5%/31.9%
Alc. dependence diagnosis (LT/current)	42.9%/34.3%	44.1%/23.5%	43.5%/29%
Past 30-day alcohol frequency/quantity reported at screening: mean (SD), range of responses			
Frequency of any use	16.6 (4.81)	17.1 (6.00)	16.82 (5.40)
	10 to 29	10 to 30	10 to 30
Frequency of heavy use	9.6 (4.03)†	8.1 (4.88)	8.85 (4.50)
	4 to 19	4 to 26	4 to 26
Drinks per drinking day	5.41 (1.75)	4.94 (1.70)	5.18 (1.72)
	2.50 to 10.59	2.00 to 10.09	2.00 to 10.59
Other self-report variables indicative of problem drinking risk assessed at screening			
Scores on Part 2 of the Impaired Control Scale (ICS)	12.83 (6.48)**	8.37 (4.54)	10.67 (6.01)
	1 to 26	0 to 19	0 to 26
Age of onset of alcohol use	16.77 (1.90)	15.73 (1.94)*	16.26 (1.98)
	13 to 19	12 to 19	12 to 19
Young Adult Alcohol Consequences Questionnaire (YAACQ) total score	13.22 (6.69)	11.80 (7.34)	12.51 (7.01)
	0 to 24	2 to 26	0 to 26
Protective Strategies Questionnaire (PSQ) total score	2.96 (0.79)	3.20 (0.86)	3.08 (0.83)
	1.5 to 5.18	1.45 to 5.27	1.45 to 5.27
PSQ direct strategies subscale	2.10 (0.81)	2.43 (1.04)	2.21 (0.95)
	0.5 to 4.5	0.5 to 4.5	0.5 to 5.5

Heavy use: 5 or more drinks in a day for men, 4 for women; Range of possible scores: ICS (0 to 40), YAACQ (0 to 48), PSQ total and direct strategies (0 to 6), statistically significant difference between study conditions at $^{**}p < 0.01$, $^{*}p < 0.05$, $^{\dagger}p < 0.07$.

infrequently, with use of direct strategies concerning manner of drinking particularly infrequent (Table 1).

Heavy drinking frequency was the only skewed variable, corrected with a log transformation. Age of onset and ICS scores differed significantly by study condition but neither correlated significantly with any outcome variable (Table 2).

Automatic Action Tendency at Baseline and Retraining

The 160 trials in the baseline and postintervention AAT were each divided first by the 4 image (alcohol or nonalcoholic) × instruction (push or pull) combinations and then in half to determine split-half reliability. For RT, correlations were very high for all combinations, at baseline and postretraining/control (r = 0.80 to 0.86), suggesting strong internal consistency reliability. Correlations were not as high for approach bias, although they were higher postretraining/control (alcohol r = 0.42, neutral r = 0.34), than at baseline (alcohol r = 0.23, neutral r = 0.22).

The mean score on the AAT in the overall sample at baseline indicated a slight automatic action tendency toward alcohol (M = 17.3, SD = 58.38); however, many participants presented without an approach tendency toward alcohol (40.3%, n = 29). Baseline automatic action tendency toward alcohol was similar between the retraining (M = 18.47, SD = 62.28) and control (M = 14.40, SD = 55.41) conditions, $t(67) = 0.29$, $p = 0.775$.

Automatic action tendency retraining was not associated with a significant decrease in approach tendency compared to control, $\Lambda = 0.97$, $F(1, 66) = 0.24$, $p = 0.61$, $d = 0.14$ (Fig. 3). In the sample as a whole, 53.6% (n = 37) showed a decrease in automatic action tendency following retraining/control; however, the percentage did not differ significantly by study condition, $\chi^2(N = 69) = 0.01$, $p = 0.91$. Alternate versions of the outcome analyses were conducted adding binary variables capturing whether participants had a baseline approach tendency and whether they were retrained successfully, including interaction terms of study condition by baseline approach tendency and retraining success; however, inclusion of these variables did not alter any results.

