Published in final edited form as:

Behav Res Ther. 2016 December ; 87: 58–69. doi:10.1016/j.brat.2016.08.010.

Randomized Controlled Trial of Attention Bias Modification in a Racially Diverse, Socially Anxious, Alcohol Dependent Sample

Elise M. Clerkin^{1, #}, Joshua C. Magee^{2, #}, Tony T. Wells³, Courtney Beard⁴, and Nancy P. Barnett⁵

¹Department of Psychology, Miami University, Oxford, OH

²Department of Family and Community Medicine, University of Cincinnati, Cincinnati, OH

³Department of Psychology, Oklahoma State University, Stillwater, OK

⁴Department of Psychiatry, Harvard Medical School and McLean Hospital, Belmont, MA

⁵Department of Behavioral and Social Sciences and Center for Alcohol and Addiction Studies, Brown University, Providence, RI

Abstract

Objective—Attention biases may be an important treatment target for both alcohol dependence and social anxiety. This is the first ABM trial to investigate two (vs. one) targets of attention bias within a sample with co-occurring symptoms of social anxiety and alcohol dependence. Additionally, we used trial-level bias scores (TL-BS) to capture the phenomena of attention bias in a more ecologically valid, dynamic way compared to traditional attention bias scores.

Method—Adult participants (N=86; 41% Female; 52% African American; 40% White) with elevated social anxiety symptoms and alcohol dependence were randomly assigned to an 8-session training condition in this 2 (Social Anxiety ABM vs. Social Anxiety Control) by 2 (Alcohol ABM vs. Alcohol Control) design. Symptoms of social anxiety, alcohol dependence, and attention bias were assessed across time.

Results—Multilevel models estimated the trajectories for each measure within individuals, and tested whether these trajectories differed according to the randomized training conditions. Across time, there were significant or trending decreases in all attention TL-BS parameters (but not traditional attention bias scores) and most symptom measures. However, there were not significant differences in the trajectories of change between any ABM and control conditions for any symptom measures.

Conclusions—These findings add to previous evidence questioning the robustness of ABM and point to the need to extend the effects of ABM to samples that are racially diverse and/or have co-

Correspondence should be addressed to Elise M. Clerkin, clerkiem@miamiOH.edu.

[#]Elise M. Clerkin and Joshua C. Magee contributed equally to this work

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occurring psychopathology. The results also illustrate the potential importance of calculating trial-level attention bias scores rather than only including traditional bias scores.

Keywords

attention bias modification; social anxiety; alcohol dependence

Alcohol Use Disorders (AUDs) and Social Anxiety Disorder (SAD) are impairing conditions, which are associated with a range of problematic outcomes (APA, 2013; Kessler, R. C., 2005). AUDs represent a heterogeneous group of problems associated with maladaptive alcohol use (McCrady, 2008), and SAD is characterized by extreme fear and/or avoidance of social situations (APA, 2013). Lifetime prevalence rates for both disorders are high, with a 12.1% lifetime prevalence rate for social phobia, and an 18.6% lifetime prevalence rate for alcohol abuse and dependence combined (Kessler, Berglund, Demler et al., 2005). Further, epidemiological research suggests that AUD and SAD commonly co-occur (Grant, Stinson, Dawson, et al., 2004; Schneier et al., 2010), potentially because socially anxious individuals use alcohol to manage physiological arousal and fears of negative evaluation, to enhance positive affect, and/or to facilitate more positive social interactions or greater social avoidance (Buckner et al., 2013). In spite of these common and significantly overlapping problems, insight into the mechanisms linking alcohol dependence and social anxiety symptoms is minimal, and there are not well-established treatment guidelines for this population (see Randall, Thomas, & Thevos, 2001; Thomas, Randall, Book, & Randall, 2008).

Attention Bias in Alcohol Use and Social Anxiety

Attention bias, the tendency to preferentially allocate attention toward or experience difficulty disengaging attention from problem-relevant cues, may confer an underlying vulnerability for both AUDs (Field & Cox, 2008; Wiers, Cox, Field, Fadardi, Palfai, Scheonmakers, & Stacy, 2006) and social anxiety disorder (Bögels & Mansell, 2004), as well as symptoms associated with both disorders. First, theory and empirical evidence suggests that attention bias for alcohol cues is associated with symptoms of AUDs (for a review, see Field & Cox, 2008). For instance, lower alcohol attention bias predicts long-term reductions in frequency of alcohol use among heavy drinkers (Cox, Pothos, & Hosier, 2007), and increased attention bias toward alcohol cues predicts poorer treatment outcome among individuals diagnosed with alcohol abuse (Cox, Hogan, Kristian, & Race, 2002). Stronger alcohol attention bias tied to the initial orienting of attention is also associated with greater addiction severity (Nöel, Colmant, Van Der Linden, Bechara, Bullens, Hanak, & Verbanck, 2006), and a meta-analysis indicated there is a significant (albeit small) positive relationship between strength of alcohol attention bias and self-reported craving (Field, Franken, & Munafó, 2009). Moving beyond correlational studies, Field and colleagues (2005) demonstrated that among heavy social drinkers, individuals who had been trained to attend toward alcohol-relevant cues consumed more beer during a post-training taste test. Such experimental findings suggest that attention bias may play a causal role in the maintenance of AUDs, although more research is needed.

Similarly, empirical evidence suggests that symptoms of social anxiety disorder are associated with biases in attention, at least in certain contexts (Bögels & Mansell, 2004). For example, Pishyar et al. (2004) found that individuals with high (vs. low) social anxiety symptoms showed an attention bias toward threatening faces, but not toward socially threatening words. In comparison to healthy control participants, individuals diagnosed with SAD showed a bias toward threatening cues at shorter (500 ms), but not longer (1250 ms), durations (Mogg, Bradley, & Philippot, 2004). Finally, in meta-analytic reviews, there is support for an attention bias toward threat broadly in anxiety, as well as specifically within SAD (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & IJzendoorn, 2007).

Although a full review is beyond the scope of this paper, research suggests that there may be critical differences in the initial *shifting* or orienting of attention toward threatening stimuli (typically assessed with exposure durations from 50–200 ms), and the *maintenance* or *disengagement* of attention from threatening stimuli (typically assessed with exposure durations above 500 ms; Field & Cox, 2008). In the context of addictions, on the one hand, meta-analytic work suggests that there may be a marginally significant effect ($p = .10$) for a larger relation between greater craving and attentional bias when measures of disengagement are used, as compared to when measures of initial orienting are used (Field et al., 2009). On the other hand, although most studies using the visual probe task have found the anticipated bias *toward* substance-relevant stimuli, there is some evidence that individuals with alcohol dependence who are in treatment show a bias *away* from alcohol-relevant cues at longer stimuli exposure durations (Field et al., 2009). There is also evidence that biases toward threatening information among socially anxious individuals may be reduced as stimulus exposure increases (Bögels & Mansell, 2004).

Linking Attention Bias in Alcohol Dependence and Social Anxiety

The Avoidance-Coping Cognitive (ACC) model highlights the importance of attention bias to help explain why socially anxious individuals may be particularly susceptible to alcohol problems (Bacon & Ham, 2010). Alcohol use may be reinforcing insofar as it reduces the salience of socially threatening cues. For individuals with social anxiety, this model predicts that the more one drinks, the less pronounced attention bias toward social threat will become. That is, individuals with social anxiety may engage in maladaptive coping strategies (e.g., excessive drinking) to alleviate attention toward socially threatening cues (e.g., negative facial expressions), which minimizes social anxiety symptoms in the short term. Guided by this theory, learning to reduce attention bias toward social threat may lead to reductions in alcohol use and social anxiety symptoms (Bacon & Ham, 2010).

The ACC model is supported by research findings that individuals with social anxiety demonstrated an attention bias toward angry faces when sober, but not after drinking alcohol (Stevens, Rist, & Gerlach, 2009). Thus, alcohol use may weaken the impact of attention bias toward social threat. Results from a different study indicated that individuals with social anxiety were less likely to perceive angry faces as rejecting following the consumption of alcohol, further strengthening the argument that heavy drinking may be negatively reinforcing for people with social anxiety (Stevens, Gerlach, & Rist, 2008).

