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ORIGINAL ARTICLE

ABC-Training for Alcohol Use During a Voluntary Abstinence Challenge: A Randomized Controlled Trial

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Abstract

The current study aimed to test the effectiveness of ABC-training in influencing drinking behaviors during voluntary abstinence challenges, compared with Approach Bias Modification (ApBM) and sham-ApBM. We conducted two randomized controlled trial studies with three between-subject conditions: ABC-training, conventional ApBM, and sham-ApBM. Assessments were conducted at baseline, midtest, and posttest and at 2-week, 3-month, and 6-month follow-ups. Participants were Dutch drinkers enrolled in the online abstinence challenge "IkPas" (Study 1: $N = 261$, mage = 57.47, SD = 10.01; Study 2: $N = 319$, mage = 55.65, SD = 10.81). Pre-registered outcomes included number of days abstinent and number of binge drinking days during the challenge and alcohol consumption at follow-ups. We found no significant difference in pre-registered outcomes between conditions. However, exploratory analysis revealed a higher success rate in abstinence during the challenge for participants who received ABC-training in both studies. Although ABC-training did not demonstrate significant effectiveness in changing pre-registered drinking behaviors compared with controls, exploratory findings suggest it enhanced success rates of abstinence during the challenge. Further research is needed to explore the generalizability of these results to broader populations, including clinical samples as well as people wanting to quit other addictions (e.g., smoking).

Keywords ABC-training · Alcohol abstinence challenge · Cognitive bias modification (CBM) · Computerized interventions · Inferential mechanism

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Heavy drinking and alcohol use disorder (AUD) carry significant health implications and societal burdens (Griswold et al., 2018; Murray et al., 2020). In the Netherlands, where this study was conducted, approximately 8% of adults can be classified as heavy drinkers (Centraal Bureau voor de Statistiek, 2022), and around 5% of deaths were linked to alcohol consumption (Organisation for Economic Co-operation & Development, 2023). With post-treatment relapse rates for AUD exceeding 50% in the first year (Cutler & Fishbain, 2005; Dousset et al., 2020; Jones et al., 2018; Sliedrecht et al., 2019), underscoring the pressing need for effective interventions and prevention methods.

Cognitive bias modification (CBM) was developed to address automatically activated cognitive biases in addictive behaviors. CBM studies typically targeted one of three cognitive biases, including biases in attention, memory, or action tendencies (Approach Bias Modification; ApBM) (Wiers et al., 2013, 2023). ApBM has been shown to reduce 1-year relapse rates when combined with abstinence-oriented treatment in several large-scale randomized controlled trials (RCTs) (Eberl et al., 2013; Manning et al., 2021; Rinck et al., 2018; Salemink et al., 2021; Wiers et al., 2011, 2023). Conversely, no differential effects were observed in online-CBM studies in self-identified problem drinkers. These findings highlighted the impact of the setting and population (e.g., lab study with students, clinical patients) and participants' goal (e.g., monetary reward from participation, behavioral change) on the intervention effects (Wiers et al., 2018).

Recent studies have suggested that the mechanisms underlying CBM effects could be different than originally conceived: an inferential perspective has been proposed that postulates inferential rather than associative mechanisms outlined in dual-process models (Van Dessel et al., 2019; Wiers et al., 2020). Evidence shows CBM effects can also be obtained through verbal guidance without actual training (Van Dessel et al., 2015) and depend on understanding of relevant contingencies, which would not be predicted by associative mechanisms (Van Dessel et al., 2016). Beliefs about the implications of the learned relationship were shown to significantly impact the effectiveness of CBM in healthy volunteers. Moritz et al. (2019) found that just imagining avoiding alcohol can reduce alcohol consumption. These findings challenged the original idea that CBM works by replacing one association (e.g., approach-alcohol) with another (e.g., avoid-alcohol) and suggest that the underlying cognitive processes may depend on propositional inferences rather than on associative processes (for a review, see Van Dessel et al., 2019).

Based on the evidence mentioned above, a novel variety of cognitive training was developed to target biased inferences: ABC-training (Wiers et al., 2020). It includes personalized antecedent cues (As) that trigger the addictive behavior, personally relevant behavioral alternatives (Bs) to the addictive behavior, and consequences (Cs) of these choices in relation to one's goals. Recent research has shown the significance of each component in ABC-training: providing a personally relevant alternative that aligns with goal-directed behavior has been found to have positive effects in the context of smokers with negative affect (Kopetz et al., 2017). Adding a consequence to the training resulted in stronger effects than standard ApBM without a consequence (Van Dessel et al., 2018) in the domain of eating among healthy volunteers when also a (generally relevant) context was added. The evidence above suggests that the innovative inferential ABC-training may be more effective than conventional associative CBM.

A recent proof-of-principle study tested the effectiveness of web-based ABC-training in hazardous drinkers recruited online (Van Dessel et al., 2023). This study, comprising two experiments, compared ABC-training (where participants chose between drinking and alternative behaviors, followed by a goal-relevant consequence) to control-training without action consequences (where participants were forced to select 50% drinking and

50% alternative behaviors). The results demonstrated that ABC-training led to a significant increase in negative alcohol outcome expectancies (e.g., “If I drink alcohol, I feel bad later/spend more money” (Fromme et al., 1993) and a decrease in positive expectancies (e.g., “If I drink alcohol, I feel better”). Notably, Experiment 2 of Van Dessel et al. (2023) also provided initial evidence for a significant reduction in drinking after ABC-training, even though participants were not selected for their desire to change drinking habits. While the study suggested potential ABC-training effectiveness, particularly in altering alcohol expectancies, it did not compare ABC-training to traditional ApBM and used an online sample motivated by payment, limiting the findings’ applicability to those intrinsically motivated to change their drinking.

Various initiatives by researchers and governments have launched campaigns to promote alcohol abstinence and mitigate its health and social harms (Bovens et al., 2022; de Visser & Piper, 2020b). In the UK, completion of the Dry January abstinence challenge was associated with short- and longer-term well-being benefits not observed in the general population who did not complete Dry January (de Visser & Nicholls, 2020). The Dutch campaign “IkPas” (NoThanks!) aims to enhance self-care, self-control, and health, by raising awareness of the risks of (excessive) alcohol use through voluntary abstinence (Bovens et al., 2017, 2022). It has been found that compared with participants who did not complete the challenge, those who did demonstrated significant improvements in general well-being, health benefits, self-efficacy, reduced consumption of alcohol, and increased appetite for non-alcoholic beverages and money savings (Bovens et al., 2021; de Visser & Nicholls, 2020; de Visser & Piper, 2020a). However, the improvements were generally small, and additional support could improve accomplishment of the challenge (de Visser & Nicholls, 2020). These findings called for supplementary supports to improve the positive outcomes of abstinence campaigns.