On a post hoc basis, as an alternative to the primary analyses based on difference scores between approach and avoid trials, we conducted a 2 × 2 × 2 × 2 mixed-design ANOVA to predict speed of RT, including within-subject factors of time (baseline/postretraining), image (alcohol/nonalcohol), instruction (approach/avoid) and between subjects factor of study condition (Di Lemma and Field, 2017). This analysis produced parallel results in that the 4-way

Table 2. Correlations Among Study Variables

Alcohol AAT		Main self-admn variables		Exploratory alcohol self-administration variables				Baseline alcohol consumption			Alcohol-related risk variables at baseline						Demographics		
	AAT post	# beer self-admn	Peak eBAC	Drink duration	IDI: 1st to 2nd drink	IDI: 2nd to 3rd drink	# Nonalc. drinks	Freq. any	Drinks drnkng day	Freq. heavy drnkng	Age onset	IC	Negative cons.	PSQ total	PSQ direct	Fam. history +	Sex	White/ non	Stud. or not
AAT pre	0.04	−0.07	−0.17	0.20	−0.04	0.00	0.22	−0.08	0.15	0.03	−0.03	−0.12	0.08	0.05	0.04	0.09	−0.01	−0.06	−0.34**
AAT post		0.13	0.27*	−0.14	−0.13	−0.23	−0.18	−0.12	0.09	−0.01	0.09	0.14	0.24*	0.03	0.00	0.00	0.02	−0.20	0.13
# beers self-admin.			0.69**	−0.65**	−0.56**	−0.21	−0.42**	0.22	0.48**	0.37**	−0.11	0.05	0.10	−0.18	−0.13	0.07	0.37**	−0.04	−0.04
Peak eBAC				−0.50**	−0.48**	−0.24	−0.42**	0.24*	0.23*	0.40**	−0.12	0.17	0.29*	−0.33*	−0.26*	0.10	−0.20	−0.19	−0.04
Drinking duration					0.18	−0.32**	0.04	−0.18	−0.18	−0.11	0.03	−0.17	−0.11	0.06	0.22	−0.02	−0.39**	0.04	0.02
IDI: 1st to 2nd drink						0.44**	0.54**	−0.24*	−0.31**	−0.35**	0.20	0.03	−0.12	0.18	0.19	−0.09	−0.13	0.16	0.04
IDI: 2nd to 3rd drink							0.44**	−0.17	−0.16	−0.34**	−0.05	−0.07	−0.08	0.01	0.01	0.00	0.00	0.10	−0.08
# Nonalc. drinks								0.05	−0.15	−0.12	−0.07	−0.11	−0.07	0.10	0.02	0.03	0.02	0.18	−0.16
Freq. any									0.03	0.57**	−0.27*	−0.01	0.10	−0.22	−0.32**	0.09	0.17	0.16	0.02
Drinks drnkng day										0.61**	−0.21	0.09	0.25*	−0.15	−0.22	0.41**	0.28*	−0.15	−0.10
Freq. heavy drnkng											−0.15	0.24*	0.38**	−0.31**	−0.34**	0.24*	0.11	−0.15	0.03
Age onset												0.32**	0.17	−0.04	−0.01	−0.07	0.01	−0.22	0.18
IC													0.62**	−0.33**	−0.17	0.13	0.03	−0.37**	0.04
Negative cons.														−0.40**	−0.41**	0.26*	−0.12	−0.43**	0.11
PSQ total															0.72**	−0.31**	0.13	0.18	0.16
PSQ direct																−0.34**	0.04	0.15	0.10
Fam. history +																	−0.06	−0.24*	−0.14
Sex																		0.11	0.12
White/non																			−0.06

*$p < 0.05$, **$p < 0.01$.

AAT: approach avoidance task; admn.: administration; eBAC: estimated blood alcohol concentration; IDI: interdrink interval; alc.: alcohol; freq. any: frequency of any-drinking days; drnkng: drinking; IC: impaired control over alcohol use; cons.: consequences; PSQ: Protective Strategies Questionnaire; fam. hist. +: family history positive; stu. or not: student or nonstudent (student coded "1", nonstudent coded "0"); sex: male coded "1", female coded "0". Frequency of heavy drinking days was log-transformed to reduce skew and self-administration of nonalcoholic beverages was converted to a 3-level ordinal variable: 0, 1, >1.

