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RESEARCH REPORT

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ABC-training as a new intervention for hazardous alcohol drinking: Two proof-of-principle randomized pilot studies

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Abstract

Background and Aims: ABC-training is a new intervention to encourage health behavior change that targets the automatic activation of adaptive beliefs (i.e. automatic inferences). The aim of this proof-of-principle study was to test the effectiveness of web-based ABC-training to change outcome expectancies of alcohol drinking in a sample of hazardous drinkers.

Design: One exploratory and one confirmatory experiment with two between-subject conditions (online ABC- and control-training) and assessments at baseline and 1 week later (after three sessions of training).

Setting: Participants recruited on Prolific Academic completed the web-based study.

Participants: Adults with self-reported hazardous alcohol drinking (Experiment 1: 193 adults, United Kingdom, age mean = 46.7 years; Experiment 2: 282 adults, different nationalities, age mean = 38.3 years).

Intervention and Comparator: ABC-training involved completing an online task that required choosing personally relevant alternative behaviors to drinking alcohol in personally relevant antecedent contexts to attain personally important outcomes. Comparator was control-training, in which participants selected both the alternative behaviors and alcohol drinking an equal number of times. Training was completed at baseline, after 3 days and after 1 week.

Measurements: Primary outcome was change in automatic and self-reported (negative/positive) outcome expectancies of alcohol drinking from baseline to after 1 week. Secondary outcomes were change in weekly alcohol consumption, self-efficacy, craving and motivation (and approach-alcohol associations in Experiment 1). Moderators were baseline outcome scores, motivation, age and alcohol dependency.

Findings: Findings of this study are as follows: stronger increase in negative outcome expectancies after ABC- than control-training (Experiment 1: self-report, 95% confidence interval of difference scores (CI_{diff}) = [0.04, Inf]; automatic, CI_{diff} = [0.01, Inf]; Experiment 2: self-report, CI_{diff} = [0.16, Inf]; automatic, CI_{diff} = [0.002, Inf]). Stronger reduction in self-reported positive outcome expectancies after ABC- than control-training (Experiment 1: CI_{diff} = [−Inf, −0.01]; Experiment 2: CI_{diff} = [−Inf, −0.21]) but mixed findings on automatic positive outcome expectancies (Experiment 1: CI_{diff} = [−Inf, 0.02]; Experiment 2: CI_{diff} = [−Inf, −0.001]).

Conclusions: ABC-training may change outcome expectancies of alcohol consumption, but testing of clinically relevant effects in other samples is warranted.

KEYWORDS
ABC-training, addiction, alcohol use disorders, automatic inferences, cognitive bias modification, outcome expectancies, predictive processing

INTRODUCTION

Heavy drinking is widespread globally. Hazardous drinkers (i.e. people who drink more than 14 alcohol units per week) [1, 2] are at risk for severe negative health consequences, with higher severity for increased use [3, 4]. Reducing the hazardous use of alcohol is, therefore, an important aim of the World Health Organization [5]. Importantly, although hazardous drinkers may have the aim to reduce their drinking, they often fail to do so [6], highlighting the need for interventions that help people succeed in this endeavor.

Traditionally, interventions to reduce alcohol drinking have targeted change in highly controlled mental processes. For instance, self-control interventions have been used to promote change in outcome expectancies of drinking [7, 8], an important potential mediator of drinking [9–11]. Considering evidence that such interventions have limited long-term effectiveness [12, 13], over the past decade, researchers have shifted their focus to more automatic cognitive processes [14, 15]. Different types of cognitive training interventions have been developed, targeting general functions such as working memory and cognitive control or specific (stimulus-related) cognitive biases (i.e. systematic regularities in automatic mental processes) such as attention to alcoholic stimuli [16]. In the first branch of these interventions, where general functions are trained, there are some promising findings for other (cognitive-motivational) functions, but robust effects on the targeted addictive behavior have not been established. In contrast, some types of cognitive bias modification (CBM) interventions have more consistently been found to improve treatment outcomes, when added to regular treatment [17–22] (but see Hellman *et al*. for a negative finding) [23]. Although promising as add-on to treatment, CBM has not shown (differential) effectiveness compared with placebo-training in online studies [24, 25] or in students not motivated to change (e.g. Lindgren *et al*.) [26].

Building on a recent shift in cognitive theorizing in which (addictive) behavior is considered to reflect automatic and goal-directed belief-based or inferential processes [27–31], a new type of CBM intervention was recently proposed for the treatment of addiction, known as ABC-training [32]. This training does not practice mere stimulus–response combinations as in approach-avoidance training, but instead, it involves repeated practice of adaptive inferences. Specifically, ABC-training targets practice of the inference that, in personally relevant antecedent contexts (A), one will make long-term goal-congruent (rather than addictive) behavioral choices (B or B′) given their relevant consequences (C or C′) (see figure 2 in Wiers *et al*.) [32]. For instance, in web-based ABC-training, a person may see an avatar representing them in a virtual environment depicting a personal risk situation of alcohol drinking (e.g. when feeling stressed after work). In this environment, they repeatedly decide between drinking alcohol and an alternative behavior (e.g. call someone on the phone) with the latter choice allowing to reach a personally relevant goal (e.g. to improve long-term happiness). As a result, participants may learn to readily apply the belief that they can and will choose alternative behavior to drinking in risk situations given the associated personally relevant positive consequences. They are informed that this retraining of habits and applied beliefs may help them to refrain from alcohol more easily in real-life, and to foster generalization to real-life risk situations.

This new type of training bears resemblance to other evidence-based therapies that promote adaptive beliefs (cognitive behavioral therapy [CBT]) [33] and goal-directed action plans (Brief Alcohol Intervention; Implementation intention interventions) [34, 35]. However, ABC-training might have important added potential because (1) it targets automatization of specific goal-directed inferences and behavior via repeated practice [36]; (2) it does so in relevant contexts [37]; and (3) it builds on recent evidence about the context-dependent automatic inferences that may underlie addictive behavior [27, 38].

Although there is evidence that effectiveness of traditional CBM can be improved when some of the components of ABC-training are added (e.g. the inclusion of consequences and personally relevant behavioral choices) [32, 39, 40], full ABC-training has not yet been tested. To this aim, we developed a training task that targets change in outcome expectancy inferences about alcohol drinking. In this task, people make behavioral choices in self-chosen contexts that resemble real-life situations in which they would drink alcohol. During training, they experience that making a (quick) decision to refrain from alcohol and emitting relevant alternative actions helps to achieve self-selected, real-life goals that conflict with drinking.