The main aim of this study was to test whether ABC-training, a novel intervention, grounded in inferential mechanisms, is more effective than a matched variety of ApBM and sham-ApBM in influencing both confirmatory and exploratory drinking-related outcomes. By investigating its impact, we seek to contribute to the understanding of how these theoretical mechanisms operate in practice. We conducted two randomized controlled trial (RCT) studies in which volunteer participants were randomly assigned to receive one of three training conditions as add-on to the challenge. By helping participants actively engage with the consequences of their behaviors, ABC-training targets goal-directed inferences that are considered crucial for behavior change. We therefore hypothesized that the ABC-training group would exhibit (a) significantly more days abstinent during the challenge; (b) reduced binge drinking days during the challenge; and (c) reduced amount of drinking at follow-ups, compared with ApBM and sham-ApBM. As an exploratory aim, we also assessed whether ABC-training would influence dichotomous outcomes of abstinence success during the challenge, positing that ABC-training may lead to higher rates of abstinence success. The two studies were conducted during IkPas: a 6-week challenge before Easter in 2021 and a 4-week challenge during Dry January in 2022.

Study 1: 2021 Easter challenge

Study Design and Participants

The study was a randomized (1:1:1 allocation ratio using an online program Lotus, https://www.lab.uva.nl/lotus/), double-blind, sham-controlled trial and pre-registered in the

Netherlands Trial Register (NTR; NL9274, https://onderzoekmetmensen.nl/nl/trial/23464). It was approved by the Ethics Review Board in the Faculty of Social and Behavioral Sciences at the University of Amsterdam (2021-DP-13138).

Participants of the "IkPas" program were invited to join a study on effects of varieties of additional training to help them stay abstinent during the challenge. A total of 532 Dutch speaking adults signed up, of which 261 participants (mean age = 57.47; SD = 10.01, 69.7% female) completed the pretest and were randomized (intention-to-treat, ITT sample), as shown in Fig. 1. Randomization was stratified by participant gender and study level to ensure an even distribution across conditions. Weights were applied to adjust for any imbalances across stratified groups, ensuring an even distribution of participants. The randomization process was fully automated and blinded in the Lotus program, with no human intervention in the allocation.

Inclusion criteria for this study required participants to sign up for the IkPas abstinence challenge and have sufficient proficiency in Dutch, as all materials and the intervention were delivered in Dutch. This language requirement was communicated in the information letter provided to participants. No further exclusion criteria were applied, as we aimed to capture a broad and representative sample of individuals participating in the challenge.

Procedure

Our study involved offering an additional intervention to volunteers who expressed a desire to quit drinking for a month from "IkPas." Participation in the study and the decision to quit drinking were both entirely voluntary. Participants were fully informed that they could choose to quit drinking with or without the intervention and that they could withdraw from the study at any time without any consequences. To minimize any potential influence, alternative support options were also provided outside of the study framework, ensuring that no participant felt compelled to join the study to receive the intervention.

After clicking the link in the "IkPas" newsletter, participants received information, and after informed consent, they proceeded to a pretest including questionnaires and cognitive tasks, followed by the training. They were randomized to ABC-training, ApBM, or sham-ApBM. The training constituted of completing a computer task in which a gender-matched avatar, representing the participant in a virtual context. This virtual environment consisted of videos (.mp4 video files) and images (.png image files) animated in iClone 7 (Reallusion), a 3D animation software.

Participants were advised to train twice a week. Automatic reminders were sent if they had not completed any training during a week. Those completing 4 sessions by the 3rd week were invited to the optional mid-assessment. Participants who completed the pretest were also invited to participate in the posttest. Follow-ups were conducted at 2 weeks, 3 months, and 6 months, respectively. All training sessions were administered using the Lotus platform integrated with lab.js (Henninger et al., 2022). The assessments employed Qualtrics (https://www.Qualtrics.com) and facilitated through Lotus.

Training

ABC-Training Before each training session, participants chose two personal drinking contexts (As), then two alternative behaviors for each context (Bs) and one important