Attention Bias Modification

Attention Bias Modification (ABM) procedures attempt to directly modify attention bias, typically via repetitive computerized tasks. This approach is based on the pioneering work of MacLeod and colleagues (2002), who first tested whether experimentally manipulating attention via a modified dot probe task was associated with later emotional vulnerability. Since then, a number of studies have tested ABM in the context of social anxiety (e.g., Amir et al., 2009; Carlbring et al., 2012; Schmidt et al., 2009) and alcohol use (e.g., Fadardi & Cox, 2009; Schoenmakers et al., 2010).

In initial demonstrations of the clinical utility of ABM, patients with social anxiety disorder who were trained to disengage their attention from socially threatening cues had significant reductions in social anxiety post-training compared to controls (Amir, Beard, Taylor, Klumpp, Elias, Burns, & Chen, 2009; Schmidt, Richey, Timpano, & Buckner, 2009). In both of these studies, participants completed eight training sessions that were administered over a 4-week period. Training consisted of a visual probe task that used faces presented for 500 ms, followed by a probe (either the letter E or F). Of note, Amir et al. (2009) found that attention training led to greater attentional disengagement from threat (stimuli were presented for 600 ms). Meta-analytic work has also provided support for the clinical utility of ABM for anxiety generally (see Bar-Haim, 2010; Beard, Sawyer, & Hofmann, 2012; Hakamata et al., 2010), as well as symptoms of social anxiety more specifically (Magoase, David, & Koster, 2014).

Although fewer studies have tested ABM in AUDs, there are some promising findings in support of the model. One study evaluated the clinical utility of ABM among patients with alcohol dependence who were being treated with cognitive behavioral therapy (Schoenmakers, Bruin, Lux, Goertz, Van Kerkhof, & Wiers, 2010). This study used a visual probe task consisting of 5 sessions, and used pictures of alcohol (as compared to neutral pictures). Training targeted both the speeded detection of alcohol cues (displaying stimuli for 200 ms), as well as difficulty disengaging from alcohol cues (displaying stimuli for 500 ms). Of note, rather than using a standard control condition in which probes were equally divided across alcohol vs. neutral stimuli, the control condition used in this study was a categorization task, similar in design to the Implicit Association Test (Greenwald, McGhee, & Schwartz, 1998). Results indicated that it was possible to train patients to disengage their attention from alcohol-relevant cues, although training did not influence speeded detection. Patients in the experimental condition (vs. a control condition) were discharged from treatment earlier and maintained abstinence an average of 1.25 months longer after treatment. Additionally, following a home-based ABM among college students who were heavy drinkers (McGeary, Meadows, Amir, & Gibb, 2014), participants in the ABM (vs. control) condition reported decreased drinking. Training in this study consisted of a visual probe task that displayed alcohol vs. neutral words for 500 ms, followed by a probe. Similar to the social anxiety trials outlined earlier, participants were asked to complete eight training sessions over a 4-week period, all administered in their home.

Although the aforementioned research speaks to the promise of ABM, there have been several unsuccessful replication attempts within the context of anxiety, often when ABM

was delivered online outside of the lab (see Heeren, Mogoase, Philippot & McNally, 2015). Further, a recent meta-analysis evaluating CBM in the context of anxiety and depression found that effect sizes were small, and that many positive outcomes may have been driven by extreme outcomes (Cristea, Kok, & Cuijpers, 2015). Authors concluded (p. 7): “CBM may have small effects on mental health problems, but it is also very well possible that there are no significant clinically relevant effects”. Similarly, in their critical review of ABM studies for alcohol use disorders and other addictions, Christiansen et al. (2015, p. 6) point out that there has been a disappointing lack of well-designed studies or replications of ABM in addicted samples, concluding: “there is little reason to be enthusiastic about the clinical potential of multiple sessions of ABM *when delivered in clinical or university settings*” (see also Beard et al., 2012; Hallion & Ruscio, 2011; Mogoase, et al., 2014).

Taken as a whole, ABM research has been decidedly mixed. Critically, however, a recent comprehensive review suggests that when the mechanism of action (i.e., attention bias) is effectively changed, there is a corresponding shift in clinical anxiety symptoms (see MacLeod & Clarke, 2015). Hence, there is at least some reason to be optimistic about the potential of using ABM as a clinical tool.

Present Study: Design and Hypotheses

The current study focused on individuals with alcohol dependence and elevated social anxiety symptoms to investigate how well individuals can be trained to shift attention away from alcohol-relevant *and* socially threatening cues. In doing so, we synthesized two parallel lines of research to gain greater clarity into the mechanisms that drive symptom improvement for co-occurring alcohol dependence and social anxiety. To this end, the current study compared the relative contributions of two ABM interventions that were: 1) designed to shift attention bias away from alcohol-relevant cues (Alcohol ABM), and 2) designed to shift attention bias away from socially threatening cues (Social Anxiety ABM). More specifically, participants were randomly assigned to one of four conditions in this between-subjects 2 (Alcohol ABM vs. Alcohol Control) by 2 (Social Anxiety ABM vs. Social Anxiety Control) design. Our primary hypotheses were that the Alcohol ABM (compared to a control) would reduce alcohol dependence symptoms, and the Social Anxiety ABM (compared to a control) would reduce social anxiety symptoms. Further, we expected that there would be an interaction effect, such that participants in the combined Alcohol ABM/Social Anxiety ABM intervention would show greater improvement in alcohol and anxiety outcomes, relative to participants in either intervention alone.

Present Study: Contributions to Existing ABM Research

The present study advances existing ABM research in three critical ways. First, this is the first investigation to use ABM to simultaneously target symptoms of co-occurring social anxiety and alcohol dependence. Critically, this design allowed us to evaluate the separate and interactive effects of the Alcohol and Social Anxiety ABM interventions. Second, the current study supplements existing ABM trials by sampling a racially diverse sample, compared to existing ABM research, which has either reported the use of predominantly European American samples (Amir, Beard, Taylor, Klumpp, Elias, Burns, & Chen, 2009;

Schmidt, Richey, Buckner, & Timpano, 2009), or which have failed to report the race of participants at all (e.g., Carlbring, Apelstrand, Sehlin, Amir, Rousseau, Hofmann, & Andersson, 2012; Fadardi & Cox, 2009; Schoenmakers, Bruin, Lux, Goertz, Van Kerkhof, & Wiers, 2010).

Finally, the current study evaluates attention bias using the traditional scoring method, in addition to a potentially more ecologically valid, dynamic method. Specifically, traditional measurements of attention bias using reaction time have been criticized for demonstrating poor reliability (e.g., Schmukle, 2005) and marked heterogeneity in their association with mood congruent stimuli (e.g., Zvielli, Bernstein, & Koster, 2014). When compared to traditional attention bias scores, recent research suggests that a novel way of conceptualizing and operationalizing attention bias in time—referred to as attention trial-level bias score (attention TL-BS)—is a more ecologically valid way of capturing the phenomena of attention bias in the context of anxiety and addiction (see Zvielli, Bernstein, & Koster, 2015b). According to authors: “selective attention is a psychological process expressed repeatedly and continuously over time” (p. 2; Zvielli et al., 2015b). Thus, TL-BSs are calculated by subtracting latencies for pairs of congruent vs. incongruent trials that were within five trials of each other. Thus, rather than just evaluating a single bias score, we were able to evaluate bias scores reflecting a bias both *toward* and *away* from the social threat/ alcohol cues, as well as the temporal stability or instability of an individual’s bias scores. This is valuable in light of the evidence reviewed earlier regarding the time course of attention bias, and the somewhat mixed findings tied to whether attentional bias in both anxiety and addictions are related to difficulties in vigilance vs. avoidance (see discussion in Field & Cox, 2008; Zvielli et al., 2015b).