In this study, we tested the effectiveness of this ABC-training in an adult population of hazardous drinkers. Participants were selected based on their hazardous drinking habits, not because of their desire to change their drinking habits. As such, this should be considered as a proof-of-principle study into mechanisms and not as a clinical randomized controlled trial [19, 41]. We compared changes in both self-reported and more automatic expectancies of drinking after 1 week of training for participants who completed three ABC-training sessions compared with participants who completed control-training. We predicted a stronger beneficial change in outcome expectancies (stronger increase in negative and decrease in positive expectancies) in the ABC-training condition. We predicted this change in both self-reported and more automatic expectancies because the ABC-training targets learning of (explicit) (outcome expectancy) inferences, which are automatized via repeated practice.

We also examined effects of ABC-training on self-reported alcohol drinking and on important established moderators of drinking such as self-efficacy, craving and motivation. Because ABC-training involves choosing alternative behaviors to drinking in risk situations in light of its positive consequences, this training not only involves practicing outcome expectancy beliefs, but could also influence beliefs related to self-efficacy (e.g. 'I am able to reduce drinking because I can choose alternative behavior') and motivation (e.g. 'I want to reduce drinking because drinking leads to negative consequences'), which may (in turn) reduce craving. However, these effects are not directly targeted in the training, and analyses on these outcomes were, therefore, registered as exploratory. For exploratory reasons, we also examined changes in approach-alcohol associations because these are often included in studies testing CBM effects [18].

METHODS

Design

Both experiments have a two-group design. Experiments were implemented online via lab.js. Participants completed three sessions. A first session included baseline assessment, after which participants were randomized to either ABC- or control-training and completed training. We used simple randomization, based on a random number generator in the experiment script. A second training session took place 4 days later. A third session 3 days later included training and post-intervention assessment.

The study protocol, hypotheses and data analysis plans of both experiments were preregistered on the Open Science Framework and are available together with the data, experiment and analysis scripts (https://osf.io/mbtwy/). Ethical approval for this study was granted by the Ghent University Ethics Committee (2019/72).

Participants

Participants were recruited via the Prolific Academic website (https://www.prolific.co/). This is a website where participants register to complete studies in exchange for money [42]. On this website, we set up a study for volunteers who had indicated in the Prolific pre-screening questionnaire that they are hazardous alcohol drinkers (i.e. they drink more than 14 units of alcohol—approximately 200 g of alcohol—on average per week) and purchase beer on a regular basis (because the training involves beer stimuli). In Experiment 1, we also required that participants are United Kingdom (UK) residents and their first language is English. In Experiment 2, participants required English fluency, but there was no restriction on country of residence. Demographic characteristics and baseline measurement scores of all participants are summarized in Table 1.*

Interventions

Participants first selected (1) an avatar to represent them in the training task; (2) a context in which they are likely to drink (selected from 19 contexts in which people often drink alcohol as identified in a pilot study); and (3) two actions that could help them not to drink alcohol in the chosen risk situation. ABC-training participants additionally selected a positive consequence of the choice not to drink alcohol that they considered important.

Both ABC- and control-training started with a practice block of 12 trials in which the avatar was presented in the chosen context. Two actions (i.e. drinking alcohol and one of the self-chosen behavioral alternatives) were then presented above the avatar in two thought bubbles, one of which had a blue frame (Figure 1). Participants were required to click the action with the blue frame, which was alcohol drinking on half the trials and the alternative action on the other trials. When participants clicked one of the actions, they saw a 2-second video of the avatar performing this action.

Participants in the control-training condition then completed two training blocks of 20 trials, which were identical to the practice block trials. The only exception is that, in the final block, participants had limited time to make their response (individualized response deadline). For participants in the ABC-training condition, in all blocks (including the practice block), a goal bar was presented above the avatar that depicted the self-chosen positive consequence of choosing not to drink alcohol and their level of goal achievement (set at 50% at the start of the task). Immediately after the avatar performed the alcohol drinking (or alternative) action, they saw the avatar feeling bad (good) and the goal status bar percentage decreased (increased). In the two training blocks, the actions did not have a blue frame and participants needed to decide themselves (before the response deadline in the final block), which action to perform for optimal goal achievement. To assess intervention quality, in Experiment 2, we asked participants after every training session where they had completed the session and how distractive this environment was.

Outcomes

In the first session, after consenting to participate, participants answered demographic questions (probing age, gender, country of residence and English proficiency), indicated how many alcohol units they drink in a typically week and completed the Alcohol Use Disorders Identification Test (AUDIT). Next, participants completed primary outcome measures (of outcome expectancies) and secondary outcome measures (of drinking, self-efficacy, motivation, craving and approach-alcohol associations). During the third session, participants completed the same outcome measures, and they answered questions about the training, demand compliance and reactance.

Primary outcomes

Self-reported negative and positive outcome expectancies of alcohol drinking were probed with four statements each: 'If I drink alcohol, I

*We performed baseline comparisons between intervention groups. These comparisons revealed no significant differences with the exception of lower self-reported negative outcome expectancies in the ABC-training compared to the control group in Experiment 1, $t_{(173)} = -2.63$, $P = 0.009$.

TABLE 1 Descriptive statistics for participant characteristics at baseline.

	Experiment 1		Experiment 2	
	ABC-training *n* = 98	Control-training *n* = 95	ABC-training *n* = 142	Control-training *n* = 140
Gender	25 women; 73 men	25 women; 70 men	40 women; 102 men	40 women; 100 men
Age	47 (14)	46 (13)	38 (13)	39 (13)
AUDIT	14.89 (7.01)	14.59 (6.26)	16.79 (6.47)	16.32 (6.64)
Weekly alcohol units	37.34 (20.65)	39.43 (24.61)	30.58 (22.72)	27.14 (19.01)
Self-reported drinking (TLFB)	31.82 (17.45)	29.48 (19.81)	28.21 (16.74)	25.71 (17.74)
Self-report negative expectancies	3.26 (1.00)	3.69 (1.15)	3.85 (1.07)	3.74 (1.05)
Automatic negative expectancies	0.06 (0.07)	0.07 (0.07)	0.07 (0.07)	0.07 (0.07)
Self-report positive expectancies	4.50 (0.76)	4.53 (0.87)	3.66 (0.88)	3.54 (0.88)
Automatic positive expectancies	0.05 (0.05)	0.06 (0.06)	0.06 (0.11)	0.06 (0.06)
Self-efficacy (SCQ)	73.37 (24.08)	65.94 (27.33)	59.82 (33.81)	62.14 (33.74)
Craving (one item)	4.31 (1.32)	4.41 (1.54)	4.36 (1.55)	4.33 (1.44)
Craving (DAQ)	2.39 (1.18)	2.66 (1.43)	/	/
Motivation (RCQ)	7.40 (1.52)	7.74 (1.47)	7.53 (1.64)	7.65 (1.61)
Approach-alcohol association (IAT)	0.52 (0.46)	0.53 (0.55)	/	/