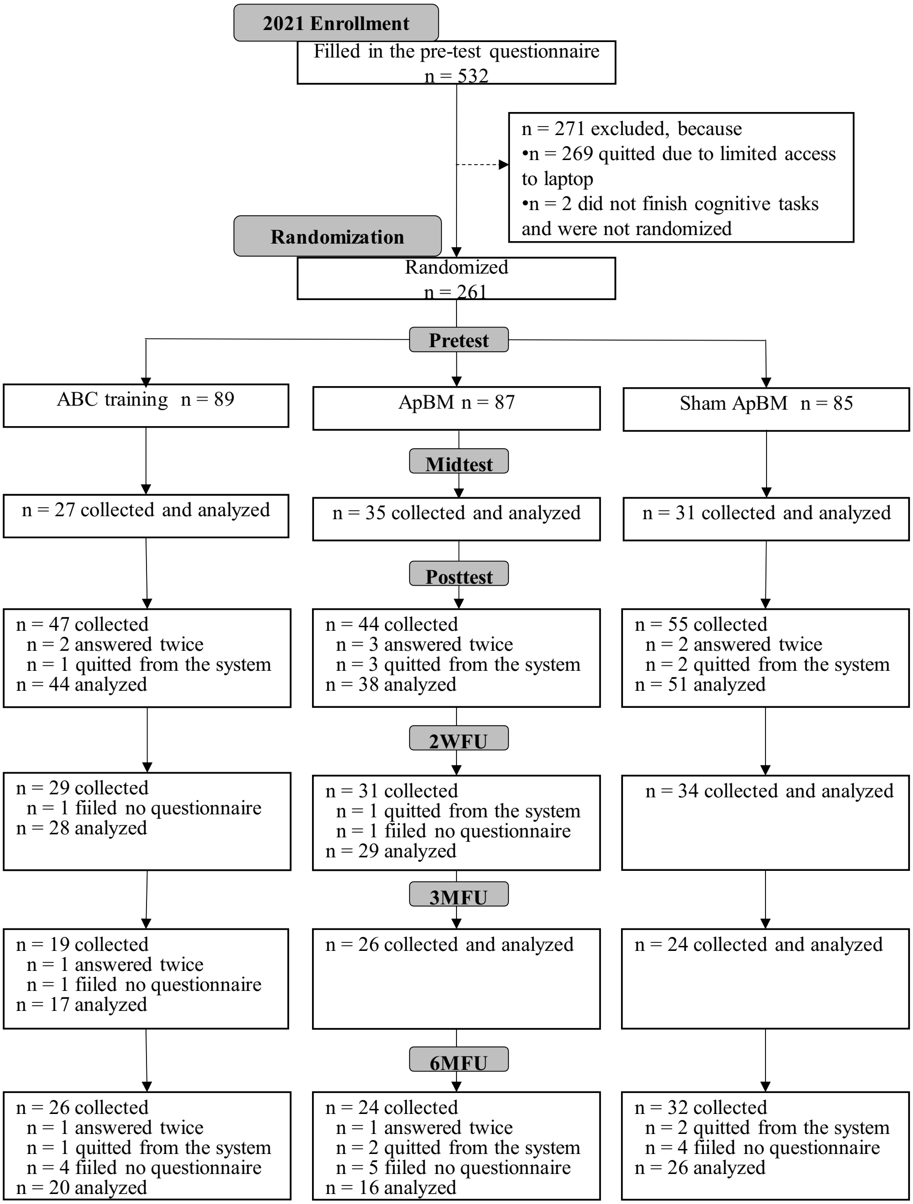

Fig. 1 Consolidated flow diagram 2021. Note. The number of participants reported here is based on the intention-to-treat (ITT) sample. Participants were eligible to perform the midtest only if they completed at least 6 training sessions by the third week of the abstinence challenge, accounting for the limited number of participants at the midtest stage. Abbreviations used in this figure include ApBM (Approach Bias Modification), 2WFU (2-week follow-up), 3MFU (3-month follow-up), and 6MFU (6-month follow-up)

consequence (C) of not drinking alcohol. All options for As, Bs, and Cs are listed in the Online Supplemental Material 1. The training contained 3 blocks: a practice block, a free-choice block without time limits, and one with a personalized time limit.

In the practice block, participants navigated avatars to choose the indicated behavior in some cases approaching alcohol and in some the non-drinking behavior. The outcomes affected a goal bar positively or negatively, representing effects of the behavior on the goal, with feedback (e.g., "I feel good," "money saved"). The training progressed to a free-choice block without time limits, followed by one with time limits encouraging fast goal-directed decision-making (C). The same process was applied to a second scenario (A2). Each of the two contexts included three blocks with 12 trials, summing to 72 trials per session (also see Van Dessel et al., 2023).

ApBM ApBM is based on associative learning theories, which suggest that automatic approach biases toward alcohol-related cues can be weakened through repeated avoidance training (Wiers et al., 2011). To control the confounding effect due to the form of training, the design of the ApBM used was identical to ABC-training except for the consequence. Participants also chose As and Bs, without choosing any Cs. Participants were instructed to choose the picture framed in blue, all of which represented alternative behaviors, meaning that the participants consistently (100%) picked the alternatives behaviors rather than alcohol drinking, as in the original ApBM.

Sham-ApBM Participants followed the same arrangement of training blocks as ApBM. The only difference was that participants kept on choosing alcohol and the alternative (indicated by the blue picture frame) for 50% of the time.

Measures

Timeline Follow-Back (TLFB) Alcohol consumption in the past week(s) was assessed using the TLFB at all assessments. The TLFB (Sobell & Sobell, 1992) is a widely used measure of alcohol consumption, and its cross-cultural validity has been established in multiple countries (Sobell et al., 2001). Participants were asked to retrospectively recall the number of "standard" drinks (defined as Dutch standard drinks containing approximately 10 g of alcohol each) consumed on each of the preceding days.

At the pretest, a 2-week TLFB was used, consisting of a table with the 14 dates, each accompanied by 5 questions that specified drink or not, type of beverage, etc. (e.g., "Did you drink? -yes, -no"; "type of alcohol beverage? -beer, -wine, -others"). The midtest and posttest used an open TLFB format to measure drinking units since the challenge began (which required a specific date and amount of alcohol consumption if any). The follow-ups used the same TLFB format as the pretest. The pretest Cronbach's α for the overall TLFB was 0.93

Confirmatory outcomes including number of days abstinent and number of binge drinking days during the challenge were annotated and calculated from the midtest and posttest TLFB results, alcohol consumption after the challenge was calculated from the follow-up TLFBs.

Alcohol Use Disorder Identification Test (AUDIT) The AUDIT (Saunders et al., 1993; Dutch translation: Schippers & Broekman, 2010) is a widely used 10-item questionnaire. It comprises two subsets: three alcohol consumption items (AUDIT-C, Bush et al., 1998) and the problem items (AUDIT-P; four items measure dependence, and three measure problems from drinking; Selin, 2006). Responses are scored 0 to 4, yielding a maximum total score of 40. The Dutch version AUDIT has shown good reliability and validity (Hildebrand & Noteborn, 2015). In this study, AUDIT showed good reliability with Cronbach's $\alpha = 0.81$.

Exploratory Measures A dichotomous question was asked in the beginning of the posttest TLFB to specify the abstinence success during the challenge (yes/no). Craving, the Desires for Alcohol Questionnaire-6 (DAQ-6), the Brief Situational Confidence Questionnaire (SCQ-8), and the Brief Readiness to Change Questionnaire (RCQ) were also examined as exploratory. Details of the exploratory measures are provided in Online Supplemental Material 2.

Statistical Methods

A priori power analysis was conducted based on the effect size of consequence-based CBM in the study by van Dessel et al. (2018), which suggested a small effect size ($d = 0.31$). Given the stronger motivation of participants to change their drinking behavior in the current study, we anticipated a slightly larger effect size ($d = 0.38$). According to Cohen's guidelines (1992), a sample size of $N = 79$ per condition would be required to achieve 90% power with an alpha level of 0.05 for a mixed ANOVA. To account for an expected 20% drop-out rate, we aimed to recruit 300 participants in total. However, the actual dropout rate was higher than expected at posttest and follow-ups. This reduced sample size decreased the statistical power of the study.