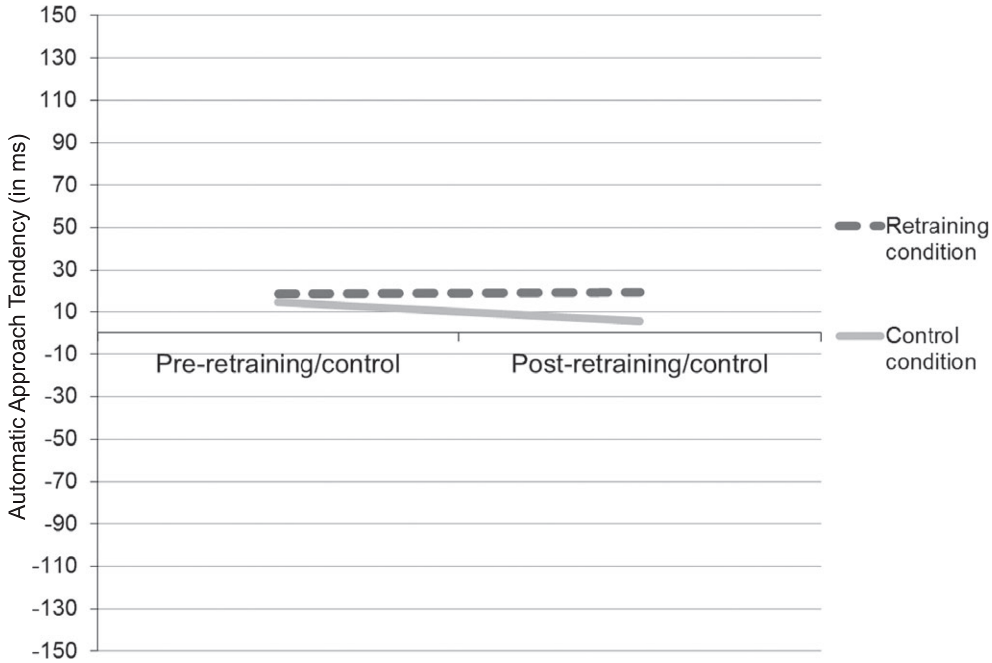

Fig. 3. Change in automatic approach tendency between pre- and postretraining by condition.

interaction was not significant, $F(1, 67) = 0.042$, $p = 0.838$, $d = 0.00$. There were significant main effects of instruction, $F(1, 67) = 8.80$, $p = 0.004$, $d = 0.72$ (faster RTs with pull instruction), and time, $F(1, 67) = 112.7$, $p < 0.001$, $d = 2.59$. Paired samples *t*-tests indicated RTs decreased significantly for all 4 image/instruction combinations from baseline (M = 746 to 760 ms, SD = 103 to 113 ms) to postretraining/control (M = 622 to 635 ms, SD range = 78 to 81 ms), $t(68) = 8.86$ to 10.64, $p < 0.001$ (full alternate results available from first author).

Alcohol Self-Administration Outcomes by Study Condition

There was a wide range of self-administration behavior. Peak eBAC varied from 0.004 to 0.10 and number of beers self-administered ranged from 1 to 8. However, paralleling the lack of retaining, neither peak eBAC (Fig. 4), $F(1, 40) = 0.69$, $p = 0.41$, $d = 0.24$, nor number of drinks self-administered (Fig. 5), $F(1, 40) = 0.17$, $p = 0.90$, $d = 0.00$, differed significantly by study condition. Similarly, none of the topography variables nor the number of nonalcoholic drinks self-administered differed significantly by study condition (Fig. S1).