Note: AUDIT, possible range of scores from 0 to 40. Weekly alcohol units: open answer; TLFB, open answer; self-report positive and negative expectancies and single-item craving: average score on Likert scale from 1 to 7. Automatic negative expectancies: AUC, with larger AUC scores indicating greater deviation of the mouse toward the alternative (false) response option, suggesting an automatic tendency to disagree with the statement, possible range of scores from 0 to 0.5; DAQ, average score on Likert scale from 1 to 7; SCQ, average score in percentages from 1 to 100; RCQ, possible range of scores from 3 to 12; IAT, possible range of scores from −2 to 2. / means 'not applicable'. For Experiment 2, these data were not collected.
Abbreviations: AUC, area under the curve; AUDIT, Alcohol Use Disorders Identification Test; DAQ, Desires for Alcohol Questionnaire; IAT, Implicit Association Test; RCQ, Readiness to change questionnaire; SCQ, Situational Confidence Questionnaire; TLFB, Timeline Follow Back Procedure.

FIGURE 1 Illustration of an ABC- and control-training trial in which the participant clicked the alternative action. Note that in the practice block of ABC-training, there was also a frame surrounding the actions.

expect negative outcomes/feel bad later/become aggressive/spend more money', 'If I drink alcohol, I expect positive outcomes/feel calm/feel courageous/act more sociable' [43, 44]. In Experiment 2, we changed the positive outcome expectancy questions to better match the outcomes included in the training task, to: 'If I drink alcohol, I expect positive outcomes/feel healthy/feel better/can achieve my goals'. Ratings were given on a Likert scale ranging from 1 (strongly disagree) to 7 (strongly agree).

Automatic outcome expectancies were probed with a Mouse-tracking Propositional Evaluation Procedure (MT-PEP) [45] that involved speeded evaluation of the same eight expectancy statements (Figure 2). Participants completed 80 probe and 40 catch trials. Each trial, one of the statements was presented word-by-word, was followed by a prompt (TRUE /FALSE/??TRUE OR FALSE??). On probe trials, the prompt TRUE or the prompt FALSE would be shown on screen, and participants needed to quickly click the corresponding word at the top-left or top-right of the screen (and ignore the statement they had read). On catch trials, the prompt??TRUE OR FALSE?? would be shown on screen, which indicated that participants needed to decide themselves whether they considered the statement to be true or false. Specifically, they needed to click TRUE or FALSE based on whether they considered the statement to be true or false. Participants responded by moving the mouse from a starting position at the bottom-center of the screen to one of two boxes at the top-left (TRUE) or top-right of the screen (FALSE). MT-PEP expectancy scores were calculated by computing the mean area under the curve (AUC) of mouse trajectories in the probe trials (split-half reliability = [0.68–0.87]).

Secondary outcomes

Alcohol consumption was registered with a Timeline Follow-Back (TLFB) procedure for the number of standard alcohol units drunk (14 g of alcohol) during the previous week ([46]). Self-efficacy-related beliefs were assessed using (1) a single question (only asked after training) asking whether participants thought the training might help them reduce their alcohol consumption; and (2) the Situational Confidence Questionnaire (SCQ-8) [47]. In Experiment 2, we only asked one question of the SCQ. We measured craving using both a single question visual analog scale [24] and the Desires for Alcohol Questionnaire (DAQ) [48]. Motivation to reduce alcohol drinking was measured with three questions of the Readiness to Change Questionnaire (RCQ) [49]. Automatic associating of alcohol with approach/avoidance was assessed with an approach-avoid Implicit Association Test (IAT) [50]. IAT scores were calculated using the recommended D600 scoring algorithm [51] (split-half reliability = [0.69–0.75]). Because Experiment 1 had already provided strong evidence for the absence of an effect on the craving DAQ and IAT and to reduce the time of the experiment (and subsequent boredom and unthoughtful responding), we removed these measures from Experiment 2.

Sample size

In Experiment 1, 363 participants were recruited in one wave. In Experiment 2, we recruited 445 participants over several waves, adding participants until we reached the required sample size after exclusions. To ensure that participants had not quit drinking recently, for Experiment 1, we excluded participants if they indicated at the start of the study that they drank <4 alcohol units (< 56 g of alcohol) during the previous week. For Experiment 2, we excluded participants after completing the AUDIT [52] when they had an AUDIT score of <8 (scores ≥ 8 indicate harmful alcohol consumption). Figures 3 and 4 show a flow-chart of the inclusion and exclusion process.

In both experiments, we aimed for 282 participants after exclusions (see preregistration). For Experiment 1, we wanted to have 90% power to observe an effect of d = 0.35 between the two training conditions in a one-tailed t test at α = 0.05. We chose d = 0.35 as effect