Baseline differences between training conditions were assessed using chi-square tests for the categorical variables and one-way analysis of variance (ANOVA) for continuous variables. Confirmatory outcomes including the number of days abstinent and of binge drinking days during the challenge were tested with mixed analysis of variance (ANOVA), with Condition (ABC, ApBM, sham-ApBM) (as between-participants factor) and Time (as within-participant factor). Alcohol consumption post-challenge was also tested with mixed ANOVA, comparing the three conditions at pretest and each follow-up (2 weeks, 3 months, or 6 months). For exploratory outcomes, successful abstinence was assessed with chi-square tests, and the repeated categorical measure of RCQ was analyzed using generalized estimating equations (GEE) with a Poisson loglinear model. Other continuous outcomes (IAT, DAQ, VAS scores) were analyzed with mixed ANOVAs. Pretest AUDIT score was included as a covariate in the analyses. All hypotheses were tested at a 0.05 significance level (two-sided).

To ensure the robustness of our findings, sensitivity analyses were conducted. These analyses included cross-referencing self-reported abstinence with TLFB-reported drinking behavior and reanalyzing data from participants with consistent self-reports of abstinence. The robustness of our findings was further tested employing maximum likelihood estimation (MLE), a method well-regarded for its efficacy in handling missing data (Schafer & Graham, 2002).

Results

Participant Demographics and Baseline Characteristics

Pretest demographics and alcohol-related characteristics are presented in Table 1. Based on RCQ, participants were predominantly in the action or contemplation stages if modifying their drinking behavior at pretest. Overall, baseline characteristics were equally distributed over the training conditions.

Confirmatory Analysis

The number of days abstinent in the past 2 weeks did not differ significantly between conditions at midtest (range = 0 ~ 14; ABC: 12.74 ± 1.85; ApBM: 12.13 ± 3.61; sham ApBM: 12.87 ± 2.68) and posttest (range = 0 ~ 14; ABC: 11.91 ± 3.15; ApBM: 10.34 ± 4.40; sham ApBM: 11.37 ± 3.59), $F_{\text{midtest}}(2, 85) = 0.58$, $p = 0.561$, $\eta_p^2 = 0.01$; $F_{\text{posttest}}(2, 130) = 1.86$, $p = 0.160$, $\eta_p^2 = 0.03$.

Binge drinking days during the challenge (ABC: 2.04 ± 3.02; ApBM: 3.24 ± 4.44; sham-ApBM: 2.78 ± 3.62) showed no significant condition difference, $F(2, 140) = 1.24$ $p = 0.292$, $\eta_p^2 = 0.02$. No significant differences across conditions for alcohol consumption at follow-ups were observed. Adding AUDIT as a covariate to the confirmatory analysis did not affect the significance of any relevant parameters.

Exploratory Outcomes

The chi-square test for abstinence success revealed a significant association between the conditions and the outcomes, χ^2 (2, $n = 133$) = 9.31, $p = 0.010$, Cramer's V = 0.27. Participants in the ABC condition reported the highest success rate during the challenge (36/44, 81.8%), compared with ApBM (20/38, 52.6%) and sham-ApBM (29/51, 56.9%). Pairwise comparisons were further conducted, ABC vs. ApBM: χ^2 (1, $n = 82$) = 8.02, $p = 0.005$, Cramer's V = 0.31; ABC vs. sham-ApBM: χ^2 (1, $n = 95$) = 6.81, $p = 0.009$, Cramer's V = 0.27; ApBM vs. sham-ApBM: χ^2 (1, $n = 89$) = 0.16, $p = 0.691$, Cramer's V = 0.04. Considering the multiplicity of these comparisons, a Bonferroni-adjusted alpha level of 0.017 was employed.

The mixed ANOVAs of alcohol expectancies revealed only significant effects of Time for high-dose negative expectancies at midtest ($M = 7.03 \pm 2.27$) and 3-month follow-up ($M = 6.73 \pm 2.50$) compared with pretest ($M = 6.45 \pm 2.49$), $F_{mittest}(1, 86) = 8.25$, $p = 0.005$, $\eta_p^2 = 0.09$; $F_{3mfu}(1, 58) = 5.42$, $p = 0.023$, $\eta_p^2 = 0.09$, indicating an increase in negative high-dose expectancies during the abstinence challenge (but no significant difference between conditions.

The GEE results revealed a significant main effect of time on the RCQ, $\chi^2(1) = 4.07$, $p = 0.044$, B = −0.02, indicating a small but significant change in the RCQ types across the timepoints, without effects of training or an interaction between training and time. A chi-square analysis to check the simple effect of time on RCQ type showed that at posttest, significantly more participants were in the "action" stage than at other timepoints (cf., Online Supplemental Material 3).

The results from the RM-ANOVA on VAS craving, SCQ (see the online supplemental materials for Time × AUDIT results), DAQ, and IAT scores showed no significant

Table 1 Demographics and alcohol-related characteristics per condition in 2021

Characteristics	ABC (*N* = 89)	ApBM (*N* = 87)	Sham-ApBM (*N* = 85)	Test statistic
Gender, *n* (%)				
Male	28 (31.5%)	26 (29.9%)	25 (29.4%)	χ^2 (2, $n=261$) = .096, $p=.953$
Female	61 (68.5%)	61 (70.1%)	60 (70.6%)	
Age, *M* (*SD*)	58.31 (10.32)	56.71 (9.27)	57.39 (10.47)	$F(2, 257)=.56$; $p=.574$
AUDIT, *M* (*SD*)	15.24 (7.28)	15.93 (6.66)	15.75 (6.82)	$F(2, 257)=.24$; $p=.790$
2-week TLFB, *M* (*SD*)				
Drinking days	6.44 (4.93)	6.67 (5.07)	5.11 (4.63)	$F(2, 243)=2.39$; $p=.094$
Drinking amount (standard glass)	27.87 (27.59)	33.54 (35.06)	27.76 (36.42)	$F(2, 243)=.83$; $p=.440$
Beer drinking days	.94 (2.49)	.81 (2.33)	.43 (1.47)	$F(2, 242)=1.21$; $p=.301$
SCQ-8, *M* (*SD*)	69.80 (23.31)	71.14 (21.01)	68.86 (22.82)	$F(2, 242)=.20$; $p=.815$
RCQ, *n* (%)				
Action	78 (95.1%)	71 (84.5%)	68 (86.1%)	χ^2 (2, $n=245$) = 5.32, $p=.070$
Contemplation	4 (4.9%)	13 (15.5%)	11 (13.9%)	
Pre-contemplation	0	0	0	
VAS, *M* (*SD*)	4.12 (1.79)	4.21 (1.70)	4.08 (1.66)	$F(2, 242)=.14$; $p=.871$
DAQ-6, *M* (*SD*)	12.63 (6.23)	11.75 (7.14)	11.37 (5.26)	$F(2, 242)=.87$; $p=.421$
Alcohol expectancy, *M* (*SD*)				
Low-dose positive	28.05 (6.95)	28.07 (7.54)	27.18 (7.66)	$F(2, 241)=.38$; $p=.683$
Low-dose negative	4.27 (1.87)	4.82 (2.18)	4.38 (2.03)	$F(2, 241)=1.69$; $p=.186$
High-dose positive	8.85 (3.10)	7.88 (3.45)	8.33 (3.41)	$F(2, 240)=1.77$; $p=.172$
High-dose negative	6.55 (2.70)	6.74 (2.38)	6.04 (2.33)	$F(2, 240)=1.74$; $p=.179$
IAT, *M* (*SD*)	−.48 (.50)	−.15 (.51)	−.14 (.52)	$\mathrm{F}(2, 229)=.94$; $\mathrm{p}=.393$
Number of training sessions, *M* (*SD*)	3.83 (3.00)	4.45 (3.14)	4.30 (3.50)	$F(2, 229)=.78$; $p=.459$