Bearing this in mind, the bulk of existing research investigating attention bias, which uses a static bias score, may not adequately or optimally reflect the dynamic expression of attention bias across time. Indeed, researchers have found that attention TL-BS uniquely predicted psychopathology and addiction over and above traditional bias scores (see Zvielli et al., 2015b). Drawing from this research, the present study used TL-BS parameters in addition to evaluating traditional bias scores to measure the dynamic expression of attention bias within participants, across time.

Method

Participants

Participants ($N = 86$ randomized into the trial) were recruited from a metropolitan, Midwestern city via advertisements placed in a variety of settings (e.g., city buses, health practices, community centers, craigslist). During an initial phone screen, participants were told that researchers were testing a new computer program designed to help people develop healthy mental habits related to alcohol and anxiety. Please see Figure 1 for a full CONSORT diagram.

Potential participants were pre-screened via phone by trained research assistants. Inclusion criteria at pre-screening included: 1) age 18 years or older; 2) met diagnostic criteria for current alcohol dependence according to the Mini-International Neuropsychiatric Interview

(M.I.N.I.; Sheehan et al., 1998; Sheehan & Lecrubier, 1992–2006); 3) experienced elevated social anxiety symptoms, i.e., 30 on the experimenter administered Liebowitz Social Anxiety Scale (LSAS; Mennin, Fresco, Heimberg, Schneier, Davies, & Liebowitz, 2002); 4) indicated that they were willing to consider cutting down on their drinking; and 5) spoke and read English. Exclusion criteria at pre-screening were 1) current psychotic or manic symptoms; 2) significant cognitive impairment; 3) past-month drug use other than marijuana and nicotine; 4) current involvement in cognitive behavioral therapy for an AUD or social anxiety (given that CBT may target a similar mechanism). Participants also needed to be stable on any psychotropic medications for at least 6 weeks. Additionally, participants' Breath Alcohol Content (BrAC) needed to be $<.02$ at the time of written informed consent, and before each assessment and intervention session.

Initially 94 participants were randomized to the treatment. However, five were excluded from analyses because during the baseline assessment they reported that they had consumed alcohol during the preceding month either "never" or "less than once per month", so did not show current alcohol problems ($n = 5$). To ensure current social anxiety symptoms, participants were also excluded from analyses if during the baseline assessment they scored more than 2 SD below the mean of a sample diagnosed with social phobia on the LSAS (i.e., <12.2 ; Heimberg, Horner, Juster, Safren, Brown, & Schneier, 1999), or if they did not report any symptoms of social anxiety on either of the other two trait measures of social anxiety ($n = 3$). This resulted in a final sample of 86 participants.

Procedure

The current project was approved by the university's institutional review board. As part of the informed consent process, participants were told that they would be randomly assigned to one of four conditions that may or may not help them. All participants received the same intervention rationale during the baseline assessment, including reasons why the intervention may help to reduce their drinking and social anxiety.

Participants were asked to complete 8 sessions across 4 weeks. There was at least one day in between all sessions, and the sessions needed to be completed within the span of 6 weeks. Each session was completed in person in the lab, lasted roughly 30 minutes, and included scheduled breaks during the tasks for participants to rest. Each of the 8 sessions consisted of 2 primary tasks: an Alcohol-relevant (ABM or control) and an Anxiety-relevant (ABM or control) task. Hence, using blocked randomization (block size 12), participants were randomized into one of 4 possible conditions: 1) Alcohol ABM and Social Anxiety control; 2) Alcohol control and Social Anxiety ABM; 3) Alcohol ABM and Social Anxiety ABM; 4) Alcohol control and Social Anxiety control. This resulted in roughly half of the 86 participants receiving the Alcohol ABM ($N = 42$) and the other half receiving the Social Anxiety ABM ($N = 44$) condition. Experimenters and participants were both blind with respect to participant condition.

Prior to and following training, and at one month follow-up, participants completed an assessment battery. Participant BrAC was taken at the time of written informed consent, and before each assessment and intervention session. Finally, the Daily Drinking Questionnaire and LSAS, our primary outcome measures, were administered weekly throughout the 4-

week trial. The Alcohol Withdrawal Symptom Checklist-Revised was also administered weekly throughout training to monitor withdrawal symptoms. Participants were compensated up to \$200 if they completed all eight sessions and three assessment batteries.

Materials

Stimuli—For both the alcohol and anxiety tasks, we created five sets of 12 stimuli pairs (alcohol-neutral or social threat-neutral). One alcohol set and one social anxiety set was used solely for the alcohol and social anxiety dot probe tasks, respectively. The same alcohol set was used for the State Subjective Alcohol Cravings measure. The other four sets were distributed so that participants encountered varying combinations of two sets in each of the 8 intervention sessions (following Schoenmakers et al. 2010). In other words, during each session, participants completed either an ABM and/or control task that included two sets of stimuli (24 picture pairs per task; 48 stimuli pairs per session). For instance, social anxiety sets 1 and 2 were used during session 1; social anxiety sets 3 and 4 were used during session 2; social anxiety sets 1 and 3 were used during session 3, etc.. This means that for a participant who completed all 8 intervention sessions, they would see the same set 4 times.

Stimuli for the alcohol-ABM, control, and attention bias assessment task consisted of alcohol-relevant (e.g., mug of beer) and neutral (e.g., bottle of water) photographs. Images were taken from sets used by researchers in the field (K. Lindgren, C. Pulido, R. Wiers) and Google searches. Twelve of each set were “active” (i.e., a human model was included in the image), whereas 12 were “passive” (i.e., the beverage stood by itself). In the Alcohol set of 12, there were 4 beer, 4 wine, and 4 liquor or mixed drink, and in the Neutral set there were 6 water and 6 non-water (e.g., Coca-Cola) stimuli. Stimuli for the anxiety-ABM, control, and attention bias assessment tasks were facial photographs from standardized databases of different facial expressions (NIMSTIM; www.macbrain.org/ and KDEF; Lundqvist, Flykt, & Öhman, 1998). Facial stimuli depicting anger and disgust were used, as these are the most well-established in the context of attention biases for social anxiety (Amir et al., 2009; Bögels & Mansell, 2004). We chose threat faces that were rated as either angry or disgusted by 90% of respondents in the database, and neutral faces that were rated neutral by 50%. Each set included 6 male (3 angry and 3 disgust) and 6 female (3 angry and 3 disgust) models. Each set included 8 white models and 4 non-white models.

Dot Probe Task—The computer-administered dot probe task is the most commonly used behavioral measure to assess attention biases, as well as the impact of ABM on attention biases. Two versions of the dot probe task were administered—one assessing attention bias toward alcohol cues (alcohol dot probe), and one assessing attention bias toward social threat (anxiety dot probe). Each version of the dot probe consisted of 96 trials that varied by probe type (arrow pointing right or left for alcohol task; E or F for anxiety task) and probe location (top or bottom). Stimuli were presented for 500 ms and immediately replaced by a probe. The probe followed the problem-specific cue (alcoholic beverage or threatening face) in 50% of the trials, and the neutral cue (neutral beverage or face) in 50% of the trials. Participants identified the direction of the arrow in the alcohol task and identified whether the probe was an E or an F in the anxiety task. Each trial in the dot probe tasks is either a congruent trial or incongruent trial. Trials are congruent when the probe appears in the

location of the threat faces in the anxiety task and in the location of the alcohol stimuli in the alcohol task, whereas trials are incongruent when the probe appears in the location of neutral stimuli.

Traditional Bias Score: Typical attention bias scores were calculated by subtracting the average reaction time on congruent trials from the average reaction time on incongruent trials (MacLeod et al., 1986).