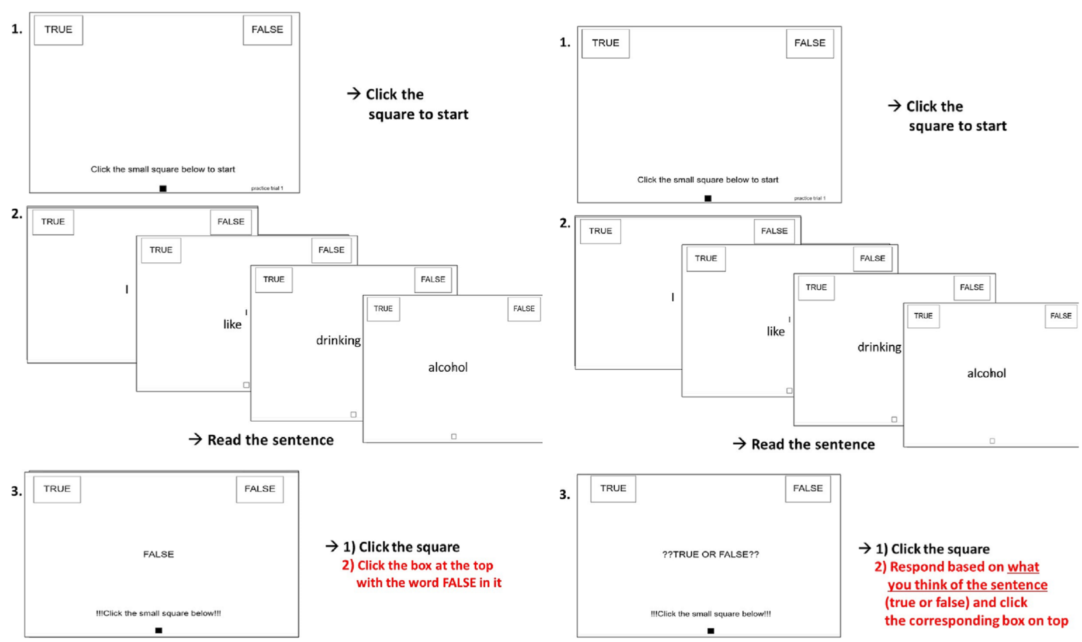

FIGURE 2 Illustration of a probe trial (left) and catch trial (right) in the mouse-tracking propositional evaluation procedure (MT-PEP).

size because this was the effect size in a prior study comparing the effectiveness of ABC- and control-training in a healthy food training context [52]. We used one-tailed *t* tests to maximize power (given the exploratory nature of the study) and because we preregistered our hypotheses and effects in the opposite direction would be of little interest. In Experiment 2, we wanted to test the replicability of the observed effects. We aimed for 282 participants to have 85% power to observe the smallest observed effect ($d = 0.32$). The final sample size after exclusions was 193 participants in Experiment 1 (50 women, 143 men, mean age = 47, SD = 14) and 282 participants in Experiment 2 (80 women, 202 men, mean age = 38, SD = 13).

Blinding

Participants were informed that they would either complete a training task to help reduce alcohol drinking habits or a control task. Participants were not informed what task they completed. There was no contact between researchers and participants.

Statistical methods

Change scores were computed for all outcome measures by subtracting baseline from post-training scores such that higher scores indicate a stronger increase in outcome scores after 1-week of training (Table 2 and 3). We fit separate linear regression models on change scores that included type of training as a factor and gender, baseline outcome scores, AUDIT, motivation and TLFB units. Significant results and main effects of type of training are presented in Table 4. We report planned linear hypotheses testing for a stronger beneficial change in outcomes in the ABC-training condition. Given the exploratory nature of this study, we report one-sided hypotheses. Reported *P*-values in the range 0.05 to 0.025 should, therefore, be viewed with

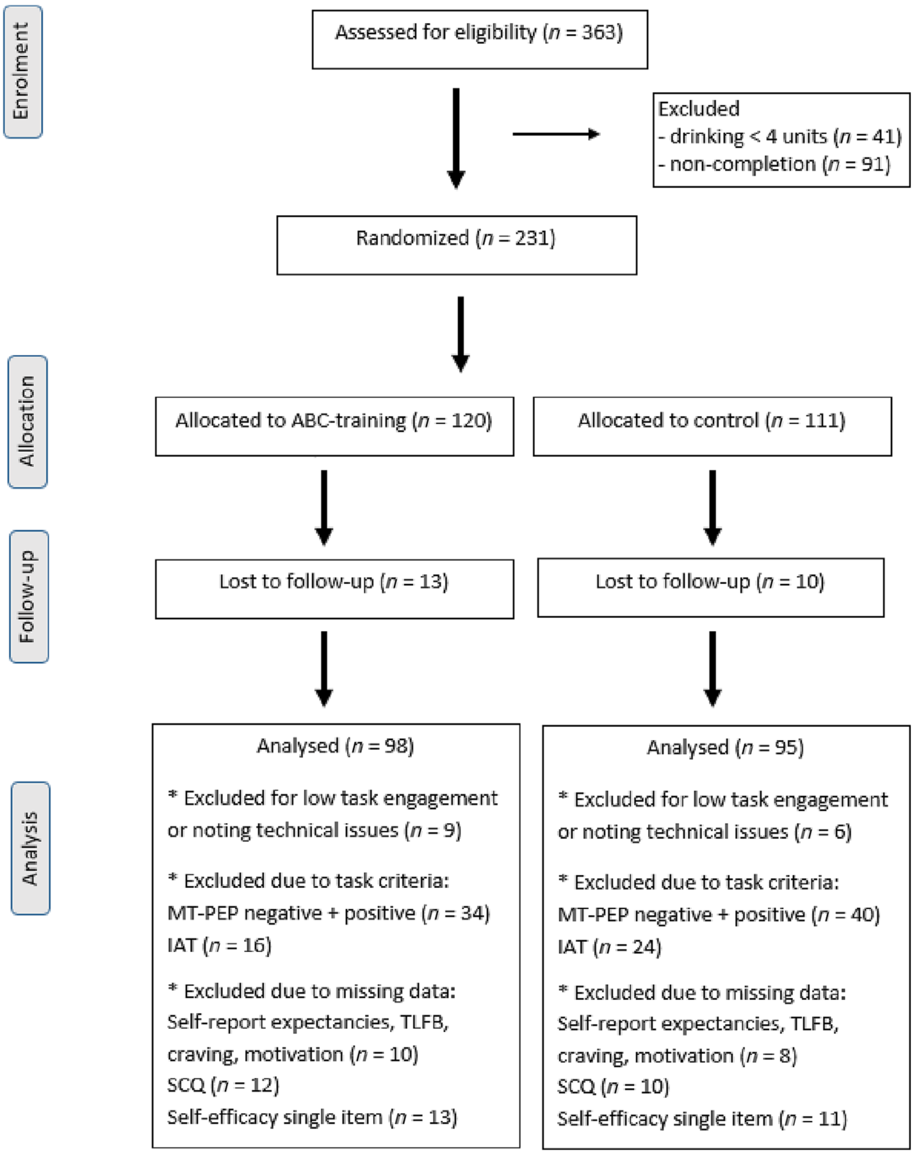

FIGURE 3 Participant flow-chart for Experiment 1.