ABC, ABC-training; *ApBM*, Approach Bias Modification; *AUDIT*, Alcohol Use Disorder Identification Test; *TLFB*, Timeline Follow-Back; *SCQ-8*, Brief Situational Confidence Questionnaire; *VAS*, Visual Analogue Scale; *DAQ-6*, Desires for Alcohol Questionnaire-6; *IAT*, Implicit Association Test differences across conditions, and a non-specific finding was found for context evaluation (participants in the ApBM condition indicated to be more often in the risk situation they had chosen during the training sessions compared with the other conditions (Online Supplemental Material 3).

Sensitivity Analysis

In assessing the reliability of self-reported abstinence from drinking during the challenge, participants' responses were cross-referenced with their reported drinking behavior in the midtest and posttest TLFB. Among participants who self-reported successful abstinence throughout the challenge, a substantial majority confirmed this behavior through their TLFB entries. Specifically, 90.7% of participants reported no drinking at the midtest evaluation, and 81.2% reported no drinking at the posttest evaluation for the corresponding challenge period. Moreover, 74.1% of these participants reported no drinking across both the midtest and posttest evaluations.

A subsequent analysis was conducted focusing on participants with consistent self-reports of abstinence. This analysis included only those participants whose self-reported abstinence was corroborated by their Timeline Follow-Back (TLFB) responses at both midtest and posttest. The reanalysis confirmed that participants in the ABC-training condition had a significantly higher rate of abstinence success compared with those in the ApBM condition, $\chi^2(1, n=64)=6.32$, $p=0.012$, Cramer's $V=0.31$, with a Bonferroni-adjusted significance threshold of 0.017. However, the comparison between ApBM and sham-ApBM conditions did not yield a significant difference. This underscored the robustness of the ABC-training's efficacy in promoting abstinence when assessed against consistent self-reported and TLFB-verified abstinence.

To assess the potential impact of attrition on our study findings, we conducted a baseline characteristic comparison between participants who completed the study and those who dropped out. As shown in Table S1 in the Online Supplementary Material 3, no significant differences were detected between participants who dropped out and those who remained in the study across all measured variables. After conducting a comprehensive analysis using maximum likelihood estimation (MLE) to address concerns regarding attrition and potential bias in our dataset, we found that the MLE results are consistent with our previously reported findings.

Study 2: 2022 Dry January

Study Design and Participants

Study 2 was conducted to replicate and extend the findings of Study 1, with some adjustments. Ethical approval was obtained from the same committee (2021-DP-14217), with pre-registration updated in the NTR (Trial NL9274). Due to unforeseen accessibility issues with the NTR website in late 2021, specific updates pertinent to Study 2 were not logged.

Regarding participant recruitment, 596 individuals filled out the pretest questionnaire, of whom 319 participants formed the ITT sample (see Fig. 2), with a mean age of 55.65, $SD=10.81$, 70.5% self-identifying as female.