Trial-level Bias Score (TL-BS): TL-BSs were calculated by subtracting latencies for pairs of congruent trials and incongruent trials that were within five trials of each other. The TL-BSs were then used to calculate five TL-BS indices. Mean TL-BS_{Positive} measures average bias toward the threat/alcohol stimuli, and mean TL-BS_{Negative} measures average bias away from the threat/alcohol stimuli. Peak TL-BS_{Positive} measures the maximum bias toward the threat/alcohol stimuli, and peak TL-BS_{Negative} measures the maximum bias away from the threat/alcohol stimuli. Lastly, TL-BS_{Variability} measures the temporal stability or instability of an individual's bias scores. Each of the five indices was calculated for the anxiety task and the alcohol task at each time point. For a more in-depth discussion of the TL-BS indices, see Zvielli et al. (2015b).

Attention Bias Modification—Attention bias modification training involved: 1) motivating participants to enhance their training performance; 2) a wide variety of training stimuli; 3) multiple training sessions; and 4) a top-bottom stimuli orientation. We based our protocol on prior studies that examined ABM separately for alcohol (Schoenmakers et al., 2010) and social anxiety (Amir et al., 2009). To enhance participants' motivation and perception that it is possible to improve their training performance and control over their attention (Fadardi & Cox, 2009; Schoenmakers et al., 2010; Wiers et al., 2006), all participants were given positively framed feedback on both their performance mean reaction time and performance accuracy. The experimenter encouraged the participant to set a goal for the next session based on those figures (e.g., decreasing overall reaction time by 10% and maintaining an error rate of less than 5%).

The *Alcohol ABM* task consisted of a modified dot probe task. To signal the beginning of each probe detection trial, a black fixation cross appeared in the center of the computer screen. After 500 ms, this cross was replaced with an alcohol-relevant (e.g., mug of beer) and neutral (e.g., glass of water) picture pair in top-down placement. After another 500 ms, the picture pair was replaced by a probe (an arrow pointing right or left), which appeared in the same spatial location as the neutral photograph. Participants were instructed to identify the probe as quickly and accurately as possibly by pushing a key. A single Alcohol ABM session consisted of 144 trials that varied by probe type (arrow pointing right or left) and probe location (top vs. bottom). The probe always followed the neutral (vs. alcohol-relevant) cue. This contingency between the probe and the neutral cue was intended to train participants to disengage their attention *away* from alcohol-relevant information, although they were never explicitly told not to look at the alcohol-relevant photograph. The *Social Anxiety ABM* followed the same procedure as the Alcohol ABM with two exceptions. First, the stimuli included picture pairs of faces—one conveying a disgusted or angry expression,

and one conveying a neutral expression. Second, the probe that replaced the neutral face was either the letter “E” or “F”.

Finally, the control conditions were standard dot probe assessment tasks, in which probes replaced neutral and alcohol/anxiety related cues with equal frequency. Thus, each control task did not attempt to train attention in any particular direction (see Amir et al., 2009; Schoenmakers et al., 2010). Again, there were two versions of the control task – one using alcohol pictures (Alcohol control), and one using social pictures (Social Anxiety control). The control task had the same instructions as the experimental tasks, set similar performance goals, matched the time spent engaged in the intervention, and showed identical alcohol and socially relevant pictures.

Symptom and Diagnostic Measures—Items from the *Mini-International Neuropsychiatric Interview* English Version 5.0.0 for DSM-IV (M.I.N.I.; Sheehan et al., 1998; Sheehan & Lecrubier, 1992–2006) were used to assess inclusion and exclusion criteria. The M.I.N.I. was selected because it requires relatively little training to administer, and can be administered quickly (Sheehan et al., 1998).

The *Daily Drinking Questionnaire* (Collins, Parks, & Marlatt, 1985) was the primary measure used to assess weekly alcohol consumption. This calendar-based measure was administered by the experimenter once per week to monitor changes in symptoms. At each assessment point, participants were instructed to report how much alcohol (measured in number of standard drinks) they drank each day during the previous week. Participants were provided with a visual aid defining a standard drink (e.g., 12 ounces, or one can or bottle of beer; 5 oz glass of wine, etc.), and a calendar was used to help orient participants. To facilitate the use of a multilevel modeling analyses requiring count data, a small number of cases originally entered with decimals (<6% across time points) were rounded to the nearest whole number. DDQ Quantity (total drinks per week) was calculated and analyzed in the current study (α T1¹ = .89; α T2 = .92; α T3 = .92).

An adaptation of the *Drinking to Cope* (DTC-Adapted; Thomas, Randall, & Carrigan, 2003) measure was used to assess the extent to which participants used alcohol to cope with anxiety associated with social situations. The following four items were averaged to create a DTC-A composite subscale: 1) What percentage of the time would you use alcohol to feel more comfortable or less anxious in social situations where alcohol was available? (0% to 100%, recoded 0 to 10); 2) What percentage of the time do you drink before engaging in a social situation (0% to 100%, recoded 0 to 10); 3) What percentage of the time do you drink after engaging in a social situation (0% to 100%, recoded 0 to 10); and 4) How much does alcohol relieve your anxiety or discomfort in a social situation (0, not at all, to 10, completely). Participants who indicated “No” for whether they ever drank during, before, or after social situations received a score of 0 on items 1–3 of the DTC, respectively. The reliability of the DTC-A in the current sample was good (α T1 = .71; α T2 = .77; α T3 = .79).

¹For reliabilities, T1 = prior to training; T2 = following training; and T3 = one month follow-up.

The *Drinker Inventory of Consequences* (DrInC; Miller, Tonigan, & Longabaugh, 1995) is a self-administered, well-validated instrument used to assess the consequences associated with drinking, including interpersonal, intrapersonal, physical, impulsive, and social consequences of drinking. Drinking consequences reported during the past month were evaluated (α T1 = .96; α T2 = .94; α T3 = .97).

The *Alcohol Withdrawal Symptom Checklist-Revised* (AWSC; Pittman, Gueorguieva, Krupitsky, Rudenko, Flannery, & Krystal, 2007) was administered at baseline and on a weekly basis to monitor withdrawal symptoms. Using a 5-point scale, participants rated 17 withdrawal symptoms (e.g., nervousness, sweating, seizures, craving for alcohol) that they had experienced during the past 24 hours (T1 α = .89; T2 α = .87; T3 α = .85).

The experimenter-administered *LSAS* (Liebowitz, 1987) was the primary measure to assess social anxiety symptoms. Similar to the DDQ, it was administered at baseline, during each week of the trial, post-training, and at 1-month follow up. This well-validated instrument assesses fear and avoidance across a range of 24 social and performance situations during the course of the previous week (T1 α = .96; T2 α = .97; T3 α = .98).

The 17-item *Social Interaction Anxiety Scale* (SIAS; Mattick & Clarke, 1998; Heimberg, Mueller, Holt, Hope, & Liebowitz, 1993; Rodebaugh, Woods, & Heimberg, 2007) and 20-item *Social Phobia Scale* (SPS; Mattick & Clarke, 1998) are well-validated self-report measures used to provide additional measures of anxiety associated with social interactions and social performance (SIAS α T1 = .93; α T2 = .95; α T3 = .97; SPS α T1 = .93; α T2 = .95; α T3 = .96).

Subjective Cravings and State Social Anxiety—The *State Subjective Alcohol Cravings* measure (SSAC; Wiers, Eberl, Rinck, Becker, & Lindenmeyer, 2011) was used in which participants rated photographs of alcoholic beverages on a scale ranging from 0 (I don't want to drink this at all) to 5 (I would love to drink this right now). Stimuli were identical to those used during the alcohol dot probe task (see below; α T1 = .91; α T2 = .92; α T3 = .92).

Speech Task: Participants were asked to speak for up to 4 minutes about an impromptu topic in front of the experimenter. They were given a period of up to 2 minutes to prepare for the speech. Following the speech, participants completed the Speech Performance Questionnaire (SPQ; Rapee & Lim, 1992) to evaluate their performance across 17 items (e.g., kept eye contact, generally spoke well) (α T1 = .89; α T2 = .93; α T3 = .88). Further, participants completed the *Brief State Anxiety Measure* (BSAM; Berg, Shapiro, Chambless, & Ahrens, 1998), which used six items to evaluate their peak anxiety while speaking (α T1 = .81; α T2 = .83; α T3 = .78).²

²All speeches were timed as an index of behavioral avoidance. Further, with participant permission, speeches were video recorded and evaluated by coders using the Speech Performance Questionnaire. However, due to substantial missing data on these variables due to many participants choosing not to be videotaped, data from these two variables are not reported here. Please contact the first author for more information.