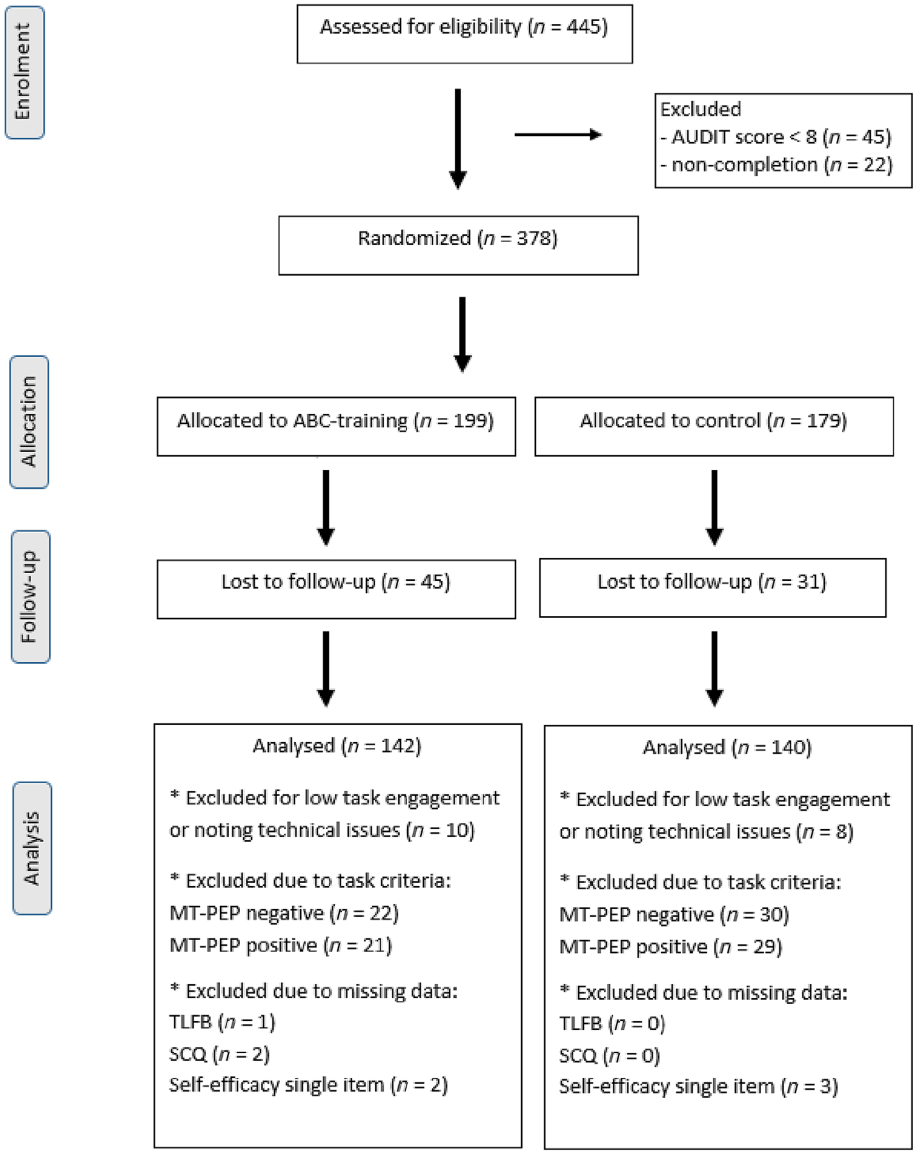

FIGURE 4 Participant flow-chart for Experiment 2.

some caution. For these hypotheses, we report the *t* test *t*-statistic (with degrees of freedom) for differences in change scores (baseline scores subtracted from post-training scores), *P*-values, effect-size Cohen's *d* and the 95% confidence interval for Cohen's *d* (CI_d). There were no deviations from the preregistered data analysis plan except for running additional exploratory analyses such as intention-to-treat analyses and linear regression analyses on post-training scores. These results are presented in the Supporting Information.

RESULTS

Primary outcomes

Negative outcome expectancies of drinking

In Experiment 1, negative expectancies showed a stronger increase for participants in the ABC- compared with the control-training, $t_{(165)} = 2.04$, $P = 0.021$, $d = 0.32$, CI_d = [0.06, Inf] (Table 2). Experiment 2 replicated this effect (Table 3), $t_{(272)} = 3.50$, $P < 0.001$, $d = 0.42$, CI_d = [0.22, Inf] (Table 3).

For automatic negative expectancies, Experiment 1 also revealed a stronger increase in negative expectancies for participants in the ABC- compared with control-training, $t_{(109)} = 2.67$, $P = 0.004$, $d = 0.48$, CI_d = [0.18, Inf]. This effect was significant also in Experiment 2, $t_{(220)} = 1.86$, $P = 0.032$, $d = 0.25$, CI_d = [0.03, Inf].

Positive expectancies of drinking

For Experiment 1, the planned linear hypothesis test indicated stronger reduction in positive expectancies for participants in the ABC- compared with the control-training, $t_{(165)} = -1.81$, $P = 0.036$, $d = 0.27$, CI_d = [0.02, Inf]. Experiment 2 replicated this effect (using a different measure—see above), $t_{(272)} = -3.55$, $P < 0.001$, $d = 0.45$, CI_d = [0.24, Inf].

TABLE 2 Outcome scores and fitted change scores from baseline to after (1 week) training in Experiment 1.