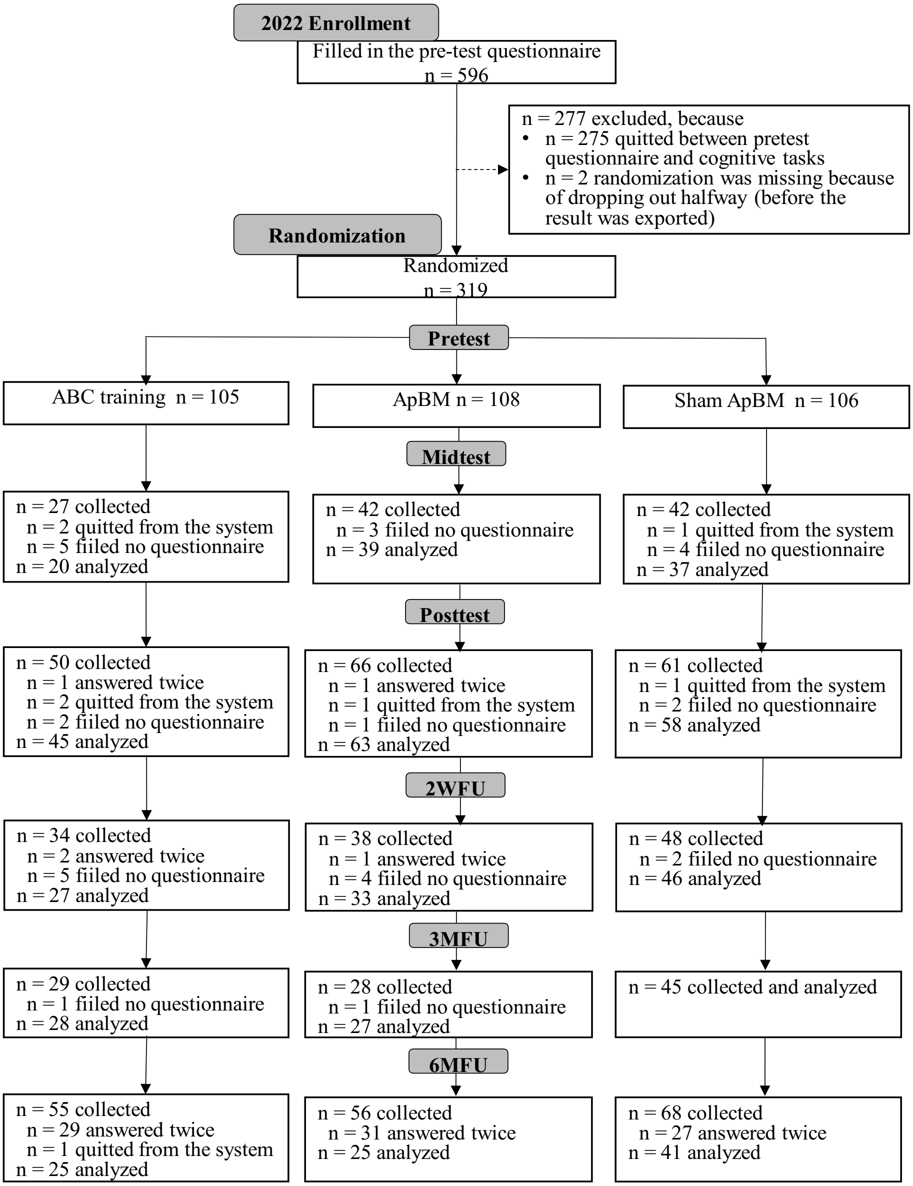

Fig. 2 Consolidated flow diagram 2022. Note. The number of participants reported here is based on the intention-to-treat (ITT) sample. Participants were eligible to perform the midtest only if they completed at least 6 training sessions by the third week of the abstinence challenge, accounting for the limited number of participants at the midtest stage. Abbreviations used in this figure include ApBM (Approach Bias Modification), 2WFU (2-week follow-up), 3MFU (3-month follow-up), and 6MFU (6-month follow-up)

Procedure

All procedures adhered to Study 1, except that the period of abstinence challenge aligned with training was during Dry January 2022 (around 4 weeks). Participants were suggested to do the training twice a week, totaling up to 8 sessions.

Measures

Most of the measurements used in Study 2 were identical to Study 1, except for a few key adjustments. A normal week of alcohol consumption (TLFB) was used instead of a 2-week retrospective TLFB at baseline, to better reflect participants' regular drinking patterns outside of the holiday season before January. The drinking behavior during the whole challenge was assessed in the posttest TLFB. Additionally, beer consumption was measured, as all alcohol stimuli in the training were beer-based. Word association task was introduced to assess spontaneous associations between ambiguous cues and alcohol-related concepts. Details are outlined in the Supplemental Material 2.

Statistical Methods

The analytical approach resembled that of Study 1. The normal-week TLFB tested was multiplied in the analysis to match the timeframe of other 2-week TLFB measurements. Significant differences at baseline were controlled for in subsequent analyses.

To explore the robustness of our findings and to increase statistical power, we conducted exploratory analysis by combining data from Study 1 with Study 2. Analysis on the pre-registered outcomes stayed the same as in Study 1; however, since the two studies were independent to each other, the round of study was included as a covariate to control for any systematic differences that may arise from combining the data sets.

Results

Participant Demographics and Baseline Characteristics

Table 2 shows the descriptive statistics of participant characteristics and outcome variables per condition at pretest. Notably, significant differences emerged between conditions in the number of training sessions and baseline word association scores. Post hoc Tukey's HSD tests showed significantly more training sessions in the sham-ApBM training than the ABC-training, $F(2, 315) = 3.71$; $p = 0.026$, $\eta_p^2 = 0.02$, and the ApBM condition showed significantly higher scores on alcohol word-associations compared with sham-ApBM, $F(2, 212) = 3.72$; $p = 0.026$, $\eta_p^2 = 0.03$. These two variables, together with the pre-registered covariate AUDIT score, were centered and included as covariates in subsequent analyses.

Confirmatory Outcomes

No differences were found between conditions in number of days abstinent, $F(2, 164) = 2.48$; $p = 0.086$, $\eta_p^2 = 0.03$, nor the number of binge days during the challenge,

Table 2 Demographics and alcohol-related characteristics per condition in 2022

	ABC (*N* = 105)	ApBM (*N* = 108)	Sham-ApBM (*N* = 106)	Test statistic
Gender, *n* (%)				
Male	33 (31.4%)	31 (28.7%)	30 (28.3%)	χ^2 (2, *n* = 319) = .29, p = .863
Female	72 (68.6%)	77 (71.3%)	76 (71.7%)	
Age, *M* (*SD*)	55.31 (10.99)	55.55 (11.73)	56.07 (9.72)	*F*(2, 307) = .13; *p* = .877
AUDIT, *M* (*SD*)	12.97 (5.43)	14.27 (6.25)	14.41 (6.23)	*F*(2, 307) = 1.78; *p* = .170
Normal-week TLFB, *M*(*SD*)				
Drinking days	4.68 (1.93)	5.05(1.88)	5.30 (1.85)	*F*(2, 215) = 1.96; *p* = .144
Drinking amount (standard glass)	20.97 (15.37)	25.43 (16.15)	26.36 (14.39)	*F*(2, 213) = 2.48; *p* = .087
Beer consumption				
Frequency, *M* (*SD*	1.58 (1.34)	1.55 (1.30)	1.44 (1.38)	*F*(2, 305) = .33; *p* = .720
Amount, *M* (*SD*	.65 (.94)	.73 (.96)	.63 (1.11)	*F*(2, 217) = .18; *p* = .834
SCQ-8, *M* (*SD*)	66.71 (25.08)	60.30 (26.10)	64.71 (21.75)	*F*(2, 215) = 1.34; *p* = .263
RCQ, *n* (%)				
Action	31 (47.0%)	29 (40.8%)	28 (41.8%)	χ^2 (2, *n* = 204) = 1.78; *p* = .777
Contemplation	34 (51.5%)	42 (59.2%)	38 (56.7%)	
Pre-contemplation	1(1.5%)	0	1(1.5%)	
VAS, *M* (*SD*)	1.83 (1.12)	1.86 (1.19)	1.86 (1.31)	*F*(2, 215) = .01; *p* = .990
DAQ-6, *M* (*SD*)	7.00 (2.15)	7.19 (2.59)	7.29 (3.09)	*F*(2, 213) = .23; *p* = .797
Alcohol expectancy, *M* (*SD*)				
Low-dose positive	26.39 (7.72)	28.26 (7.86)	27.51 (8.37)	*F(*2, 215) = 1.02; *p* = .363
Low-dose negative	3.68 (1.26)	4.06 (1.45)	4.07 (1.61)	*F*(2, 215) = 1.75; *p* = .176
High-dose positive	8.18 (3.22)	8.90 (3.27)	8.66 (3.06)	*F*(2, 215) = .95; *p* = .389
High-dose negative	5.32 (1.89)	6.08 (2.37)	5.61 (1.97)	*F*(2, 215) = 2.44; *p* = .089
IAT, *M* (*SD*)	-.04 (.51)	-.06 (.57)	-.09 (.53)	F(2, 279) = .26; p = .773
Number of training sessions, *M* (*SD*)	2.46 (2.23)	3.00 (2.36)	3.32 (2.40)	*F*(2, 315) = 3.71; *p* = .026
Word association score, *M* (*SD)*	3.37 (1.68)	3.88 (1.83)	3.13 (1.56)	*F*(2, 212) = .3.72; *p* = .026