Bivariate Correlations Between Automatic Approach Tendency and Other Variables Measured at Baseline and During Sessions

There were no significant correlations between baseline alcohol approach tendency and any baseline alcohol-related variables. In contrast, alcohol approach tendency postretraining was correlated significantly and positively with peak

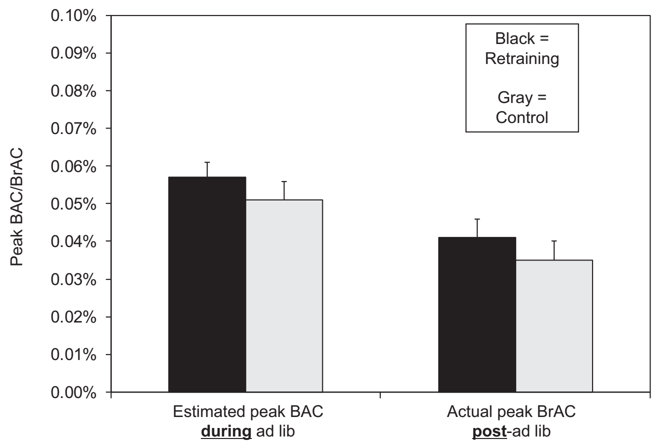

Fig. 4. Blood alcohol concentration-related outcomes. On the left, peak estimated blood alcohol concentration (BAC) during a 3-hour ad libitum-drinking period in the retraining and control conditions. On the right, peak actual breath alcohol concentration (BrAC) obtained after the end of the ad libitum-drinking period in the retraining and control conditions.

eBAC during the alcohol drinking session (Table 2); however, similar correlations were observed between approach tendency toward nonalcoholic drink images and peak eBAC ($r = 0.27$, $p < 0.05$). A partial correlation holding constant nonalcoholic approach tendency was not significant ($r = 0.17$).

Validity of the Alcohol Self-Administration Paradigm

In the primary outcome model, baseline heavy drinking, $F(1, 40) = 14.26$, $p = 0.001$, $d = 1.20$, drinking session, $F(25, 40) = 3.02$, $p = 0.001$, $d = 2.73$, and gender (male higher), F

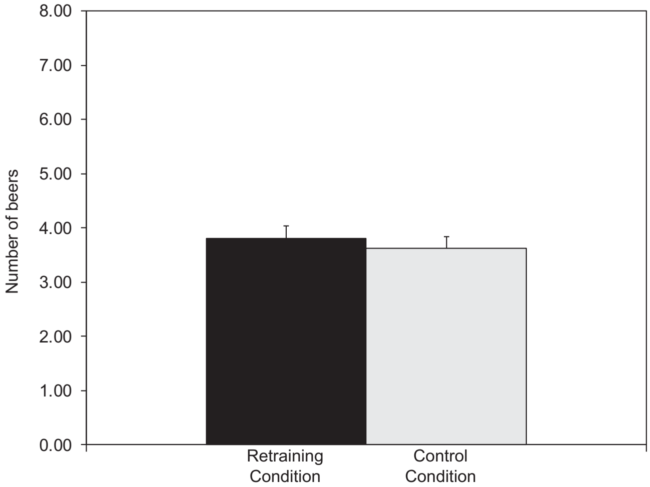

Fig. 5. Number of beers self-administered during a 3-hour ad libitum-drinking period in the retraining and control conditions.

(1, 40) = 6.69, p = 0.013, d = 0.82, predicted peak eBAC significantly. Similar results were found for number of beers self-administered: drinks per drinking day, $F(1, 40) = 22.21$, $p < 0.001$, $d = 1.49$, alcohol drinking session, $F(25, 40) = 2.87$, $p = 0.001$, $d = 2.73$, and gender (male higher), $F(1, 40) = 9.27$, $p = 0.004$, $d = 0.96$.

There were several significant correlations between baseline and alcohol self-administration variables. Baseline negative consequences of alcohol use, frequency of consumption, drinks per drinking day, and heavy drinking frequency correlated positively with peak eBAC during the drinking session. Drinks per drinking day and heavy drinking frequency were correlated positively with number of beers self-administered, and males self-administered more beers. Multiple baseline variables were associated with drinking topography, particularly the interval from first to second beer (Table 2). PBS use, particularly strategies directly pertaining to manner of drinking, was negatively associated with several drinking session outcomes.