Data Analysis Plan

Following Carlbring et al.'s (2012) ABM trial for SAD, the primary analyses used multilevel modeling to capture both the trajectories of symptoms within individuals (i.e., level 1) and the hypothesized between-subject moderators of these trajectories, alcohol and anxiety attention training (i.e., level 2). This method analyzes all available data for each participant, conducting intent-to-treat analyses in a manner that optimizes power for controlled clinical trials with missing data (Chakraborty & Gu, 2009). Unless otherwise noted, the best fit to the data was provided by a scaled identity covariance matrix for level 1, which assumed a constant variance over the measurements, and an unstructured covariance matrix for level 2, which freely estimated the relationship between the random intercept and slope (Heck, Thomas, & Tabata, 2014). Generalized multilevel models were used to accommodate the variety of distributions of the dependent variables. For the DDQ, DrInC, AWSC, and all attention bias variables, a log link function was specified to account for positive skew; as a result, model results are presented in log units. All other models were relatively normally distributed and used an identity link function to relate predicted values of the model to the dependent variables without transformation. Terms were initially included in all models representing three-way interactions between the alcohol and anxiety training conditions and the trajectories of symptoms within individuals, but these were dropped as none neared significance ($p > .10$).

Results

Sample Characteristics and Session Completion

We first checked that randomization resulted in no significant group differences in participants' demographics or baseline measures. Chi-square tests and one-way ANOVAs indicated there were no significant differences among the four conditions ($p > .05$), with the exception of age ($F(3, 82) = 2.81, p = .05, \eta_p^2 = .09$). Given this, we initially included age as a covariate, but dropped it for parsimony because the pattern of results did not differ whether or not age was included. See Table 1 for sample demographics and baseline measures. Note, the average time between sessions was 3.83 days. On average, participants completed 6.79 sessions over the course of 25.86 days.

Changes in Attention Bias

To examine shifts in attention bias over treatment, we conducted multilevel models examining change in attention bias, using both the traditional unitary scoring of attention bias, as well as the scoring proposed by Zvielli et al. (2015b) that separates out different components of trial-level attention bias. As seen in Tables 2 and 3, there were different patterns for attention bias according to the scoring method. For both alcohol-relevant and social anxiety-relevant attention bias, there was no evidence of significant time-related change using the traditional scoring method ($p > .10$). In contrast, using the newer scoring method (i.e., attention TL-BS parameters), there were significant linear decreases for all of the five components of attention bias across both alcohol and social anxiety.

For these multilevel models only, mean negative and peak negative bias scores were multiplied by negative 1 to enable analysis with a log link function. Thus, within the

multilevel models, TL-BS_{Positive} scores should be interpreted as higher values indicating greater bias toward threat, TL-BS_{Negative} scores should be interpreted as higher values indicating greater avoidance of threat, and TL-BS_{Variability} scores measure variability in bias scores, or a tendency to swing back and forth between attention toward and avoidance of threatening stimuli. Thus, as shown in Tables 2 and 3, participants demonstrated reductions in attention bias that were consistent across parameters that measured biases 1) toward and away from problem-relevant stimuli; 2) as characterized by mean levels, peak levels, and variability; and 3) across socially threatening and alcohol stimuli. However, these reductions were not significantly tied to the ABM training conditions.

Training Condition Comparisons: Symptoms

Alcohol outcomes—Next, we examined whether trajectories of alcohol symptoms would differ according to participants' training conditions. See Table 4 for multilevel model predicted means and standard deviations for primary social anxiety and alcohol-related outcomes. For the DDQ Quantity, we examined change across seven time points using a model that specified a negative binomial distribution with a log link function. Although the fixed linear term did not reach significance (estimate = $-.10$, $SE = .07$, $F(1,517) = 2.44$, $p = .12$), as seen in Table 5, the fixed quadratic term was significant, indicating an accelerating decrease in the quantity of drinking over time (estimate = $-.01$, $SE = .006$, $F(1,517) = 5.26$, $p = .02$). There were no significant differences in the linear trajectories between the Alcohol ABM and control condition (estimate = $-.03$, $SE = .07$, $F(1,517) = .18$, $p = .67$, $<0.1\%$ of the variation in individual slopes) or between the Social Anxiety ABM and control condition (estimate = $.07$, $SE = .07$, $F(1,517) = 1.01$, $p = .32$, $<0.1\%$ of the variation in individual slopes). Multilevel models examining trajectories for convergent measures of drinking consequences (DrInC) and withdrawal symptoms (AWSC) found linear decreases over three and seven time points, respectively, with both reaching significance. Unlike the measure of drinking quantity, there was no quadratic trend for the DrInC; for the AWSC, the significant quadratic term indicated that the linear decrease significantly *lessened* over time. Similar to the DDQ, there were no significant differences in the linear trajectories between the Social Anxiety ABM and control condition or between the Alcohol ABM and control condition for either measure ($ps > .10$).

For state subjective alcohol cravings (SSAC), results indicated a similar pattern. There was a significant linear decrease over time in subjective cravings (estimate = $-.58$, $SE = .12$, $F(1,219) = 28.19$, $p < .001$), with this linear decrease lessening over time (estimate = $.12$, $SE = .03$, $F(1,219) = 19.14$, $p < .001$). However, this reduction was not significantly tied to the ABM training conditions ($ps > .05$). There were no other significant terms ($ps > .10$).

Social anxiety outcomes—Following this, we tested the social anxiety symptom measures (Table 4). For the LSAS, which examined change across seven time points, a diagonal covariance matrix was specified for level 1 as the best fitting. The fixed linear term indicated that, on average, social anxiety symptoms decreased over time (estimate = -3.11 , $SE = 1.07$, $F(1,517) = 18.45$, $p < .001$). As seen in Table 4, the fixed quadratic term was a trend, indicating that this decrease non-significantly lessened over time (estimate = $.18$, $SE = .11$, $F(1,517) = 2.76$, $p < .10$). However, again there was no difference in the size of the

linear decreases between the Social Anxiety ABM and control condition over the entire study (estimate = $-.80$, $SE = .95$, $F(1,517) = .71$, $p = .40$, $<0.1\%$ of the variation in individual slopes). Similarly, there was no difference in the size of the linear decreases between the Alcohol ABM and control condition in social anxiety symptoms over the entire study (estimate = $.27$, $SE = .95$, $F(1,517) = .08$, $p = .78$, $<0.1\%$ of the variation in individual slopes). Multilevel models examining symptom trajectories over three time points for the convergent measures of social anxiety symptoms (SIAS and SPS) demonstrated the same pattern; there were significant linear decreases in symptoms over time, with these decreases significantly lessening over time (i.e., quadratic effects). However, there were no significant differences in the linear trajectories between the Social Anxiety ABM and control condition or between the Alcohol ABM and control condition for either measure ($ps > .10$).

For the speech task, we examined change across three time points for the SPQ, which examined participants' perception of speech performance, and the BSAM, examining self-reported peak anxiety. There was no quadratic trend for the SPQ, so this term was dropped. There was not significant individual variation in the linear slopes for either model, so only intercepts were modeled as randomly varying between individuals. For the SPQ, the fixed linear term indicated that, on average, distorted speech cognitions decreased over time (estimate = -1.52 , $SE = 1.06$, $F(1,201) = 12.42$, $p = .001$). However, this reduction was not significantly tied to the ABM training conditions ($ps > .05$), and there were no other significant terms ($ps > .10$). For the BSAM, although there was not sufficient individual variation in slopes to be modeled, group trajectories followed the same pattern as findings for the LSAS, SIAS, and SPS, with no significant moderation by the Anxiety or Alcohol ABM conditions ($ps > .10$).