ABC, ABC-training; *ApBM*, Approach Bias Modification; *AUDIT*, Alcohol Use Disorder Identification Test; *TLFB*, Timeline Follow-Back; *SCQ-8*, Brief Situational Confidence Questionnaire; *VAS*, Visual Analogue Scale; *DAQ-6*, Desires for Alcohol Questionnaire-6; *IAT*, Implicit Association Test

$F(2, 185) = 0.73$; $p = 0.483$, $\eta_p^2 = 0.01$. Mixed ANOVAs on alcohol at follow-ups did not reveal significant differences between conditions.

Exploratory Outcomes

The chi-square test on success rates yielded a significant difference between conditions, χ^2 (2, $n = 157$) = 11.30, $p = 0.004$, Cramer's V = 0.27. ABC-training demonstrated the highest success rate during the abstinence challenge (39/42, 92%), compared with the ApBM training (49/59, 83.1%) and sham-ApBM (37/56, 66.1%). Pairwise analyses with a Bonferroni-adjusted alpha level of 0.017 showed higher success rates in the ABC vs. Sham-ApBM, χ^2 (1, $n = 76$) = 9.89, $p = 0.002$, Cramer's V = 0.32; however, no significant differences were found between ABC and ApBM or between ApBM and sham-ApBM.

Significant Time × Condition interactions were observed for low-dose positive expectancies at midtest, F (2, 65) = 3.30, $p = 0.043$, $\eta_p^2 = 0.09$. Participants in the sham-ApBM experienced a stronger decrease in low-dose positive expectancies compared with the other two conditions. However, post hoc comparisons within each training did not reveal significant differences between the time points. High-dose negative expectancies increased significantly from pretest ($M = 5.82 \pm 2.07$) to midtest ($M = 5.88 \pm 2.63$), F (1, 65) = 5.04, $p = 0.028$, $\eta_p^2 = 0.07$. No significant differences between conditions or other expectancy types were found; see Online Supplemental Material 3 for more detailed results.

The GEE results revealed no significant effect on the RCQ. The RM-ANOVA on VAS craving, SCQ, DAQ, and word association showed no significant results. ANOVA on evaluation questions showed no significant results. For participants' acceptability and evaluation results, see Online Supplemental Material 3.

Sensitivity Analysis

The reliability of self-report abstinence success and TLFB was high. Specifically, for those who reported a success for the abstinence, 94.6% reported no drinking at midtest, 96.8% at the posttest, and 93.6% across both midtest and posttest. Baseline characteristics comparison between drop-out and remaining participants showed no significant difference. MLE analysis was consistent with the results. Analyses on participants who consistently reported no drink during the whole challenge and succeeded in abstinence did not bring any change to the results.

Results Combining 2021 and 2022

The ANCOVA results indicated no significant differences between conditions for our pre-registered outcomes (all $ps > 0.05$). However, the exploratory chi-square analysis of abstinence success was consistent with the results in Study 1. Specifically, the ABC-training was found to be significantly more effective in promoting abstinence success compared with both the CBM and SHAM conditions, $\chi^2(2, n = 290) = 15.67$, $p < 0.001$, Cramer's V = 0.23.

Discussion

Two studies examined the effects of ABC-training compared with ApBM and sham-ApBM, alongside an abstinence challenge. Opposite to our hypothesis, no effects were found on the pre-registered outcomes (days abstinent and binge drinking days during the challenge, and alcohol consumption after the challenge). However, exploratory analysis showed significantly higher abstinence success rates in the ABC-training than in the other two conditions in Study 1, and higher abstinence success rate in ABC-training compared with sham-ApBM (but not with ApBM) in Study 2.

In the analysis of days abstinent and binge drinking days during the abstinence challenge, no significant differences were observed between training conditions. This lack of observed differences might be attributed to a ceiling effect for days abstinent and a floor effect for binge drinking days (see the means in the confirmatory results of Study 1). Specifically, many participants reported mostly days abstinent and low number of binge drinking, thereby reducing the detectable difference between conditions. Furthermore, the context of our study merits consideration. As highlighted by Wiers et al. (2018), the efficacy of interventions like CBM can differ between laboratory settings and randomized controlled trials (RCTs) and among various populations (e.g., clinical vs student population). Our study's setting, involving voluntary participants of an online abstinence challenge, may not fully mimic the conditions under which these interventions are tested in clinical trials or laboratory experiments. Therefore, while the findings suggest that the training conditions did not significantly impact abstinent or binge drinking days, these results must be interpreted within the specific context of our study's design and participant characteristics.

Alcohol consumption at follow-ups also showed no significant difference between conditions, and potential explanations include the following: (1) participants in the study mainly held a temporary goal to pause drinking during the challenge rather than reducing drinking in a longer term, thus the consumption bounced back quickly and the training effect did not last; (2) brief interventions like ABC-training had very limited effect on changing consumption, and a Bayesian meta-analysis study on CBM efficacy showed similar results that the intervention led to no reduction on substance use compared with control conditions, while a small effect on reducing relapse (Boffo et al., 2019).

The exploratory findings from both studies suggest ABC-training enhances abstinence success rates. While the superiority of ABC-training over ApBM was not statistically significant in Study 2, likely due to limited statistical power, the overall pattern supports our hypothesis of training efficacy being ABC > ApBM > sham-ApBM. Further analyses of participants with consistent abstinence and TLFB reports and the combined study analysis, while exploratory, offers compelling evidence that ABC-training may indeed facilitate higher abstinence rates. These findings underscore the potential of ABC-training as a promising approach (Van Dessel et al., 2023) and provide initial evidence that ABC-training could be more effective than classic ApBM for promoting abstinence as a goal (even a temporary abstinence goal).