DISCUSSION

Automatic action tendency retraining was not successful, despite multiple retraining iterations. The same number of retrainings was implemented in Wiers and colleague's (2011) study in an inpatient sample, which was associated with successful retraining and decreased likelihood of subsequent relapse. The present findings dovetail with a pair of experimental laboratory studies by Lindgren and colleagues (2015), involving social and heavier drinking young adults in which no effect was shown following 2 retrainings.

Given the lack of a retraining effect, it was expected that no significant differences would be found between the retraining and control conditions on alcohol self-administration. Similarly, Wiers and colleagues (2010) did not show significant differences in alcohol self-administration among hazardous-drinking male students on a taste test between retraining and control conditions in their full sample. Despite evidence of retraining, Sharbanee and colleagues (2014) also did not find a significant difference between retraining and control in amount of alcohol self-administered.

Potential reasons for our results include possible failure of the retraining to engage participants cognitively; the study's design as an experimental laboratory study enrolling less severe drinkers; and the nature of the alcohol self-administration paradigm. Regarding cognitive engagement, the retraining required participants to respond according to the direction of a slight, 3-degree tilt of the image to the right or left, as opposed to the more common approach of requiring participants to respond according to the picture or landscape orientation of the image. The tilt option was chosen based on the expectation that this variant of the task would be more challenging and thus more engaging for our population of younger, less severe drinkers than in prior retraining studies (Eberl et al., 2013; Wiers et al., 2011). The one other published automatic action tendency retraining study enrolling young participants using the tilt approach also failed to find a significant retraining effect for cigarette cues (Kong et al., 2015). Studies that have shown a retraining effect among young adults have utilized the portrait/landscape version (Di Lemma and Field, 2017; Sharbanee et al., 2014; Wiers et al., 2010), although there have been null retraining effects among young adults with the portrait/landscape version (Lindgren et al., 2015). If participants did not engage with the images and instead, responded according to a different strategy (e.g., looking only at a corner of the image to judge tilt), this may help to explain the lack of effects in this study.

There are several other distinctions between the aforementioned studies in young adults and those that have reported the strongest retraining effects (Eberl et al., 2013; Wiers et al., 2011). Summarizing results in clinical and nonclinical studies of alcohol cognitive bias modification, Wiers and colleagues (in press) concluded that the differential effects are found in people with an alcohol use disorder who wish to quit, but have difficulty doing so because of strong cue-reactivity, which is decreased by retraining (Wiers et al., 2015). Relatedly, Field and Wiers (Wiers et al., in press) have pointed to the distinction between randomized controlled trials, enrolling severe drinkers with motivation to change, and laboratory studies that tend to enroll less severe drinkers with less inherent motivation. In laboratory studies enrolling nontreatment-seeking young adults, even when retraining has occurred, it has not resulted consistently in less alcohol self-administration (Sharbanee et al., 2014; Wiers et al., 2010). In the present study and Lindgren and colleagues (2015), lack of motivation to change may have hampered even the ability to show an effect of retraining on automatic action tendency. These findings may be explained by Lewin's (1935, 1951) assertion that while it is possible to manipulate goals people already hold, it is difficult to induce goals people do not already have.

Further, the elaboration likelihood model posits that long-term attitude and behavior change typically do not occur when information is processed only along the peripheral route, which is often driven by cues or features of stimuli. For long-term changes, information must be processed via the central route, which entails greater effort, thus requiring sufficient ability and motivation (Petty and Cacioppo, 1986). For drinkers with less motivation, retraining may never advance past the peripheral route, making any changes in attitude or behavior fleeting.

Another, related distinction between laboratory and clinical studies (Eberl et al., 2013; Wiers et al., 2011) is differing levels of alcohol problem severity. In addition, participants in the present study and 3 prior young adult retraining studies (Lindgren et al., 2015 [2 studies reported in 1 paper]; Sharbanee et al., 2014) did not evince a clear, substantial automatic action tendency toward alcohol stimuli at baseline. Thus, in these studies, there was no strong tendency for retraining to fix.