Drinking to Cope—Finally, as seen in Table 4, we examined drinking to cope using the DTC. Initial model building indicated that there was no quadratic trend, so this term was dropped. In addition, a scaled identity covariance matrix was specified for level 2 as the best fitting, and there was not significant individual variation in the linear slopes, so only intercepts were modeled as randomly varying between individuals. Again, the results paralleled the overall pattern of findings, as the fixed linear term indicated that, on average, drinking to cope decreased over time (estimate = $-.80$, $SE = .25$, $F(1,220) = 17.56$, $p < .001$), but this group trajectory was not moderated by the Anxiety or Alcohol ABM conditions ($ps > .10$).

Discussion

The primary aim of this study was to test whether ABM targeting alcohol and socially threatening cues would lead to reductions in attention biases, alcohol use disorder, and social anxiety symptoms in a community-based, alcohol dependent sample with elevated symptoms of social anxiety. This is the first ABM trial to investigate two (vs. one) targets of attention bias within a sample explicitly recruited for having co-occurring symptoms of social anxiety and alcohol dependence. Further, in addition to traditional attention bias scores, we used attention TL-BS parameters, which may be more ecologically valid insofar as they better reflect the dynamic expression of attention bias across time (Zvielli et al., 2015b).

Across conditions, multilevel models examining symptom trajectories demonstrated a clear, consistent pattern with reductions across multiple measures of alcohol use disorder symptoms (DrInC, AWSC, SSAC), social anxiety symptoms (LSAS, SIAS, SPS, SPQ, BSAM), and drinking to cope with anxiety (DTC-Adapted). Critically, there were also significant reductions in attention bias across time for all parameters of the attention TL-BS parameters, including: 1) toward and away from threatening stimuli; 2) as measured by mean levels, peak levels, and variability; and 3) across socially threatening and alcohol stimuli. Finally, contrary to expectations, there were not significant differences in the trajectories of change between any ABM and control conditions for any symptom measures, suggesting that reductions in symptoms were not specifically tied to the probe location contingencies in the ABM tasks.

The current pattern of results, i.e., both groups showing improvement in symptoms or attention bias, is consistent with many other studies targeting either social anxiety or alcohol use in isolation (e.g., Carlbring et al., 2012; Wiers, Houben, Fadardi, van Beek, Rhemtulla, & Cox, 2015). There are several possible ways to interpret this lack of a Condition x Time effect on symptoms. First, it is important to acknowledge that perhaps changing attention bias is not a meaningful or clinically significant way to influence symptoms of comorbid alcohol dependence and social anxiety. This interpretation is consistent with reviews that have been critical of the clinical utility of ABM for anxiety and alcohol use disorders (see Christiansen et al., 2015; Cristea et al., 2015). Further, highly powered replication attempts are warranted to extend the effects of ABM outside of laboratory settings, as well as to investigate samples that are racially diverse and/or have co-occurring psychopathology. With the accumulation of additional data showing null or small effects, one outcome may be that ABM does not demonstrate a treatment impact on par with its early laboratory promise. Another possibility is that treatment attempts may need to be diverted toward particular subgroups for whom there are theoretical reasons to expect larger effects, such as those patients with social anxiety and/or alcohol dependence who also demonstrate high levels of attention bias (e.g., Kuckertz et al., 2014).

Second, it is also possible that the ABM intervention did not produce robust changes in attention bias. As cogently detailed in their recent review (MacLeod & Clarke, 2015), when an intended ABM training has not selectively influenced attention to threat as a function of training condition, typically, there is also a corresponding failure to selectively influence anxiety symptoms. Although the MacLeod and Clarke review focused on anxiety disorders, given the similar mechanisms of action thought to function in ABM for anxiety and alcohol, it seems plausible that the same logic should apply to alcohol dependence. In short, because individuals across all conditions improved in attention bias, it is perhaps not surprising that we did not see a differential impact of condition on social anxiety or alcohol dependence symptoms. Among other explanations, the lack of group differences in attention bias could have occurred due to small effects of ABM for social anxiety on attention bias and social anxiety symptoms (Heeren et al., 2015) or insufficient dosage. Although prior studies in non-comorbid samples have demonstrated positive effects with similar protocols, it is worth noting that other types of computerized cognitive interventions in severe mental illness typically use longer protocols and target multiple cognitive impairments to improve functioning (Chan, Hirai, & Tsoi, 2015). Relatedly, using the dot probe task to modify

attention bias—a process that is not static (see Zvielli et al., 2015)—is potentially problematic. Instead, it may be advantageous for researchers to utilize methods capable of targeting the dynamic process of attention bias, which fluctuates from moment to moment from “overengagement” to “avoidance” *in real time* (Zvielli, Amir, Goldstein, & Bernstein, 2015a). For example, Zvielli and colleagues (2015a) recently developed a training procedure called “Attention Feedback Awareness and Control Training (A-Fact) that delivers *in vivo* feedback to participants synchronized with their dynamic attention bias expression.

Third, the current results may be related to recent concerns regarding the limitations with existing “control” conditions typically used in cognitive bias modification trials, including ABM (see Capozzoli & Hope, 2013; Menne-Lothmann et al., 2014). More specifically, the control condition used in this paper has many advantages, including facilitating a tidy, double-blind experiment, and controlling for many critical elements of training such as duration of trial, and exposure to threatening vs. neutral stimuli. However, the use of attention contingencies comprised of 50% threat and 50% neutral, although consistent with previous research, may be problematic for individuals starting with a higher ratio of threat to neutral attention bias (e.g., 90% threat to 10% neutral). For these individuals, 50%/50% would actually be an improvement in attention style and thus be expected to lead to symptom reduction (see discussion in Premo, Sarfan, & Clerkin, in press). Moreover, use of the existing control ABM assumes that probe location is the only potential mechanism of action underlying changes in attention. However, it is possible that repeatedly completing a standard dot probe task may have positive effects on attention control. Indeed, a recent study showed that a control dot probe task improved the alerting and executive components of attention (Heeren, Mogoia e, McNally, Schmitz, & Philippot, 2015). In particular, the current study’s enhanced motivation to reduce reaction time and error rates in all groups may have led to better performance and potential effect on attention control above and beyond practice effects.

Finally, in their Internet-delivered, ABM trial for social anxiety, Carlbring and colleagues (2012), found a similar pattern of findings as seen here; i.e., reductions across time in social anxiety symptoms, but no differential impact on anxiety as a function of condition. Researchers concluded that the most likely explanation for their time effects were that participant scores were simply regressing to the mean (see Barnett, van der Pols, & Dobson, 2005), which is a possibility here. To help test for this in the future, researchers may opt to use a multiple baseline design in concert with a more typical control condition (see discussion in Clerkin, Beard, Fisher, & Schofield, 2015). This design would allow researchers to determine whether participants are improving prior to the beginning of training (i.e., during the multiple baseline portion of treatment), or whether improvement begins after the training portion of the trial starts and is therefore due to something about the actual control condition. Future trials that include a non-dot probe task control, like that used in Schoenmakers et al. (2010), also may help clarify these issues. In sum, notwithstanding the possible explanation for *why* there was not a significant Condition x Time interaction in the present study, this research adds to mounting evidence that researchers employing ABM must think more critically about effectively employing control conditions to evaluate change processes.

Strengths of the current study include the diverse community sample, including a large number of participants who identified as African American and who reported a relatively low education level. There is a great need to more systematically include participants who identify as ethnic and/or racial minorities in psychological research (Sue, 1999), particularly given the shifting demographic characteristics in the United States (Taylor, 2014; U.S. Census Bureau, 2012). Another strength was the inclusion of a follow-up assessment. Additionally, the current study illustrates the importance of calculating trial-based attention bias scores rather than only including traditional bias scores. Whereas traditional bias scores suggested no changes in attention, newer scoring methods revealed significant reductions in all indices of attention bias over time.