	ABC-training			Control-training			Difference in change, ABC vs control	
	Baseline	Post-training	Change score	Baseline	Post-training	Change score	Difference score	t test
Self-report negative expectancies	3.26 (1.00)	3.71 (0.93)	0.39 (0.61)	3.69 (1.15)	3.83 (1.07)	0.20 (0.61)	0.19 (1.21)	$t_{(165)}$ = 2.04, *P* = 0.021
Automatic negative expectancies	0.06 (0.07)	0.03 (0.06)	0.03 (0.06)	0.07 (0.07)	0.07 (0.08)	0.00 (0.06)	0.03 (0.12)	$t_{(109)}$ = 2.67, *P* = 0.004
Self-report positive expectancies	4.50 (0.76)	4.51 (0.71)	−0.03 (0.60)	4.53 (0.87)	4.66 (0.76)	0.13 (0.58)	−0.16 (1.18)	$t_{(165)}$ = −1.81, *P* = 0.036
Automatic positive expectancies	0.05 (0.05)	0.03 (0.06)	0.01 (0.06)	0.06 (0.06)	0.05 (0.08)	0.01 (0.06)	0.00 (0.12)	$t_{(109)}$ = 0.43, *P* = 0.67
Self-reported drinking (TLFB)	31.82 (17.45)	28.74 (20.45)	−2.39 (9.23)	29.48 (19.81)	26.38 (20.56)	−2.83 (9.00)	0.45 (17.73)	$t_{(173)}$ = 0.01, *P* = 0.99
Self-efficacy (one item)	/	3.15 (1.43)	/	/	2.67 (1.48)	/	0.40 (3.32)	$t_{(167)}$ = 2.16, *P* = 0.032
Self-efficacy (SCQ)	73.37 (24.08)	77.00 (23.52)	2.72 (19.51)	65.94 (27.33)	70.88 (26.01)	4.30 (19.12)	−1.58 (38.63)	$t_{(165)}$ = −0.54, *P* = 0.59
Craving (one item)	4.31 (1.32)	3.69 (1.41)	−0.65 (1.29)	4.41 (1.54)	3.78 (1.51)	−0.52 (1.25)	−0.13 (2.54)	$t_{(165)}$ = −0.67, *P* = 0.50
Craving (DAQ)	2.39 (1.18)	2.20 (1.31)	−0.25 (0.87)	2.66 (1.43)	2.37 (1.44)	−0.17 (0.85)	−0.08 (1.72)	$t_{(165)}$ = −0.60, *P* = 0.55
Motivation (RCQ)	7.40 (1.52)	7.52 (1.58)	0.13 (1.20)	7.74 (1.47)	7.67 (1.55)	0.01 (1.18)	0.12 (2.38)	$t_{(167)}$ = 0.68, *P* = 0.50
Approach-alcohol association (IAT)	0.52 (0.46)	0.50 (0.61)	−0.11 (0.58)	0.53 (0.55)	0.52 (0.51)	0.00 (0.59)	−0.12 (1.17)	$t_{(165)}$ = −1.24, *P* = 0.22

Abbreviations: DAQ, Desires for Alcohol Questionnaire; IAT, Implicit Association Test; RCQ, Readiness to Change Questionnaire; SCQ, Situational Confidence Questionnaire; TLFB, Timeline Follow-Back.
Note: / means not applicable. There are no data for this.

For automatic positive expectancies, in contrast to our hypothesis, we did not observe a stronger reduction in expectancies for participants in the ABC- compared with the control-training, $t_{(109)} = 0.43$, $P = 0.67$, $d = -0.08$, $CI_d = [-0.40, Inf]$. We did, however, observe an effect on the automatic positive expectancy measure in Experiment 2, $t_{(222)} = -1.73$, $P = 0.042$, $d = 0.24$, $CI_d = [0.01, Inf]$.

Secondary outcomes

Self-reported drinking

In Experiment 1, we did not observe a stronger reduction in self-reported alcohol units for participants in the ABC- compared with the control-training, $t_{(173)} = 0.01$, $P = 0.99$, $d = -0.06$, $CI_d = [-0.34, Inf]$. In contrast, we did observe this effect in Experiment 2, $t_{(271)} = -1.74$, $P = 0.042$, $d = 0.22$, $CI_d = [0.01, Inf]$.

Self-efficacy-related beliefs

In Experiment 1, participants gave higher ratings that performing the training might help to reduce their alcohol consumption in the ABC- than in the control-training, $t_{(167)} = 2.16$, $P = 0.032$, $d = 0.33$, $CI_d = [0.01, Inf]$. Experiment 2 replicated this effect, $t_{(269)} = 4.05$, $P < 0.001$, $d = 0.52$, $CI_d = [0.31, Inf]$. We did not observe type of training effects on SCQ scores.

Motivation

In Experiment 1, we did not observe a stronger increase in motivation for participants in the ABC- compared with the control-training, $t_{(167)} = 0.68$, $P = 0.50$, $d = 0.01$, $CI_d = [-0.16, Inf]$. In contrast, Experiment 2 did show a stronger increase in motivation scores in the ABC- compared with the control-training, $t_{(274)} = 1.96$, $P = 0.025$, $d = 0.24$, $CI_d = [0.04, Inf]$.

Craving, approach-alcohol associations

We did not observe significant results of linear hypothesis tests for craving or approach-alcohol association change scores.

DISCUSSION

This study provides a proof-of-principle test of the potential effectiveness of alcohol drinking ABC-training. An online sample of hazardous drinkers performed a computerized task, in which they received training to choose relevant alternative actions to alcohol drinking in relevant antecedent contexts to fulfill relevant goals, with the aim to change their (automatic) outcome expectancies of alcohol drinking. Compared

TABLE 3 Outcome scores and fitted change scores from baseline to after (1 week) training in Experiment 2.

	ABC-training			Control-training			Difference in change, ABC vs control	
	Baseline	Post-training	Change score	Baseline	Post-training	Change score	Difference score	*t* test
Self-report negative expectancies	3.85 (1.07)	4.33 (1.01)	0.51 (0.73)	3.74 (1.05)	3.98 (1.00)	0.20 (0.74)	0.31 (1.44)	$t_{(272)} = 3.50$, $P < 0.001$
Automatic negative expectancies	0.07 (0.07)	0.05 (0.06)	0.02 (0.08)	0.07 (0.07)	0.07 (0.09)	0.00 (0.08)	0.02 (0.16)	$t_{(220)} = 1.86$, $P = 0.032$
Self-report positive expectancies	3.66 (0.88)	3.09 (1.15)	−0.61 (0.95)	3.54 (0.88)	3.37 (1.03)	−0.21 (0.95)	−0.40 (1.86)	$t_{(272)} = -3.55$, $P < 0.001$
Automatic positive expectancies	0.06 (0.11)	0.07 (0.08)	0.00 (0.05)	0.06 (0.06)	0.06 (0.06)	0.02 (0.05)	−0.01 (0.12)	$t_{(222)} = -1.73$, $P = 0.042$
Self-reported drinking (TLFB)	28.21 (16.74)	23.94 (16.51)	−4.37 (14.06)	25.71 (17.74)	24.91 (22.17)	−1.45 (14.08)	−2.92 (28.21)	$t_{(271)} = -1.74$, $P = 0.042$
Self-efficacy (one item)	/	3.26 (1.66)	/	/	2.47 (1.64)	/	0.80 (3.29)	$t_{(269)} = 4.05$, $P < 0.001$
Self-efficacy (SCQ)	59.82 (33.81)	64.24 (30.33)	2.37 (27.41)	62.14 (33.74)	61.53 (31.13)	−0.14 (26.74)	2.50 (41.98)	$t_{(270)} = 0.78$, $P = 0.44$
Craving (one item)	4.36 (1.55)	4.06 (1.52)	−0.21 (1.20)	4.33 (1.44)	3.96 (1.65)	−0.34 (1.20)	0.13 (1.93)	$t_{(274)} = 0.93$, $P = 0.36$
Motivation (RCQ)	7.53 (1.64)	7.78 (1.73)	0.28 (1.41)	7.65 (1.61)	7.45 (1.74)	−0.04 (1.40)	0.33 (2.25)	$t_{(274)} = 1.96$, $P = 0.025$