For alcohol expectancies, only a small, temporal increase in negative expectancies after drinking a high-dose of alcohol was observed (in both studies), in the absence of a differences between the conditions (except for a non-replicated Time × Condition interaction for low-dose positive expectancies in Study 2). These findings differ from those of Van Dessel et al. (2023), where ABC-training significantly improved negative expectancies and decreased positive expectancies in two studies. One potential explanation relies on the fact that outcome expectancies is not a uniform construct. Whereas Van Dessel et al. measured expectancies related to the aim of the learned inferences in the study, here general dose-relevant positive and negative alcohol outcome expectancies were used (Wiers et al., 1997). Further, Van Dessel's study involved paid online volunteers, whereas ours involved Dutch volunteers committed to stay abstinent for the duration of the challenge. Additionally, the reliability of current negative expectancies was relatively low.

Exploratory outcomes like readiness to change, cravings, and situational confidence showed no significant changes across time or conditions in both studies. One exception was a main effect of time on RCQ in Study 1, revealing an improved motivation (from contemplation to action) for a few participants, but the *p*-value was not convincing. This *p*-value, while suggesting a possible trend toward improvement, lacks the robustness typically required to confirm a clear effect of the intervention. The effect can be explained by the positive effect brought by the abstinence challenge (Bovens et al., 2017, 2022; de Visser et al., 2015; de Visser & Nicholls, 2020; de Visser & Piper, 2020b) and the engagement in an intervention. The time effect on RCQ was absent in Study 2, which might be due to differences in baseline sample characteristics and study power.

Our results provided nuanced insights regarding the novel theoretical approach of ABC-training. ABC-training targets the automatic inferences underpinning addictive behaviors, with a specific emphasis on contextually activated beliefs about anticipated behavioral consequences, resonating with emergent inferential theories of cognition in addiction. Within this theoretical framework, contextual cues activate beliefs, which in turn generate automatic predictions about effects of (addictive) behaviors (Van Dessel et al., 2018, 2023; Wiers et al., 2020). This contrasts with the original ApBM which was based on dual-process models, including an associative perspective on alcohol cognitions and therefore includes only consistent pairings of stimuli and responses. Further study is needed to examine whether ABC-training could be more effective (compared with ApBM without relevant consequences) and whether relevant consequences are important for training effectiveness to further test the utility of these theoretical models.

Given the inherent challenges of online voluntary training, our study experienced a relatively high attrition, which is not uncommon in such research settings (Christensen et al., 2009; Eysenbach, 2005). Our analysis revealed no significant baseline differences between participants who completed the study and those who did not, which suggests that attrition did not compromise the integrity of our results, underlining their robustness against the effects of attrition. Moreover, the robustness of our findings is further supported by an exploratory analysis employing MLE, a method well-regarded for its efficacy in handling missing data. Though the drop-out pattern may not have biased the outcomes, it is still notable that the power of follow-up assessments was relatively low, for example, the minimum detectable effect size at 6-month follow-up for 2021 and 2022 are $\eta_p^2 = 0.31$ and 0.26, to reach a power of 0.8.

Our findings have implications for both researchers and practitioners. For researchers, this study adds to the evidence on inferential mechanisms in cognitive bias modification, suggesting that ABC-training could be an effective tool based on this framework. For practitioners, ABC-training offers a scalable and easy-to use approach for individuals who are unable to receive inpatient treatment, potentially increasing their chance to maintain abstinence. While the current results are preliminary, they highlighted the potential utility of ABC-training as part of a broader intervention strategy as add-on to treatment-as-usual, particularly when tailored to specific goals like promoting (temporary) abstinence.

The study's conclusions are constrained by several limitations. First, as an online intervention program among volunteers recruited from society (with a mean age of over 50), the results cannot be readily generalized to other samples or age groups (e.g., clinical samples who are diagnosed with AUD (Wiers et al., 2018)). Next steps should test the training as add-on to treatment-as-usual and examine the effectiveness of ABC-training as add-on compared with ApBM or no intervention (Van Dessel et al., 2023). Second, the current training showed limited visualization and immersiveness according to participants' feedback (see Online Supplemental Material 3), with generic avatars and limited animation of the training contexts and behaviors. Third, there was no direct comparison with the traditional (non-avatar) ApBM. While the current study leveraged a contextualized avatar version to maintain consistency in training formats, future research is warranted to elucidate the differential impacts, if any, between other (more typical) varieties of ApBM. Moreover, traditional CBM has been changed to be comparable to ABC-training; therefore, there is no direct comparison with the original joystick-based ApBM that has repeatedly shown add-on effects in the treatment of AUD (for a review, see Wiers et al. (2023)). This more direct comparison in patients will be done in a future clinical RCT.

Finally, it is crucial to address the significant drop-out rate observed from the pretest questionnaire to the commencement of the actual training, which was approximately 50%. This attrition was primarily attributed to the training's limitation to computerized formats, excluding broader access through tablets or mobile devices. Despite our analysis indicating that this drop-out pattern did not substantially bias the outcomes, the attrition notably affected the statistical power of our follow-up assessments. This highlights the importance of developing mobile versions of the training to improve access to the training and mitigate drop-out rates (Eiler et al., 2020; Laurens et al., 2020).

Conclusion

In conclusion, this study offered a nuanced picture of ABC-training in online abstinence challenges. There were no robust condition effects for the confirmatory outcomes including number of days abstinent and binge drinking days during the challenge or alcohol consumption after the challenge; however, ABC-training consistently outperformed other training variations in the exploratory abstinence success. The findings suggest ABC-training's promise yet underscore the necessity for further research to examine the efficacy of the ABC elements, especially the contextualized consequences in the training. Moreover, future studies should investigate factors that could promote effective ABC-training, including the development of more accessible and immersive training platforms, and testing ABC-training in clinical settings.

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Author Contribution TP: Data collection; formal analysis; writing, original draft; writing, manuscript finalizing. VS: Conceptualization, data collection, methodology. JL: Conceptualization, data collection. PVD: Conceptualization, task implementation, writing—review and editing. RB: Resources, participant recruitment. HL: Supervision, writing—review and editing. RW: Supervision, conceptualization, writing—review and editing.

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Data Availability The anonymized data that support the findings of this study are openly available in OSF at https://osf.io/e39y6/.

Declarations

Ethics Approval and Consent to Participate All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2000 (5). Informed consent was obtained from all patients for being included in the study.

Conflict of Interest The authors declare no competing interests.

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