Although there were no significant differences between study conditions in alcohol self-administration, our findings support the validity of the impaired control human laboratory paradigm as an objective way to measure alcohol consumption among young adults and as a means of observing direct PBS use. A wide range of alcohol self-administration behavior was observed similar to our initial proof of concept study (Leeman et al., 2013). The primary (peak eBAC) and secondary outcomes (number of beers self-administered) related to multiple baseline alcohol use variables. The ability to measure drinking topography is a strength of human laboratory paradigms and in this study, interdrink interval between first and second beer had particularly strong relationships to baseline variables. Longer drink durations and interdrink intervals correspond to the direct PBS of "pacing" taught in motivational interviewing-based interventions for young adults (Dimeff et al., 1999). The paradigm also captures the social element of young adult alcohol use (Sayette et al., 2012; Wood et al., 2001). Conduct of alcohol self-administration in an actual bar enhances ecological validity. A random effect of alcohol drinking session group predicted self-administration outcomes, suggesting participants were affected by their fellow participants' drinking behavior. At the same time, the impact of individual difference variables (i.e., gender and baseline drinking) on alcohol self-administration was still clearly observable. Thus, there is every reason to believe significant differences between an efficacious intervention and control condition could be observed using the impaired control paradigm.

Other paradigms such as the taste test, which has been frequently used in the cognitive bias modification literature, can be used to show whether an experimental manipulation has any immediate, observable effect on alcohol consumption (Di Lemma and Field, 2017). Self-administration in the taste test has been found to be sensitive to multiple experimental manipulations and has construct validity in relation to baseline measures (Jones et al., 2016), although it lacks ecological validity. While the objective of the impaired control laboratory paradigm is also to determine whether manipulations and interventions affect drinking, it attempts to capture young adult alcohol drinking in an ecologically valid manner. While the range of self-administration behavior observed here and in our prior study (Leeman et al., 2013) suggests the paradigm's potential sensitivity to intervention and manipulation effects, the taste test is probably more sensitive to short-term, subtle, small-effect manipulations.

There were other strengths to this study, which was the first to test multiple iterations of automatic action tendency retraining in succession followed by laboratory alcohol self-administration. There was little attrition with 69 of 72 participants who began retraining completing it, and among the 69, only 1 participant missed a single retraining. The sample contained a considerable proportion of nonstudents and participants had heavier baseline alcohol consumption than many human laboratory studies in this population. Thus, the present sample arguably came close to approximating the population of at-risk drinkers targeted by secondary prevention interventions.

The study had limitations as well. Selection of participants with interest in changing their drinking behavior may have represented a somewhat closer approximation of the samples in Wiers and colleagues (2011) and Eberl and colleagues (2013) and might have produced differing results. While relative ecological validity is a strength of our paradigm, laboratory studies necessarily entail artificial contingencies.

In conclusion, the present findings do not support automatic action tendency retraining for heavy drinking young adults without motivation to change their drinking with the caveat that the version of the task utilized may not have engaged participants optimally. Despite null findings regarding effects of retraining, measures of the relationship between baseline variables and outcomes measured during the laboratory session suggest the impaired control laboratory paradigm is a valid laboratory-based measure of young adult alcohol consumption that provides opportunity to observe drinking topography and direct PBS.

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FINANCIAL DISCLOSURES

The authors report that they have no financial conflict of interests with respect to the content of this manuscript. Dr. O'Malley reports being a consultant or an advisory board member of Alkermes, Amygdala, Cerecor, Indivior, Mitsubishi Tanabe, Opiant; a member of the American Society of Clinical Pharmacology Alcohol Clinical Trials Initiative supported by Amygdala, Ethypharm, Lilly, Lundbeck, Otsuka, Pfizer, Arbor Pharmaceuticals, and Indivior; and donated study medications from Pfizer and Astra Zeneca. All other authors have no disclosures.

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SUPPORTING INFORMATION

Additional Supporting Information may be found online in the supporting information tab for this article:

Fig. S1. Depicts, from left to right, the mean duration taken to consume up to the first 3 beers during a 3-hour ad libitum-drinking period by study condition; the mean interval between the end of the first and the beginning of the second beer by condition; and the mean interval between the end of the second and the beginning of the third beer by condition, all differences were not statistically significant.