Abbreviations: RCQ, Readiness to Change Questionnaire; SCQ, Situational Confidence Questionnaire; TLFB, Timeline Follow-Back.
Note: / means not applicable. There are no data for this.

with control-training, two experiments showed greater increase in negative outcome expectancies of drinking, both when measured with self-report ratings and with a speeded task assessing automatic expectancies. Initial evidence for an effect of ABC-training on positive expectancies was also observed, but this effect was small in Experiment 1 and only observed on self-report ratings. In Experiment 2, we measured a different set of positive expectancies of alcohol drinking that better matched with the training (e.g. the expectancy to achieve their goals rather than to feel calm). We observed a moderate effect on self-report ratings and a small effect on automatic expectancies.

ABC-training targets automatic inferences thought to underlie addictive behavior. This approach is embedded in increasingly influential inferential theories of cognition in general (predictive processing theories) [27, 53] and addiction specifically [31, 32]. From this perspective, addictive behavior is supported by contextually activated beliefs (networks of hidden causes) about expected consequences of this behavior. Specifically, contextual cues trigger beliefs that generate automatic predictions of engaging in this behavior, which then impact behavior [54]. Effective treatment may, therefore, require practicing inferences that draw on beliefs about the expected positive value of alternative actions (outcome expectancies) to install these beliefs and make them more 'generative' (i.e. they more strongly generate automatic behavioral predictions). Although it is difficult to adequately measure such inferences, it seems promising that ABC-training influenced both self-reported and more automatic outcome expectancies. Effects were smaller for the automatic expectancies, but this may relate to the typically more noisy measurement of the target construct in implicit measures [55]. Overall, effects were small to moderate (*ds* = [0.25–0.48]), which may be promising for changing expectancies for practical purposes because the intervention only involved short online training (compared with a strict control). Practicing in multiple sessions and in more relevant (real-life) contexts with generalization exercises (e.g. during clinical treatment) might increases the effect.

Similar to outcome expectancies, in the inferential theory, changes in beliefs about being able to reduce drinking are also seen as crucial for treatment success to the extent that they may inform automatic behavioral predictions of drinking [38]. Results showed robust training effects on participants' self-reported beliefs about whether the training might help them reduce their alcohol consumption. This is promising because these beliefs may inform predictions of change because of the training that are thought to determine actual behavior change. In accordance with this idea, exploratory analyses revealed a negative relation between this score and change in TLFB alcohol units in the ABC-training condition (Experiment 1: $r = -0.23$, $P = 0.033$; Experiment 2: $r = -0.27$, $P < 0.001$). Note that we did not observe differential effects on SCQ scores that also probe self-efficacy related beliefs. This might relate to the fact that SCQ questions refer to momentary self-efficacy and to situations that may have been less representative for the trained drinking situations. Future studies could test effects on SCQ scores for other situations and also probe more automatic application of self-efficacy beliefs (e.g. with the MT-PEP).

TABLE 4 Results of the linear regression models on outcome change scores.

	Experiment 1				Experiment 2			
	Estimate	SE	F	P	Estimate	SE	F	P
Self-report negative expectancies	n = 175				n = 282			
Intercept	0.30	0.05	41.88	<0.001	0.36	0.04	66.90	<0.001
Baseline ratings	−0.29	0.05	36.16	<0.001	−0.30	0.05	45.30	<0.001
AUDIT	0.12	0.05	5.67	0.018				
Type of training	−0.19	0.09	4.17	0.043	−0.31	0.09	12.21	<0.001
Automatic negative expectancies	n = 119				n = 230			
Intercept	0.01	0.01	4.97	0.028	0.01	0.01	4.56	0.034
Baseline ratings	0.02	0.01	17.90	<0.001	0.03	0.01	44.67	<0.001
Gender					0.02	0.01	4.55	0.034
Type of training	−0.03	0.01	7.14	0.009	−0.02	0.01	3.46	0.064
Type of training × baseline ratings							6.30	0.013
ABC-training					0.04	0.01		
Control-training					0.02	0.01		
Self-report positive expectancies	n = 175				n = 282			
Intercept					−0.41	0.06	53.05	<0.001
Baseline ratings	−0.28	0.04	47.75	<0.001	−0.22	0.05	17.25	<0.001
Type of training	0.16	0.09	3.28	0.072	0.40	0.11	12.59	<0.001
Type of training × baseline ratings							3.98	0.047
ABC-training					−0.18	0.08		
Control-training					0.04	0.08		
Automatic positive expectancies	n = 119				n = 232			
Intercept	0.01	0.01	4.50	0.036	0.01	0.01	2.98	0.086
Baseline ratings	0.01	0.01	7.20	0.008	0.03	0.01	51.54	<0.001
Motivation					0.00	0.01	4.51	0.035
Type of training	0.00	0.01	0.18	0.67	0.01	0.01	3.00	0.084
Type of training × motivation			5.78	0.018				
ABC-training	−0.01	0.01						
Control-training	0.02	0.01						
Self-reported drinking (TLFB)	n = 175				n = 281			
Intercept	−2.61	0.69	2.15	0.15	−2.91	0.84	12.04	<0.001
Baseline ratings	−0.85	0.70	4.63	0.033	−2.95	0.86	11.82	<0.001
Type of training	−1.06	2.38	0.20	0.66	2.91	1.68	3.03	0.083

TABLE 4 (Continued)