Although the present study represents a rigorously controlled, theoretically sound trial, present findings must be interpreted in light of a number of limitations. We used the most up to date guidelines for calculating attention bias scores; however, we still relied on only reaction time indices of attention. Given the inconsistent findings in the ABM literature, it would have been preferable to have a multi-modal assessment of attention including eye tracking or EEG. Additionally, although our sample size for tests of the primary hypotheses was equal to or larger than most ABM clinical trials in the literature, both the current null findings and the potentially small effect sizes in the literature (Hallion & Ruscio, 2011) suggest that larger sample sizes are needed to conduct highly powered tests of ABM over time, as well as to test potential moderators. For example, one would expect that ABM would only benefit individuals for whom attention bias plays a key role in their psychopathology. Future studies that test a precision medicine approach, matching individuals to ABM based on baseline attention bias levels, might reveal more robust findings. Future research might also extend this approach to other co-occurring symptoms, including other types of anxiety or mood symptoms. The promise of such an approach, however, depends upon our ability to reliably assess an individual's attention bias, as well as knowledge of how to define who has a pathological level of attention bias.

Acknowledgments

The authors are thankful for the performance site where this research was conducted, the Department of Family and Community Medicine, University of Cincinnati College of Medicine, as well as for the research assistance and staff support provided by Harini Pallerla, E. Marie Parsons, Susan McDonald, Tricia Minton, Namratha Sandella, and Rebecca Wang. Thank you also to the additional content consultants on this grant, Drs. Kristen Lindgren, Bethany Teachman, and Reinout Wiers.

This project was supported by a Research Excellence Award from the Center for Alcohol & Addiction Studies at Brown University, and a National Institute on Alcohol Abuse and Alcoholism R21AA02151 grant awarded to Elise M. Clerkin at Miami University.

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Highlights

- Evaluated Attention Bias Modification for social anxiety and alcohol dependence.
- Trial level-bias scores reflected the dynamic facets of attention across time.
- Both symptom measures and trial level-bias scores tended to decrease over time.
- Change trajectories did not differ among Attention Bias Modification conditions.

Figure 1.
Consort Diagram

*Note, 8 participants were randomized to the treatment, but were excluded from analyses because they were subsequently determined to have not met eligibility requirements. See page 13 of the manuscript for detail.

Table 1
Descriptive Statistics for Sample Demographics and Baseline Measures by Training Condition

	Training Conditions				Total
	Alc. ABM + Social Anxiety Cont.	Alc. Cont. + Social Anxiety ABM	Alc. ABM + Social Anxiety ABM	Alc. Cont. + Social Anxiety Cont.	
	<i>n</i> (%) or <i>M</i> (<i>SD</i>)	<i>n</i> (%) or <i>M</i> (<i>SD</i>)	<i>n</i> (%) or <i>M</i> (<i>SD</i>)	<i>n</i> (%) or <i>M</i> (<i>SD</i>)	<i>n</i> (%) or <i>M</i> (<i>SD</i>)
Sex (Female)	9 (45%)	9 (38%)	7 (32%)	10 (50%)	35 (41%)
Race					
White	9 (45%)	10 (42%)	9 (41%)	6 (30%)	34 (40%)
Multiracial	0 (0%)	0 (0%)	1 (5%)	4 (20%)	5 (6%)
American Indian/ Alaska Nat.	0 (0%)	0 (0%)	1 (5%)	0 (0%)	1 (1%)
Asian	1 (5%)	0 (0%)	0 (0%)	0 (0%)	1 (1%)
African American	10 (50%)	14 (58%)	11 (50%)	10 (50%)	45 (52%)
Education					
HS Grad.	9 (45%)	7 (29%)	11 (50%)	6 (30%)	33 (38%)
Some Coll.	11 (55%)	17 (71%)	11 (50%)	14 (70%)	53 (62%)
Age *	47.40 (10.94)	42.50 (10.95)	47.68 (9.83)	39.70 (10.62)	44.31 (10.93)
Total	20	24	22	20	86

* Note: indicates $p = .05$. Percentages may not add up to 100% for a column due to rounding. "Alc." refers to alcohol, "Cont." to control condition, "ABM" to attention bias modification, "HS" to high school, "Grad." to graduate, "Coll." to college. To evaluate condition differences across race using a chi-square test, race was dichotomized as "White" vs. "Other" ($p > .10$).

Table 2

Multilevel Models Examining Alcohol-Relevant Attention Bias

	Tradit. AB	Mean		Peak		Mean		Peak		TL-BS _{Variability}
		Estimate (SE)	Estimate (SE)	Estimate (SE)	Estimate (SE)	Estimate (SE)	Estimate (SE)			
Fixed Effects										
Intercept	5.00 [*] (.02)		4.43 [*] (.07)		5.51 [*] (.09)		4.42 [*] (.07)		5.52 [*] (.08)	4.26 [*] (.07)
Time	.01 (.04)		-.13 [*] (.08)		-.10 [*] (.08)		-.10 [*] (.07)		-.08 [*] (.08)	-.09 [*] (.07)
Time^2	-		.10 [*] (.01)		.14 [*] (.02)		.09 [*] (.01)		.12 [*] (.02)	.09 [*] (.01)
Social Anxiety ABM	-.007 (.03)		.05 (.08)		.06 (.09)		.06 (.08)		.09 (.09)	.05 (.08)
Alcohol ABM	-.002 (.03)		.15 ⁺ (.08)		.19 [*] (.09)		.19 [*] (.08)		.23 [*] (.09)	.14 ⁺ (.08)
Soc Anx ABM X Time	-.02 (.04)		-.13 (.09)		-.15 ⁺ (.09)		-.11 (.08)		-.13 (.08)	-.14 ⁺ (.08)
Alcohol ABM X Time	-.04 (.04)		.02 (.09)		-.02 (.09)		.02 (.08)		-.03 (.08)	.01 (.08)
Variance Components										
Intercept	.005 [*] (.002)		.09 [*] (.02)		.13 [*] (.03)		.10 [*] (.02)		.11 [*] (.02)	.09 [*] (.02)
Slope	.02 [*] (.006)		.12 [*] (.03)		.11 [*] (.02)		.08 [*] (.02)		.08 [*] (.02)	.08 [*] (.02)
Residual	466.29 [*] (62.56)	717.54 [*] (104.44)	9556.33 [*] (1315.06)	696.35 [*] (99.50)	8323.61 [*] (1160.60)	386.21 [*] (56.88)				

* Note: Indicates significance at $p < .05$ or less

⁺ indicates $p < .10$. "Tradit." refers to traditional, "AB" refers to attention bias, "Time" to linear time, "Time²" to quadratic time, and "ABM" to attention bias modification. All results are presented in log units. To enable analysis with a log link function, a constant was added to traditional attention bias scores, and mean negative and peak negative bias scores were multiplied by negative one. Therefore, the direction of coefficients should be interpreted similarly across both positive and negative trial-level bias scores. The traditional attention bias model specified a diagonal covariance matrix for level 2 as the best fitting. Social Anxiety ABM and Alcohol ABM are coded 1=training, 0=control, so that coefficients correspond to changes in the dependent variable for the training conditions in comparison to the control conditions.