	Experiment 1				Experiment 2			
	Estimate	SE	*F*	*P*	Estimate	SE	*F*	*P*
Type of training × baseline ratings							5.30	0.003
ABC-training					−5.51	1.27		
Control-training					−0.39	1.16		
Self-efficacy (single item)	*n* = 169				*n* = 277			
Type of training	−0.40	0.26	4.61	0.033	−0.80	0.20	16.40	<0.001
Self-efficacy (SCQ)	*n* = 171				*n* = 280			
Intercept	3.51	1.46	5.77	0.017				
Baseline ratings	−8.39	1.42	34.85	<0.001	17.20	1.60	116.25	<0.001
Audit					−4.15	1.64	6.43	0.012
Type of training	1.58	2.92	0.29	0.59	−2.50	3.23	0.60	0.44
Type of training × gender			5.08	0.025				
ABC-training	−10.65	4.08						
Control-training	2.28	4.03						
Type of training × AUDIT							12.31	<0.001
ABC-training					1.59	2.37		
Control-training					−9.88	2.25		
Type of training × motivation							4.04	0.045
ABC-training					−2.08	2.15		
Control-training					4.13	2.22		
Craving (single item)	*n* = 175				*n* = 282			
Intercept	−0.58	0.10	37.18	<0.001	−0.28	0.07	15.19	<0.001
Baseline ratings	−0.49	0.10	24.67	<0.001	−0.46	0.08	35.77	<0.001
AUDIT					0.21	0.08	7.25	0.008
Type of training	0.13	0.19	0.45	0.51	−0.13	0.14	0.86	0.36
Craving (DAQ)	*n* = 175							
Intercept	−0.21	0.07	10.60	0.001				
Baseline ratings	−0.31	0.06	23.97	<0.001				
Type of training	0.08	0.13	0.35	0.55				
Motivation	*n* = 175				*n* = 282			
Baseline ratings	−0.38	0.09	17.41	<0.001	−0.43	0.08	29.25	<0.001
Gender					0.43	0.17	6.64	0.010
Type of training	−0.12	0.18	0.46	0.50	−0.33	0.17	3.86	0.050

(Continues)

TABLE 4 (Continued)

	Experiment 1				Experiment 2			
	Estimate	SE	F	P	Estimate	SE	F	P
Approach-alcohol association	n = 153							
Baseline ratings	−0.33	0.04	56.88	<0.001				
Motivation	−0.11	0.05	4.70	0.032				
Type of training	0.12	0.09	1.53	0.22				
Type of training x motivation			5.61	0.019				
ABC-training	−0.23	0.07						
Control-training	0.01	0.07						

Abbreviations: AUDIT, Alcohol Use Disorders Identification Test; DAQ, Desires for Alcohol Questionnaire; SCQ, Situational Confidence Questionnaire; TLFB, Timeline Follow-Back.

To the extent that relevant and generalizable inferences are learned in ABC-training, effects should also emerge on alcohol drinking. This was not the focus of our study because, in online studies, interventions often lead to nonspecific self-reported change in drinking, with little or no differential treatment effects [24]. Indeed, Experiment 1 revealed a significant reduction in alcohol drinking in the ABC-training, but also in the control-training group and a (weak) effect of the type of training was only observed in Experiment 2. This could relate to the specific (online) sample [42] and also the low number of training sessions or the sensitivity of the measure [56, 57]. Note further that beneficial changes over time in the control-training condition were also observed for outcome expectancies, self-efficacy and craving. This accords with other (CBM) studies showing some effectiveness of this type of control-training [14, 58], which might be further increased here because control-training involved making relevant behavioral choices in relevant contexts (on half the trials). Future studies may use assessment-only conditions or traditional CBM conditions as comparator, use other measures of drinking, examine effects over time and use other (e.g. general population) samples.

Exploratory analyses also revealed initial evidence for treatment effects on motivation and for moderation by baseline drinking. First, Experiment 2 found a stronger increase in motivation for participants in the ABC-training condition. This is promising because inferences underlying behavior may be goal-directed [30] and intervention effects may, therefore, require motivation to change (which explains why CBM effects are not typically observed in online samples that might have weaker motivation than clinical samples) [19]. The motivation effect in Experiment 2, however, was small and requires replication. Second, in line with the idea that targeting automatic inferences is crucial to change addictive behaviors, results suggest ABC-training could be more effective in reducing alcohol drinking for heavier drinking participants (moderation by baseline drinking in Experiment 2; see also moderation effects on outcome expectancies and SCQ scores). Therefore, ABC-training may hold potential for use in general samples (e.g. as an e-health intervention). However, similar to CBM interventions, ABC-training could also be used as add-on treatment in clinical settings. As a next step in intervention development, randomized clinical trials are needed that test ABC-training in clinical populations. In these studies, alcohol-dependent patients could be assigned to either (1) treatment as usual; (2) treatment as usual plus ABC-training; or (3) treatment as usual plus traditional add-on CBM (which yielded a reduced relapse rate of ∼10% 1 year after treatment discharge) [18, 22, 59]. These studies may then compare relapse at 1-year follow-up between the three groups. Note that these studies may include more than three sessions of training (e.g. 12 weekly sessions) [22] whereas other studies could assess the optimal number of ABC-training sessions [60].

In sum, this study provides preliminary evidence supporting the potential effectiveness of ABC-training as an intervention for hazardous alcohol drinking. Our results suggest that ABC-training may be effective in changing outcome expectancies of alcohol drinking, which is promising, especially when compared with the lack of beneficial effects found with other CBM interventions in similar (online) samples. However, the limitations of our study, such as the lack of an active control group, the use of an online sample and the short follow-up period of 1 week, suggest that these findings should be interpreted with caution. Further testing is needed to determine the effectiveness of ABC-training as an add-on to clinical treatment and to address the limitations of our study design.

PRE-REGISTRATION

The pre-registration plan (with pre-registered hypothesis), materials, data and analysis scripts are available at https://osf.io/mbtwy/ (pre-registration: Experiment 1: https://osf.io/msrxk; Experiment 2: https://osf.io/s843y).

AUTHOR CONTRIBUTIONS

Pieter Van Dessel: Conceptualization (lead); formal analysis (lead); funding acquisition (lead); investigation (lead); methodology (lead); writing—original draft (lead); writing—review and editing (lead). **Jamie Cummins:** Conceptualization (supporting); formal analysis (supporting); software (supporting); writing—review and editing (supporting). **Reinout Wiers:** Conceptualization (supporting); investigation (supporting); writing—review and editing (supporting).

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DECLARATION OF INTERESTS

None to declare.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are openly available on the Open Science Framework (https://doi.org/10.17605/OSF.IO/MBTWY).

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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