Table 3

Multilevel Models Examining Social Anxiety-Relevant Attention Bias

	Tradit. AB	Mean TL-BS _{Positive}	Peak TL-BS _{Positive}	Mean TL-BS _{Negative}	Peak TL-BS _{Negative}	TL-BS _{Variability}
	Estimate (SE)	Estimate (SE)	Estimate (SE)	Estimate (SE)	Estimate (SE)	Estimate (SE)
Fixed Effects						
Intercept	6.21* (.01)	4.53* (.07)	5.66* (.09)	4.57* (.09)	4.80* (.23)	4.38* (.08)
Time	-.02 (.02)	-.20* (.07)	-.22* (.09)	-.22* (.11)	-1.64* (.31)	-.19* (.08)
Time ²	-	.10* (.01)	.13* (.02)	-	-.45* (.05)	.07* (.02)
Social Anxiety ABM	-.02 (.02)	-.003 (.07)	.04 (.09)	-.01 (.10)	-.14 (.22)	.02 (.08)
Alcohol ABM	-.02 (.02)	.15* (.07)	.22* (.09)	.25* (.10)	.36 (.22)	.19* (.08)
Soc Anx ABM X Time	.04 (.02)	-.009 (.07)	-.03 (.09)	-.13 (.12)	-.30 (.29)	-.06 (.09)
Alcohol ABM X Time	.006 (.02)	-.003 (.07)	.04 (.09)	.07 (.12)	.27 (.29)	.004 (.09)
Variance Components						
Intercept	-	.09* (.02)	.12* (.03)	.10* (.02)	.33* (.08)	.09* (.02)
Slope	.005* (.002)	.08* (.02)	.11* (.03)	.15* (.04)	.85* (.21)	.09* (.02)
Residual	.01* (.002)	415.50* (62.57)	14443.47* (1898.17)	2715.99* (333.41)	54103.34* (6384.86)	793.98* (108.31)

* *Note:* Indicates significance at $p < .05$ or less

[†] indicates $p < .10$. "Tradit." refers to traditional, "AB" refers to attention bias, "Time" to linear time, "Time²" to quadratic time, and "ABM" to attention bias modification. All results are presented in log units. To enable analysis using a gamma distribution with a log link function, a constant was added to traditional attention bias scores. In addition, to enable analysis using a log link, mean negative and peak negative bias scores were multiplied by negative one. Therefore, the direction of coefficients should be interpreted similarly across both positive and negative trial-level bias scores. The traditional attention bias model specified a diagonal covariance matrix for level 2 as the best fitting. Social Anxiety ABM and Alcohol ABM are coded 1=training, 0=control, so that coefficients correspond to changes in the dependent variable for the training conditions in comparison to the control conditions.

Table 4

Multilevel Model Predicted Means and Standard Deviations for Primary Social Anxiety and Alcohol-Related Outcomes

	Training Conditions				
	Alc. ABM + Social Anxiety Cont.	Alc. Cont. + Social Anxiety ABM	Alc. ABM + Social Anxiety ABM	Alc. Cont. + Social Anxiety Cont.	Total
	<i>M (SD)</i>	<i>M (SD)</i>	<i>M (SD)</i>	<i>M (SD)</i>	<i>M (SD)</i>
LSAS					
Baseline	70.69 (22.99)	73.19 (27.01)	69.80 (22.11)	76.12 (24.24)	72.42 (23.95)
Week 1	68.37 (22.96)	69.74 (27.11)	66.01 (22.33)	72.84 (24.47)	69.19 (24.08)
Week 2	64.53 (23.44)	66.79 (28.24)	61.19 (24.30)	67.42 (24.69)	64.99 (25.06)
Week 3	62.78 (25.08)	61.45 (26.86)	58.05 (25.10)	65.42 (27.09)	61.69 (25.62)
Week 4	61.53 (26.30)	55.23 (29.60)	54.30 (26.57)	56.28 (24.84)	56.85 (26.47)
Post-Treatment	60.62 (27.78)	57.04 (30.57)	52.82 (27.43)	55.25 (26.43)	56.40 (27.79)
1 Month Follow-Up	60.07 (29.47)	55.65 (32.55)	50.74 (28.90)	52.45 (28.06)	54.75 (29.53)
DDQ					
Baseline	24.56 (15.83)	29.89 (18.36)	28.22 (14.69)	23.62 (19.87)	26.77 (17.19)
Week 1	23.83 (17.79)	30.11 (18.71)	26.89 (16.91)	21.04 (18.80)	25.72 (18.08)
Week 2	22.00 (19.51)	29.50 (20.70)	27.60 (20.07)	19.26 (18.42)	25.09 (19.84)
Week 3	22.19 (20.71)	28.29 (24.54)	27.00 (22.06)	18.36 (18.48)	24.44 (21.73)
Week 4	21.16 (21.06)	25.50 (32.10)	27.21 (23.73)	19.00 (18.10)	23.51 (24.14)
Post-Treatment	19.77 (20.76)	27.83 (34.58)	24.78 (24.55)	15.72 (17.32)	22.62 (25.77)
1 Month Follow-Up	18.06 (19.85)	27.06 (39.94)	23.08 (24.92)	13.65 (16.30)	21.11 (27.71)

Note: "Alc." refers to alcohol, "Cont." to control condition, "ABM" to attention bias modification, "DDQ" to Daily Drinking Questionnaire, and "LSAS" to Liebowitz Social Anxiety Scale. Values are presented in their original scale units to facilitate understanding by the reader.

Table 5

Multilevel Models Examining Social Anxiety and Alcohol-Related Outcomes

	LSAS	SAS	SPS	SPQ	BSAM	DDQ	DrInC	AWSC	SSAC	DTC-A
	Estimate (SE)	Estimate (SE)	Estimate (SE)	Estimate (SE)	Estimate (SE)	Estimate (SE)	Estimate (SE)	Estimate (SE)	Estimate (SE)	Estimate (SE)
Fixed Effects										
Intercept	75.58* (4.92)	27.32* (2.77)	24.35* (3.05)	28.70* (1.85)	2.18* (.12)	2.90* (.16)	3.25* (.13)	2.74* (.12)	1.64* (.23)	6.46* (.41)
Time	-3.11* (1.07)	-4.31* (1.30)	-5.39* (1.43)	-1.52* (1.06)	-1.16* (.08)	-1.10 (.07)	-.28* (.08)	-.19* (.04)	-.58* (.12)	-.80* (.25)
Time^2	.18* (.11)	.83* (.27)	.81* (.28)	-	.06* (.03)	-.01* (.006)	-	.008* (.004)	.12* (.03)	-
Social Anxiety ABM	-1.94 (5.51)	-.72 (3.10)	.64 (3.41)	-1.18 (2.06)	-.08 (.13)	.25 (.18)	.25* (.14)	-.09 (.13)	.40 (.26)	.38 (.45)
Alcohol ABM	-4.34 (5.50)	-.98 (3.09)	-.06 (3.40)	-4.55* (2.06)	-.17 (.13)	.06 (.18)	.17 (.14)	-.03 (.13)	-.23 (.26)	-.68 (.45)
Soc Anx ABM X Time	-.80 (.95)	-.83 (1.41)	1.48 (1.56)	-2.13* (1.14)	-.09 (.09)	.07 (.07)	.08 (.08)	.05 (.03)	.25* (.13)	.07 (.28)
Alcohol ABM X Time	.27 (.95)	.73 (1.40)	1.80 (1.55)	1.14 (1.13)	.07 (.09)	-.03 (.07)	.01 (.08)	-.009 (.03)	.21 (.13)	.37 (.27)
Variance Components										
Intercept	612.90* (101.49)	187.04* (31.61)	227.39* (38.92)	68.79* (13.75)	.23* (.05)	.56* (.11)	.32* (.07)	.30* (.06)	1.27* (.22)	3.20* (.67)
Slope	14.31* (3.14)	19.45* (6.48)	25.99* (7.84)	-	-	.09* (.02)	.05* (.02)	.01* (.004)	.16* (.06)	-
Residual	<i>a</i> *	30.14* (5.13)	32.53* (5.55)	40.94* (5.22)	.25* (.03)	.22* (.02)	111.67* (18.82)	18.77* (1.42)	.30* (.05)	2.75* (.33)

* Note: Indicates significance at $p < .05$ or less,

⁺ indicates $p < .10$.

^a Due to a diagonal covariance matrix for level 1, there are separate residual estimates and standard deviations for each of the 7 time points. Each residual estimate was significant at $p = .01$ or less, and is available from the first author upon request. "DDQ" to Daily Drinking Questionnaire, and "LSAS" to Liebowitz Social Anxiety Scale, "Time" to linear time, and "Time^2" to quadratic time. The DDQ, DrInC, & AWSC, which were examined using log link functions, are presented in log units. Social Anxiety ABM and Alcohol ABM are coded 1=training, 0=control, so that coefficients correspond to changes in the dependent variable for the training conditions in comparison to the control condition.